The climate and health nexus in Europe and central Asia: a technical brief

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Abstract

The pace and extent of environmental changes pose serious challenges to the global health gains made over recent decades. Human activities, principally the emission of greenhouse gases (GHGs), have unequivocally caused increasing global temperatures, with 2024 being the first calendar year with a global mean temperature of more than 1.5°C above the 1850–1900 average. Temperatures across the WHO European Region are rising at twice the global average, with urban heat islands amplifying extreme heat exposure. Climate change presents a fundamental threat to health, with disproportionate adverse effects on marginalized and vulnerable groups, including children, older people, women and those with pre-existing medical conditions.

Climate change effects on human health are mediated both by direct pathways (e.g. heat, drought, flooding, wildfires) and indirect pathways involving ecosystems (e.g. food and nutrition security, water quality, disease vector distribution) as well as socioeconomic systems (e.g. migration, declining labour productivity). Although the scale, nature and timing of adverse effects of climate change on physical and mental health vary between and within countries, there are common challenges.

Promoting health and equity requires better integration of mitigation (reducing emissions) and adaptation (moderating harm) solutions. Much more can be done now to use the evidence already available, alongside systems-based approaches and cross-sector collaboration, to inform policy and practice, thereby effecting rapid and decisive action both to reduce long-term risks to health and bring near-term benefits. Acting on the evidence – for people, place and planet – warrants increasing investment in solutions underpinned by partnerships across borders, scientific disciplines, sectors and levels of governance.

Deep, rapid cuts in GHGs are needed to limit future temperature increases, yet current progress remains inadequate to meet the goals of the Paris Agreement; a legally binding international treaty on climate change, adopted by 196 Parties at the United Nations Climate Change Conference in Paris, France in 2015. More ambitious mitigation of GHG emissions can also deliver significant health co-benefits, such as reduced air pollution and healthier diets. The health sector must reduce its own emissions, including those from supply chains, while simultaneously strengthening care quality and equity.

Adaptation is not a substitute for mitigation; rather, mitigation increases the scope for effective adaptation, including through heat-health action plans, resilient infrastructure and early warning systems. Moreover, health adaptation is not only the domain of the health sector but intersects with the climate priorities of sectors such as urban planning, construction, transport, energy and agriculture. Many adaptation responses remain fragmented, incremental and inadequately evaluated. However, there are growing opportunities to pursue adaptation actions that deliver triple wins for health, equity and environmental sustainability, while recognizing limits to adaptation, risks of maladaptation and the need for transformative approaches to health system resilience and accessibility.

Critical gaps remain in achieving equitable outcomes. Disparities in climate-health vulnerability, health system resilience and health workforce preparedness across the Region point to the urgency of targeted and context-sensitive approaches. Similarly, health remains underrepresented in climate financing frameworks and cross-border policy collaborations. Addressing these challenges calls for scaling successful innovations, strengthening community participation and leveraging transdisciplinary collaboration. Cross-cutting priorities include the attribution of health effects to climate change; economic valuation of health impacts and interventions; building community ownership; countering mis- and disinformation; enabling scale-up of climate-smart technologies; and improving science–policy interfaces. Protecting and promoting health in the face of climate change requires not only effective health-care responses but also cross-sectoral policies that deliver health equity in a climate-safe future.

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Contents

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Abbreviations

COP29	the 29th United Nations Climate Change Conference
EHP	European Environment and Health Process
GHG	greenhouse gas
LT-LEDS	Long-term Low Emission Development Strategies
NDCs	Nationally Determined Contributions
PECCH	Pan-European Commission on Climate and Health
$PM_{2.5}$	particulate matter < 2.5 mm
UNFCCC	United Nations Framework Convention on Climate Change

About this document

This document summarizes the key evidence of the multiple links between climate change and health in Europe and central Asia. It was produced to provide background information on the current knowledge about climate-related health effects for the Pan-European Commission on Climate and Health (PECCH) – an independent advisory group convened by the WHO Regional Office for Europe to raise the political profile, awareness and support for stronger action to address the health impacts of climate change.

The PECCH is chaired by former Icelandic Prime Minister Her Excellency Katrín Jakobsdóttir, and supported by Chief Scientific Advisor, Sir Andrew Haines, Professor of Environmental Change and Public Health at the London School of Hygiene and Tropical Medicine. The PECCH comprises 11 Commissioners, all of whom bring a unique and comprehensive understanding of the nexus between climate, health and policy-making from across the WHO European Region.

The PECCH's research team, in close collaboration with its Chief Scientific Advisor developed this document for PECCH members and an audience of policy-makers to provide an overview of the current evidence on the threats to health posed by climate change, the main trends and the types of actions that would be needed in view of the European Region's greatest needs and vulnerabilities. It also identifies cross-cutting issues, knowledge gaps and their implications. The evidence compiled in this document offers a scientific foundation to assist the PECCH in formulating its recommendations and a "call to action" to accelerate progress and political commitment towards achieving greater resilience and adapting to and mitigating climate change in Europe and central Asia

1. Introduction

- Climate change is a major threat to health, but also a major opportunity for healthier, fairer societies.
- The WHO European Region is heating faster than the global average, with growing, diverse health risks across all countries.
- Placing health at the heart of climate action can save lives, reduce inequalities and drive a just transition.

The publication *Zero regrets: scaling up action on climate change mitigation and adaptation for health in the WHO European Region, second edition* released in 2023, *(1)* emphasizes that climate change is already affecting lives and livelihoods worldwide. Without significant action to mitigate and adapt to climate change, substantial increases in preventable mortality and morbidity, adverse impacts on quality of life and a widening equity gap can be expected over the coming decades and beyond. The pace and extent of recent environmental change poses serious challenges to global health gains made over recent decades as well as putting the health of future generations at risk. It is vitally important to expand efforts to define and quantify the threats to health and, crucially, implement evidence-based solutions.

The purpose of this technical brief for the Pan-European Commission on Climate and Health is to bring together some key pieces of available, robust evidence and advice to support leadership in local and regional efforts and to identify important gaps in knowledge. The pathways whereby climate change exerts adverse effects on health are multiple and interlinked. In this technical brief we introduce the principal threats and impacts in order to identify the potential for evidence-based solutions. There are unprecedented health threats but also unprecedented opportunities to use available knowledge to effect rapid and decisive action as well as to generate new evidence to inform policy development and practice.

Climate change presents a fundamental threat to human health *(2)*. Evidence for its worsening effects worldwide is rapidly accumulating *(3–5)*. Countries that contribute least to greenhouse gas (GHG) emissions and vulnerable and marginalized groups within countries at different levels of economic development are disproportionately affected, but impacts are experienced throughout the WHO European Region[1]. Environmental risk factors are estimated to account for at least 1.4 million premature deaths annually in the Region. This is likely to be a substantial under-estimate. Some of these risks are exacerbated directly or indirectly by climate change or the drivers of climate

1 WHO European Region comprises 53 countries, covering a vast geographical region from the Atlantic to the Pacific oceans: Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands (Kingdom of the), North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Turkmenistan, Ukraine, United Kingdom of Great Britain and Norther Ireland and Uzbekistan.

change *(6)*. Furthermore, according to 2019 data (published in 2023), approximately 97% of the population in the Region was exposed to particulate matter < 2.5 mm ($PM_{2.5}$) concentrations above the WHO air quality guideline level *(7)*, much of which arises from the burning of fossil fuels, the principal driver of climate change *(8)*. Air pollution is also intensified by climate change through mechanisms such as wildfires. Thus, major health benefits will result from effective actions to adapt to and to mitigate climate change.

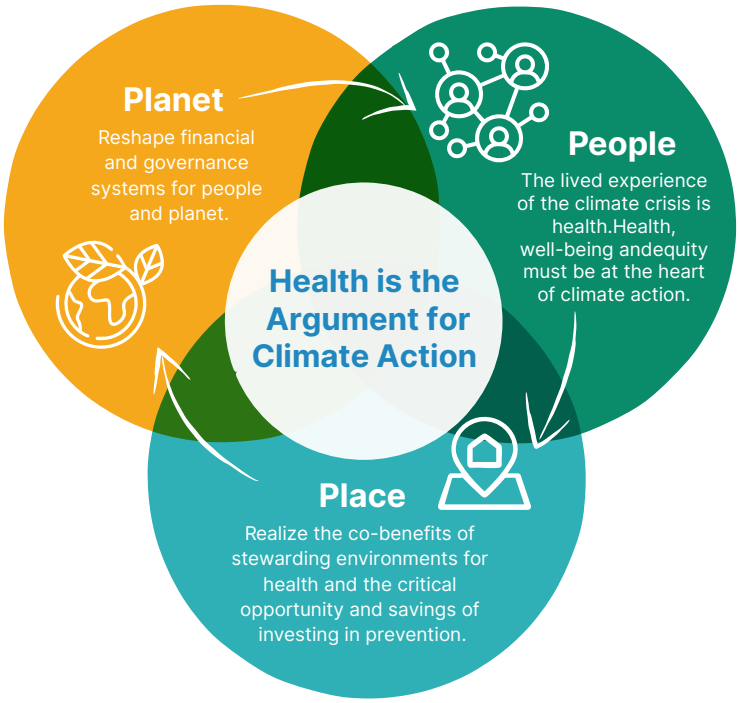
Lack of access to clean water can be worsened by climate change-induced droughts and floods, increasing disease risk and complicating adaptation. The food system drives climate change and environmental degradation through land use change, freshwater depletion, and nitrogen, phosphorus and pesticide pollution, while also contributing to diet-related disease burdens. Addressing these interconnected risks is essential to achieving health and climate goals. Given the wide diversity of climate-related health risks across the WHO European Region, it is essential for governments to assess and understand the specific hazards and vulnerabilities within their national contexts in order to design and implement appropriate, context-sensitive responses.

Country efforts to implement action on climate change and health across national priorities and various sectors can be guided by international commitments on leaving no one behind in addressing the core drivers of climate change and health by implementing the United Nations Framework Convention on Climate Change (UNFCCC) *(9)*, the Paris Agreement *(10)* and the Agenda for Sustainable Development *(11)*. The Budapest Declaration *(12)* adopted during the Seventh Ministerial Conference on Environment and Health emphasized taking a whole-of-government and whole-of-society approach to transformative governance, with a strong emphasis on prioritizing action to tackle the health challenges related to climate change. In 2024 the WHO 77th World Health Assembly adopted a strong resolution on climate change and health *(13)*, with action prioritized as the first of all WHO strategic objectives. Both the WHO Fourteenth Global Programme of Work *(14)* and 77th World Health Assembly resolution – along with the upcoming Second European Program of Work *(15)* – have established responding to climate change as a core priority, including through low-carbon and climate-resilient health systems.

In outlining recommendations for governments, the global health community and other sectors to place health at the heart of climate solutions, the WHO 29th United Nations Climate Change Conference (COP29) special report on climate change and health *(16)* framed the required responses (Fig. 1) in terms of:

- **PEOPLE**: mobilizing the health workforce, creating climate-proof health systems together with urgent action across multiple sectors to achieve equity, protect rights and ensure a just transition for all in benefitting from climate strategies;
- **PLACE**: recognizing the core importance of cities, in contributing to GHG emissions but also as a source of solutions to drive change; and of natural systems, whose sustainability (for delivering clean air, safe water and productive land) must be protected and restored; and
- **PLANET**: requiring realignment of economic, financial and other governance systems to support human health within safe and just Earth system boundaries *(17)*.

Fig. 1. The people-place-planet framework: key pillars of taking action for climate change and health



Source: (16).

Countries across the WHO European Region are among those already experiencing the greatest regional heating worldwide. The year 2024 was the joint warmest on record according to the World Meteorological Organization Europe domain, and a 0.28°C increase from 2020 *(18)*. It can be difficult to compare relative health impacts of absolute temperature rises above a baseline in different regions. Nonetheless, there are significant adverse health impacts *(4,19)* and projections for worse ahead *(20)*, including in European Union Member States *(21)*, western Asia *(22)*[2] and central Asia *(23,24)*[3] and their neighbours, for example in the Mediterranean (including north Africa and the Middle East) *(25)*. Furthermore, rising temperatures create an increasing risk of crossing several earth system tipping points (whose exceedance can result in self-perpetuating changes in the climate and other interconnected subsystems). Initial modelling of European and global impacts arising from crossing tipping points predict large economic losses and financial instability (inadequately covered by the insurance sector) which, together with biophysical impacts, will threaten national and international security *(26)*.

The WHO Regional Office for Europe is active in its commitment to improve the resilience and capacity of national health systems and to facilitate intersectoral collaboration to deal with the adverse effects of climate change. The Working Group on Health in Climate Change, established under the European Environment and Health Process

2 Western Asia comprises Armenia, Azerbaijan, Georgia, Israel and Türkiye. The country grouping is as per the United Nations Geoscheme (19)

3 Central Asia comprises Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The country grouping is as per the United Nations Geoscheme *(19)*.

(EHP), produced a second updated edition of the "Zero regrets" paper *(1)*, articulating and consolidating an action-oriented health and climate change position for the WHO European Region, including enhanced coordination with the European Commission and the European Union Observatory on Climate Change and Health. The EHP Partnership for Health Sector Climate Action, under the leadership of Ireland and in collaboration with the WHO Secretariat, is a community of practice established by Member States of the WHO European Region. The Partnership aims at unpacking implementation challenges and chart solutions to developing climate-resilient, low-carbon health systems. In addition, the work of WHO together with UNFCCC in constructing Health and climate change country profiles *(27)* provides a valuable resource to inform action and collaboration.

While climate change impacts everyone, climate-induced changes are not experienced equally across geographical regions, genders, income levels, classes, ethnicities, ages or physical abilities. The scale, nature and timing of adverse effects on health and equity are complex and vary within the Region, but there are common challenges for a just climate-health transition, that can be tackled by better integrated mitigation and adaptation actions. This necessitates addressing health priorities through effective, cross-sectoral, transdisciplinary policy development and implementation: this is not always the case, as illustrated by the recent Dushanbe Declaration on green development priorities, which did not mention health *(28)*.

Finally, whereas this technical brief is focused on climate change, the prospects for health and development are being undermined by the increasing transgression of multiple earth system boundaries. As noted by the "Zero Regrets" paper *(1)*, climate change, environmental pollution, biodiversity loss (and other land system changes) and the energy challenge are intertwined and converging global crises, which require integrated and cross-sectoral responses. Therefore, it is increasingly necessary to take a transdisciplinary approach with research transcending different disciplines and working jointly on concepts, methods and translation to practice, to understand multiple intersecting threats *(29)*.

In subsequent chapters we provide an overview of the impactions of climate changes on health; describe current and potential science-based solutions; and set these opportunities into their policy and strategic frameworks for governance for health-centred climate action.

2. Health impacts of climate change

- Climate change is already damaging health across the Region, through both direct (e.g. heatwaves, wildfires, floods, droughts) and indirect pathways (e.g. shifting disease patterns, food insecurity, air pollution).
- Vulnerable populations, including older adults, socially and economically disadvantaged groups, and those with pre-existing health conditions, are disproportionately affected, with rising risks to both physical and mental health.
- Integrated climate and health action can prevent disease, improve quality of life, address common drivers such as fossil fuel combustion, and reduce health inequalities across the Region.

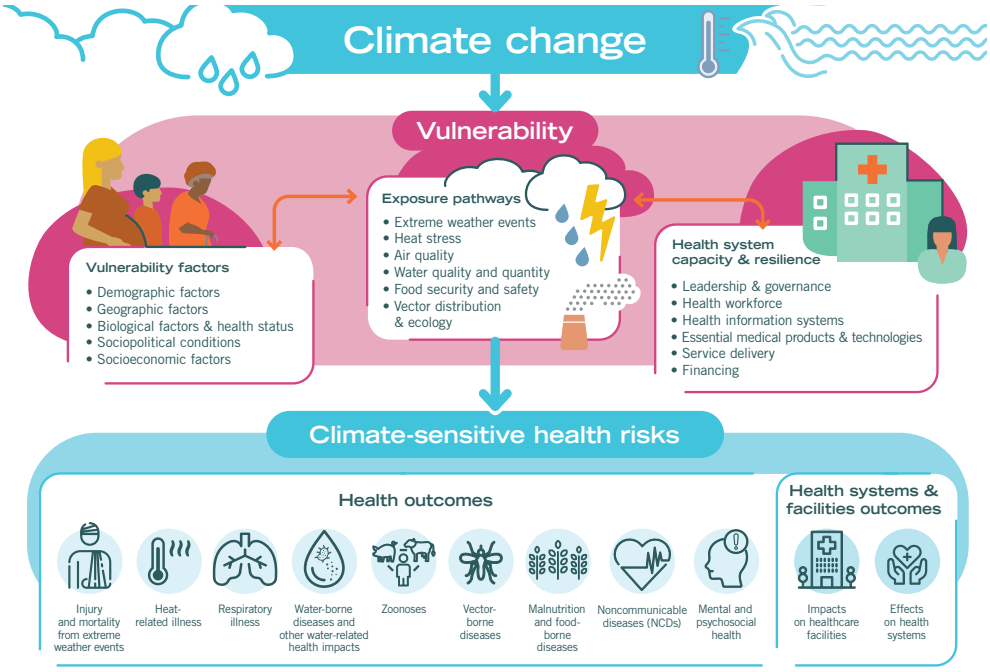
2.1. Background

There is a growing body of evidence detailing health and social impacts of climate change in the European Region *(2–5)*. As emphasized in the "Zero Regrets" paper *(1)*, the evidence is compelling, offering strong arguments for transformative change towards creating healthy and sustainable societies, committed to achieving equitable health now and for future generations, without breaching ecological limits.

Evaluation of the evidence (Fig. 2) needs to take account of:

- pathways of exposure and impact, such as heat-related effects, infectious disease, risks to food safety, and water and food security;
- places where people are more exposed, such as urban, river and coastal areas;
- those who are more vulnerable, such as the chronically ill, older people *(30)* and pregnant women *(31)* or whose occupations result in high exposure (e.g. agricultural and construction workers) or whose recreational and active mobility activities result also in a high exposure (e.g. running, walking and cycling during climate extremes); and
- other indirect pathways (e.g. via disruption of supply chains, increasing the risk of viral contamination of donated blood supplies *(32)*.

Fig. 2. Direct and indirect pathways of exposure to climate change and their health consequences



Source: (1).

In response to the evidence, regional and local collaborations are increasingly influential in advancing climate action, but significant evidence gaps exist and improved data availability and access for underrepresented regions and vulnerable populations remain a priority in all parts of the Region *(33)*.

In the following sections in this chapter, we provide further details on the main current and projected climate-health threats – direct and indirect – facing the WHO European Region, or parts thereof if data are not available for all countries.

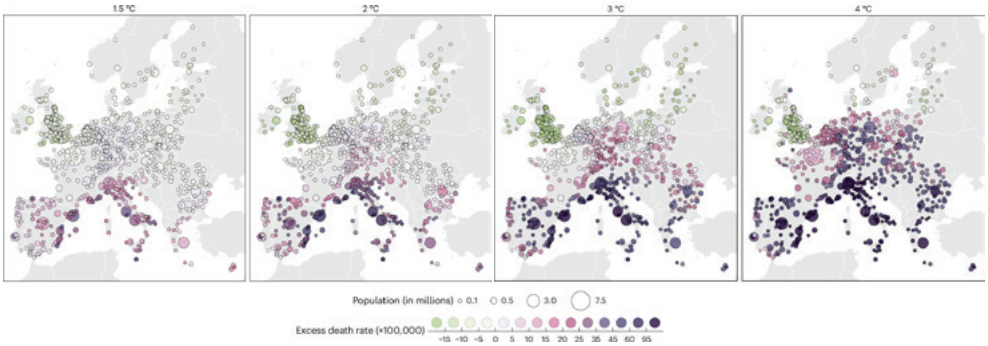
2.2. Heat-related illness and mortality

Heat is the deadliest climate-related health threat in Europe, and it's worsening rapidly.

Heating in continental Europe is expected to be greater than global mean projections. In winter, the temperature increase is most noticeable at northern latitudes, while in summer it is more pronounced in central and southeastern Europe and the Mediterranean *(3,18)*. Extreme heat has occurred more frequently in western Europe compared to earlier decades, contributing to an unparalleled rise in heatwaves over the past twenty-five years, while a recent report of trends in a heat vulnerability index for the Region – capturing both exposure and susceptibility – reported the highest increases since 1990 in southern Europe (11%) and western Asia (11.6%) *(19)*. Rising temperature extremes in both western and central Asia, and increased threat of drought are projected with high confidence, with high projections of extremely hot days expected to occur in central Asia *(23,24)*.

The effects of high temperatures on mortality have been studied in detail (Fig. 3 for municipalities in the Region and Fig. 4 for European country-level assessment) and a range of other adverse health effects have also been documented *(2–4,19)*, particularly in vulnerable groups, for instance, for mothers and newborns *(30,31)*. Recent analyses highlight that heat is already the deadliest climate-related hazard in the WHO European Region, with temperature-related mortality increasing significantly over the past decades *(1,19)*.

Fig. 3. Temperature-related excess mortality for 854 European municipalities under a scenario of minimal mitigation or adaptation



Note: Though cold-induced deaths under warming climate scenarios will decline, this is not expected to outpace the increase in heat-induced deaths, with projections of net increases under various climate scenarios. Even the most optimistic scenario of sustainability and mitigation actions resulted in cumulative excess deaths of 616 798 projected for the same time period.

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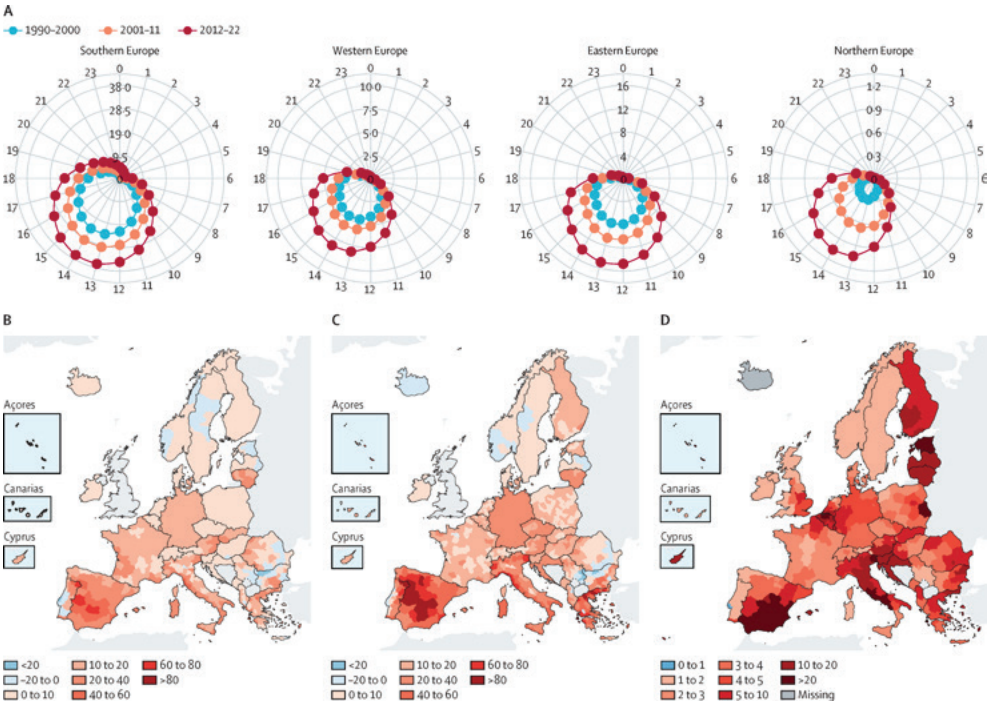
As illustrated in Fig. 3, projections indicate a continued and substantial rise in heat-related deaths across European cities, particularly in southern and eastern Europe. Pooled analyses of the quantitative effects of heat on maternal and neonatal health from a global review *(35)*, including 36 studies from Europe, concluded that for each 1°C rise in ambient heat exposure above the optimal level, the odds of preterm birth increased by 4% and, during exposure to heatwaves, by 26%. Heat-related health

risks are compounded by demographic changes such as Europe's aging population, urbanization, migration and increasing pressures on energy, transport and health-care systems and related costs.

Fig. 4. Change in the likelihood of extreme heat-related mortality due to anthropogenic warming



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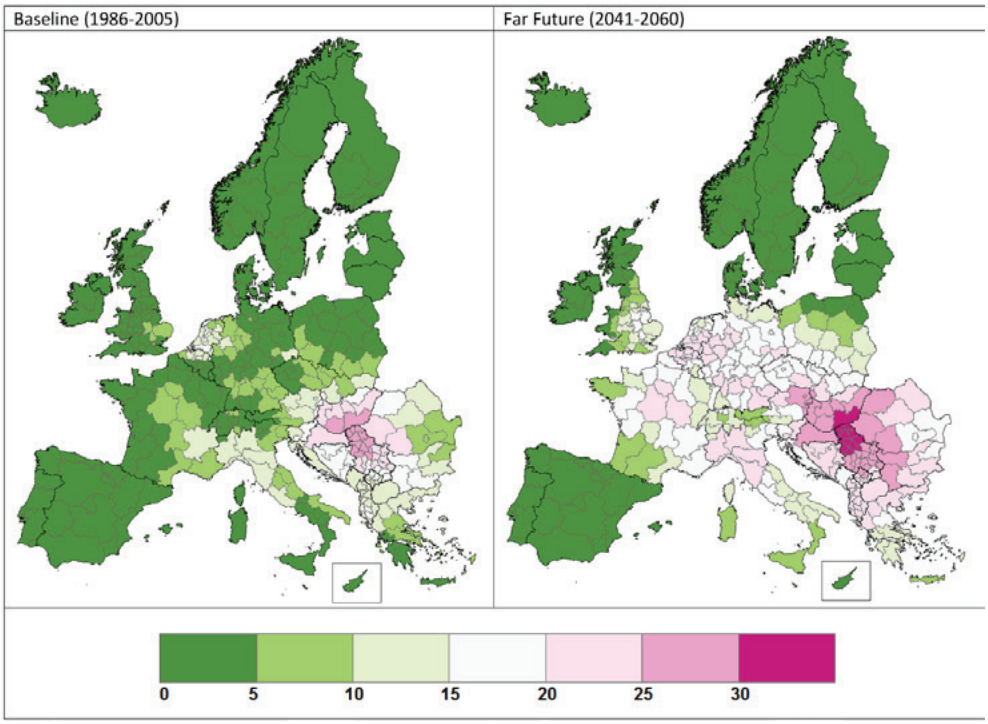
In addition to direct effects, rising temperatures may affect health in other, indirect ways. For example, flowering trends for birch, alder and olive trees, particularly in mountainous regions, have occurred earlier in the season under increasing temperatures, suggesting that the severity of seasonal allergies, which already impact an estimated 40% of the European population, may increase. Projections for increasing allergic sensitization to ragweed pollen are illustrated in Fig. 5. Rising temperatures also intensify other non-lethal health impacts, such as exacerbations of cardiovascular and kidney diseases, while contributing to mental health challenges and reduced overall well-being.

Fig. 5. Percentage of population sensitized to ragweed pollen baseline (1986–2005) and future (2041–2060)



Note: Projections of sensitisation to ragweed pollen suggest a doubling of impact, affecting 77 million people by 2041–2060, particularly in Hungary and the Balkan countries where ragweed is common, but also in France Germany and Poland.

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2.3. Infectious diseases

Climate change is driving the spread of infectious diseases into new regions and exposing millions to emerging health threats.

Nearly 60% of all known infectious diseases are aggravated by climate hazards *(37)*. Climate change influences the spread of infectious diseases by altering the distribution of vectors and pathogens, extending transmission seasons and increasing human exposure through environmental changes such as rising temperatures, shifting precipitation patterns, floods and land-use change *(29,37)*.

In parts of the Region, particularly southern and eastern Europe, diseases like West Nile Virus have expanded, with 709 cases and 67 deaths reported in 2023, driven in part by warmer spring temperatures *(38)*. Scenario modelling suggests that vector-borne diseases, including chikungunya and dengue, may become established in new regions as climatic conditions become more favourable *(5,30,36)*. These mosquito vectors (*Aedes albopictus* and *Aedes aegypti*) are also capable of transmitting Zika virus *(32)*.

Warming trends are also linked to increased risks of zoonotic diseases, such as Lyme borreliosis, cryptosporidiosis and the spread of Crimean-Congo haemorrhagic fever vectors into central Europe *(39,40)*. Furthermore, campylobacter infections, already one of the most common causes of gastrointestinal illness, are projected to nearly

double in northern European countries by the end of 2080s under a high-emissions scenario *(41)*. Additionally, higher sea surface temperatures, particularly in the Baltic Sea, have led to increased ecological suitability for waterborne pathogens like non-cholera *Vibrio* species – an effect that, by 2022, was estimated to potentially expose up to 150 million people across 21 countries. While not all of this exposure is solely due to climate change, warming seas are a key driver of the expanding distribution of these pathogens *(19)*.

Climate change thus contributes to both the resurgence and the emergence of non-endemic infections, posing evolving challenges for surveillance, prevention and health-care systems across the Region.

2.4. Mental and psychosocial health

Climate change is driving a growing mental health burden through both extreme events and chronic stress, especially among youth and other vulnerable groups

The literature identifies three broad pathways through which climate change affects mental health: the direct psychological consequences of acute, sudden-onset events such as floods or wildfires; the chronic mental health effects associated with slow-onset changes, including prolonged droughts and heat stress; and climate-related anxiety, characterized by anticipatory distress in response to perceived environmental threats, particularly among children and young people *(42,43)*.

For example, in the United Kingdom, studies observed that the impact of flooding on psychological morbidity effects lasted at least 3 years after the event *(44)*. While most studies on sudden-onset climate events link mental health outcomes to event exposure using a trauma-focused lens, this approach is less appropriate for slow-onset climate events such as long-term drought or high temperatures. In these circumstances research has instead focused on depression, anxiety, non-specific distress and negative emotions affecting well-being. In contrast to the stronger body of causal evidence associating mental health outcomes with sudden-onset climate events, relationships with long-term climate changes are more difficult to study partly because of the need for sustained data collection. The concept of solastalgia has been developed to describe the emotional distress caused by environmental change *(45)*, including from drought.

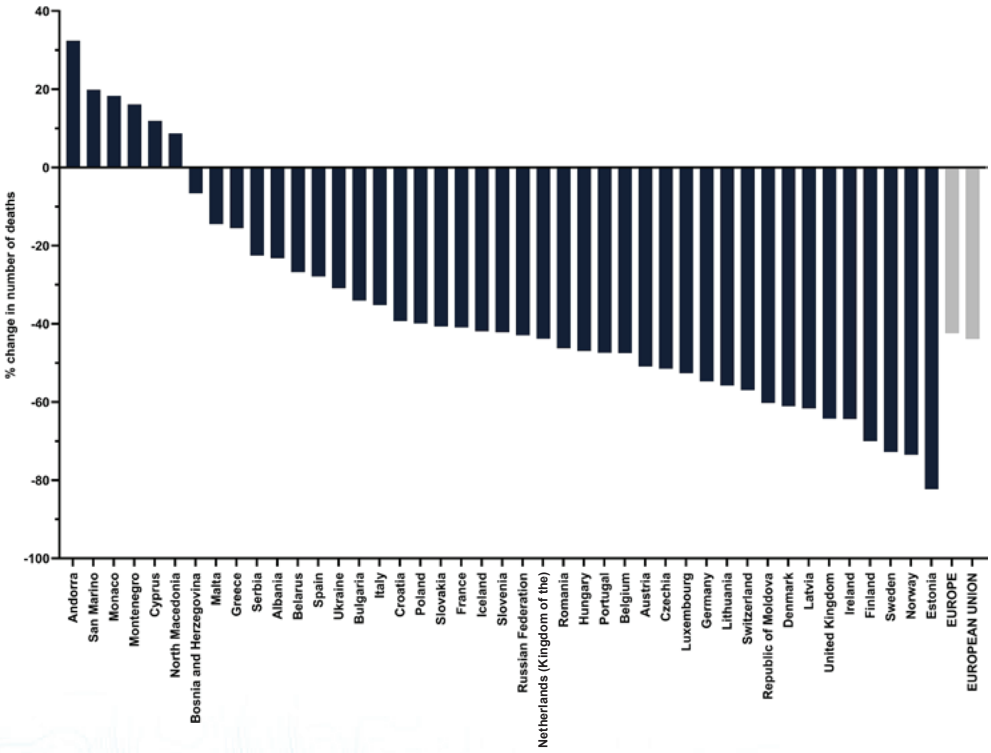
The fear of climate change – along with ecological changes related to pollution and biodiversity loss – as a global threat may itself also create emotional stress and anxiety about the future, particularly in children and adolescents *(36)*. Overall, in a 10-nation global survey, about 59% of young people were very or extremely worried and 84% were at least moderately worried about climate change *(46)*.

2.5. Air pollution

Cutting emissions tackles both air pollution and climate change, delivering near-term and long-term health benefits.

Air pollution and climate change share common roots in fossil fuel combustion, meaning that actions to reduce emissions can deliver major co-benefits for health and climate. Air pollution exposure is a risk factor for respiratory, cardiovascular, cancer and diabetic outcomes, as well as a contributor to adverse neonatal outcomes and premature mortality. Estimates vary, as discussed for example by the European Academies' Science Advisory Council *(36)*, but about 570 000 deaths in the WHO European Region were attributable to ambient air pollution in 2019, with an additional 154 000 deaths attributed to household air pollution *(47)*. Sources of air pollution – including particulate matter – from fossil-fuel combustion in households and energy and transport sectors, are also important sources of GHGs, such as carbon dioxide and methane and, therefore, mitigation efforts lead to reduced air pollution. The relationship between climate change and air quality is complex: for example, reducing sulphate aerosols in isolation can exacerbate temperature increases because they are cooling *(36)*. In Europe, marked reductions in deaths attributable to air pollution exposure have been observed (Fig. 6) *(19,48)*, but deaths are still high because about 97% of the population breathes air above WHO recommended air pollution levels.

Fig. 6. Changes in deaths attributable to air pollution in 43 European countries in 2019 compared to 1990



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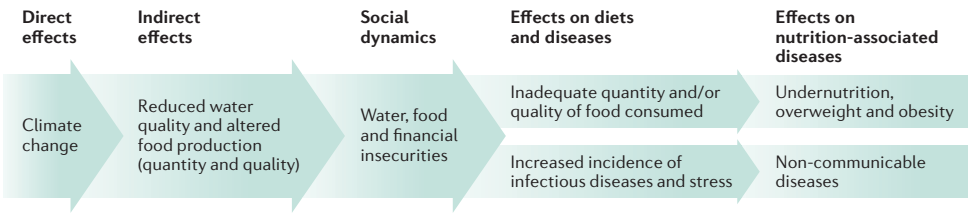
Measures taken to reduce air pollution in parts of Europe include improving energy efficiency and switching to lower emission fuels. Further, public health in many countries across the European Region continues to be affected by transboundary air pollution, which remains a significant challenge and is addressed under the United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution *(49)*. WHO provides useful resources to support air pollution reduction policies to protect health *(47)*. Lack of ground-level air quality monitoring infrastructure in parts of the European Region, such as in central Asia, limit the availability of studies on air pollution and its health impacts. A recent investigation *(50)* used monitoring stations located in United States of America Embassies in six central Asian cities, where contributors to fine particulate matter ($PM_{2.5}$) included coal fuel combustion for heating, energy and transport; exhaust emissions from traffic; and dust storms. Annual concentrations of $PM_{2.5}$ were 4–12 times higher than the WHO annual air quality guideline levels with maximum concentrations revealing a strong seasonal pattern, likely related to seasonal demand for heating and stagnant weather which reduces dispersion.

2.6. Food and nutrition security

Climate change threatens food security, nutrition, and livelihoods across Europe, with growing risks for vulnerable populations.

Climate change threatens food security and safety across the WHO European Region by disrupting agricultural production through more frequent droughts, heatwaves and heavy rainfall events (Fig. 7) *(51–53)*. In turn, agriculture and other steps in the food chain contribute significantly to GHG emissions worldwide (Fig. 8).

Fig. 7. Effects of climate change on nutrition-associated diseases



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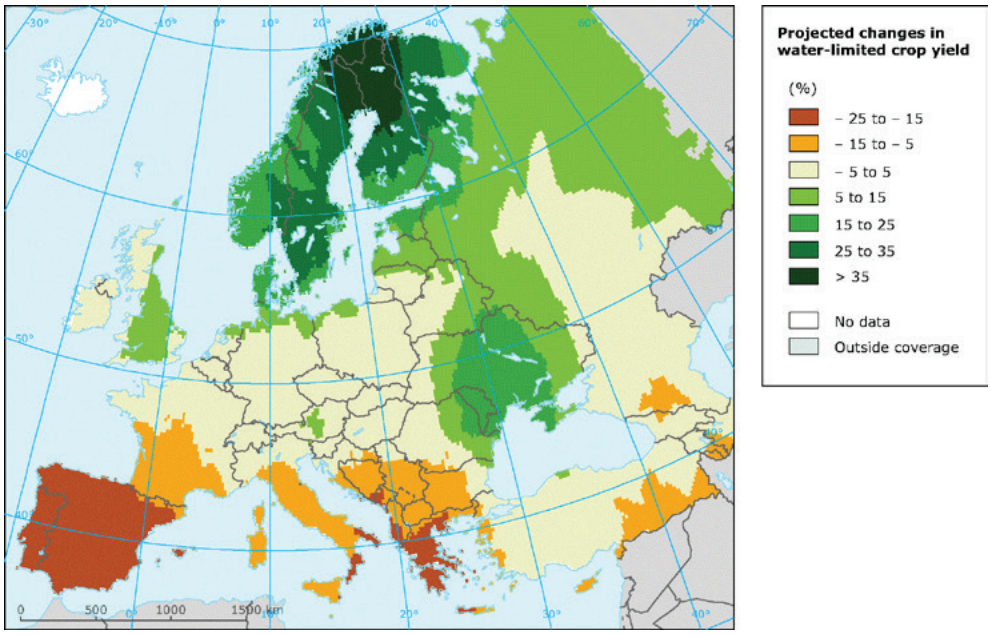
Climate-related stresses reduce crop yields and quality, with projections indicating that future declines due to droughts and heatwaves may be worse than currently estimated (Fig. 8) *(55)*. Rising temperatures also impact the productivity of agricultural workers, particularly in southern and eastern Europe *(56)*. Productivity declines at temperatures above 24–26°C, and workers performing moderate-intensity tasks lose up to 50% of their work capacity at 33–34°C *(56)*.

Fig. 8. A regional comparison of the projected effects of climate change on agricultural crops in Europe



Note: this is an aggregated picture of expected changes in crop yields across Europe for the 2050s as compared with 1961–1990. The simulations include effects of changes in temperature, precipitation and carbon dioxide concentration on crop yields of three main crops assuming current irrigated area.

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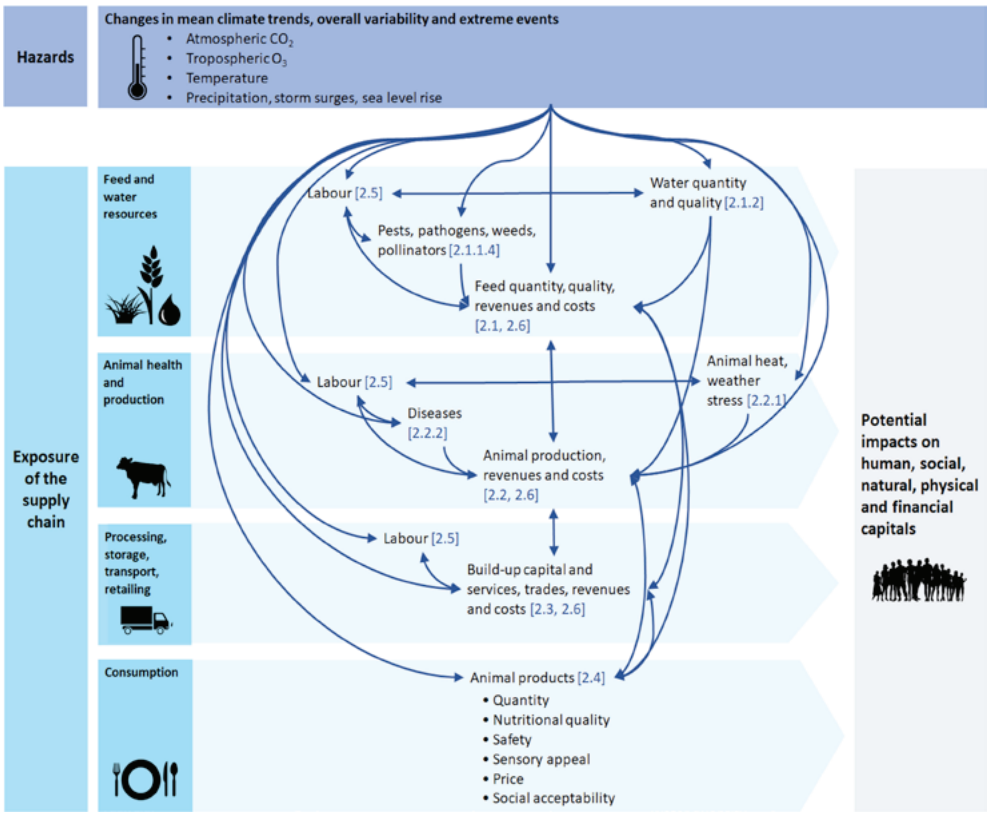
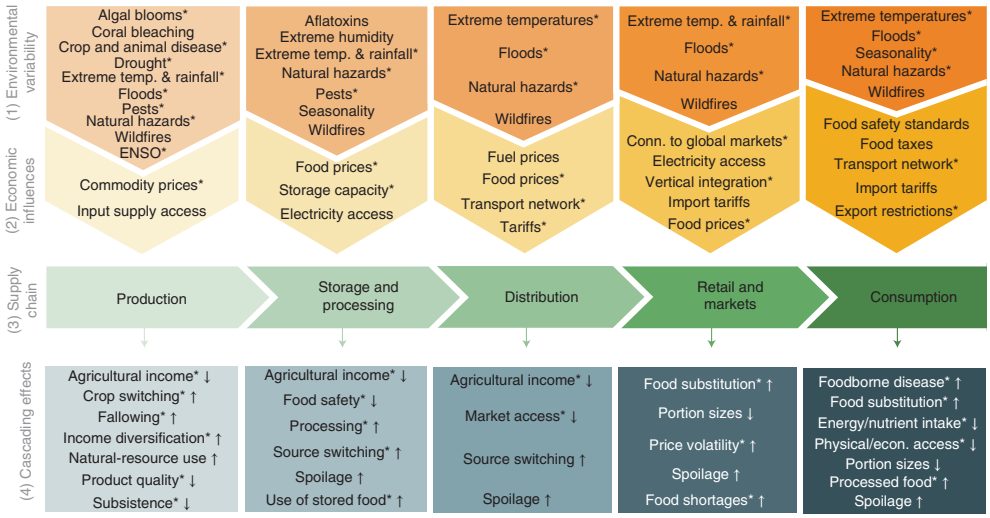
In addition to lowering yields, elevated carbon dioxide levels and climate stressors reduce the nutritional value of key crops, exacerbating risks of micronutrient deficiencies *(52,53,58)*. By 2050, it is projected that increased carbon dioxide concentrations will reduce protein, iron and zinc content, impacting key crops essential for a healthy diet – such as fruits, nuts, vegetables and legumes *(58)*. Livestock, fisheries and aquaculture face similar pressures, with heat stress reducing productivity and fertility in animals (Fig. 9). For example, increased heat has been linked to declines in milk quality from dairy cows *(58)*; and heat stress and warming waters reduce marine productivity and alter the distribution of aquatic species in the Region, notably in the Baltic and Caspian seas *(59,60)*. Climate change further disrupts food supply chains (Fig. 10), increases food price volatility and heightens food safety risks through greater exposure to foodborne diseases, mycotoxins and chemical contaminants *(61,62)*.

Fig. 9. Impacts of climate change on the livestock food supply chain



Source: *(63)*. Reproduced under the CC-BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

Fig. 10. Impacts of climate change throughout food chain



Source: *(61)*. Reproduced with permission from Springer Nature BV.

Changes in temperature and humidity can heighten the risk of foodborne diseases, contaminants and zoonoses. During storage, rising temperatures and altered rainfall patterns create favourable conditions for bacterial growth, increasing the risk of foodborne diseases, particularly where cold storage facilities are insufficient *(61)*. Countries reliant on food imports, including from countries more affected by climate change, are particularly vulnerable to global supply disruptions, while low-income populations face disproportionate impacts as climate change drives shifts toward less healthy, ultra-processed diets.

2.7. Wildfires

Rising wildfires endanger lives, worsen air quality and increase long-term physical and mental health risks.

The frequency, intensity and geographic spread of wildfires are increasing across the WHO European Region due to rising temperatures, prolonged droughts and shifting wind patterns linked to climate change. Notably, wildfires are now occurring outside traditional fire seasons and in areas previously unaffected, driven by conditions such as heatwaves and extended dry periods *(3,18,19,21)*. Wildfires pose immediate and long-term health risks. Beyond direct injuries and fatalities, exposure to wildfire smoke significantly increases respiratory and cardiovascular morbidity, particularly among vulnerable groups such as older adults, children and those with pre-existing conditions *(4,19)*. $PM_{2.5}$ from wildfire smoke can travel vast distances, exacerbating air quality far beyond the fire zones *(19)*. Additionally, wildfires contribute to long-term mental health impacts, including anxiety, depression and post-traumatic stress disorder, especially in communities repeatedly exposed to such events *(42,43)*. With climate projections indicating a continued rise in wildfire risk, particularly in southern and eastern Europe, integrated approaches to forest management, wildfire prevention, emergency response and public health protection are critical *(19,20)*.

2.8. Drought

More frequent and severe droughts are undermining water security, food systems and public health resilience.

Droughts are becoming more frequent, prolonged and severe across the WHO European Region, driven by rising temperatures, altered precipitation patterns and increasing water demand. In central Asia, countries such as Turkmenistan and Uzbekistan are among the most water-stressed globally, facing compounded challenges from climate change and unsustainable water management practices *(64)*. Furthermore, while central Asia, southern Europe and the eastern Mediterranean are traditionally vulnerable, recent trends show that central and western Europe are also experiencing significant drought events, exacerbated by overuse of water resources, particularly in agriculture *(3,18,21,64)*.

The health impacts of drought are multifaceted. Water scarcity can lead to reduced water quality, increasing the risk of waterborne diseases such as diarrhoeal illnesses, particularly among children *(4)*. Drought conditions also compromise food security by reducing agricultural yields, contributing to malnutrition and related health outcomes *(50,52,53,55)*. Furthermore, prolonged droughts are associated with heightened risks of respiratory diseases due to dust exposure, worsening air quality, and increased incidence of mental health disorders linked to economic stress, displacement and environmental degradation *(42,43)*. Given the projected intensification of drought under climate change scenarios, comprehensive strategies are needed to safeguard water security, ensure safe drinking water, protect food systems and address the broader public health consequences *(3,21)*.

2.9. Flooding

Floods are becoming more dangerous and frequent, causing deaths, disease outbreaks and lasting impacts on mental health and infrastructure.

Flooding events are increasing in frequency, intensity and duration across the WHO European Region due to climate change-induced shifts in precipitation patterns, rising sea levels and the growing occurrence of extreme weather events *(3,18,19,21)*. Both coastal and inland areas are at heightened risk, with urbanization and inadequate drainage infrastructure further amplifying flood impacts in many regions *(21)*. Floods pose significant immediate and long-term health risks. Acute impacts include drowning, injuries and outbreaks of waterborne diseases due to contaminated water supplies *(4)*. Beyond these direct effects, floods contribute to medium-term increases in all-cause, cardiovascular and respiratory mortality. A global study found that such mortality peaks approximately 25 days after flood exposure and can persist for up to 60 days, with the most severe impacts observed among older adults and socioeconomically disadvantaged populations *(65)*.

Mental health consequences, including anxiety, depression and post-traumatic stress disorder, are common in flood-affected communities, particularly where repeated events erode social and economic resilience *(42,43)*. Additionally, flooding can disrupt health services, displace populations and damage critical infrastructure, compounding health risks during and after events *(12,19)*.

With projections indicating further increases in flood risk across Europe, particularly in river basins and low-lying coastal zones, there is an urgent need for integrated adaptation strategies. These include early warning systems, resilient infrastructure, urban planning reforms and targeted support for vulnerable populations.

2.10. Cross-cutting and emerging issues

Addressing the systemic health risks of climate change through integrated responses can drive more resilient, equitable health systems.

Climate change, including increases in the frequency and intensity of extreme weather events, creates complex, interconnected health risks that extend beyond specific hazards, placing growing strain on health systems, exacerbating social inequities and amplifying vulnerabilities among marginalized populations. Emerging challenges include climate-related displacement, disruptions to health-care delivery, declining workforce productivity and potential pathogen release linked to environmental changes such as permafrost thawing *(3,66,67)*. Furthermore, climate change interacts with biodiversity loss, land degradation and pollution, creating feedback loops that threaten health and livelihoods *(17)*. In addition to physical health, the mental health impacts of these converging crises – ranging from acute trauma to chronic anxiety – are increasingly recognized, particularly among youth and vulnerable groups, however, responses remain fragmented and under-resourced, with limited integration into broader climate and health strategies *(42,43)*. Although attribution of such complex outcomes to human-induced climate change remains challenging, advances in detection and attribution science are rapidly strengthening the evidence base (see further discussion in Annex 1).

3. Adaptation and mitigation: progressing solutions

- Integrating health into climate adaptation and mitigation delivers both immediate and long-term benefits for people and the planet.
- Resilient, low-carbon health systems are essential to protect populations from worsening climate impacts.
- Stronger governance, financing and cross-sector collaboration are critical to turn climate commitments into health-positive action.
- Many health systems remain insufficiently adapted to climate-change related health impacts.

As emphasized in the "Zero Regrets" paper *(1)*, the imperative to protect and improve the health of current and future generations is one of the strongest arguments for action on climate change and sustainable development. Adaptation and mitigation strategies are interconnected and essential for building healthy, resilient societies. Global frameworks such the Paris Agreement *(10)*; Nationally Determined Contributions (NDCs); and Long-term Low Emission Development Strategies (LT-LEDS) provide opportunities to integrate health into climate negotiations, including co-benefits. However, uneven progress and significant gaps remain in the integration of health into all policies, their implementation and accountability in governance systems.

In this chapter we discuss the evidence for adaptation and mitigation solutions emphasizing the imperative to work across sectors, target the most vulnerable and co-design with the communities affected. We then consider some of the challenges and opportunities for progressing these solutions in the context of generating and maintaining science-policy linkages across the WHO European Region and the need to align initiatives within the Region with other – global – policy developments. In the broader context we also emphasize that effective governance of equitable climate-health solutions requires both engagement with all interested parties – with a core part of this engagement countering false information – and examination of transformative approaches to financing *(68)*.

3.1. Adaptation and health gains

Adaptation offers a powerful opportunity to protect health, especially when it is community-driven, equitable and designed to build long-term resilience.

Adaptation measures encompass a broad range of public health interventions, such as heat-health action plans, urban cooling systems and water/sanitation initiatives, all designed to enhance community resilience. For instance, countries, subregions and cities in the Region develop and implement heat-health action plans that consists of a portfolio of actions at different levels, to prevent, respond to and contain heat-related risks to health. Currently, 19 out of 53 Member States of the WHO European Region have national/federal-level heat-health action plans. However, the impact of health adaptation is often uncertain due to the interplay of various complicating factors, including the risk of maladaptation and the limits to adaptation effectiveness *(4)*. Risk assessments and early warning systems are central to effective adaptation in responding to threats such as extreme heat events and disease outbreaks. For instance, urban heat mapping has proven effective in identifying areas where targeted interventions, such as the creation and protection of green spaces and reflective roofing, can reduce health risks. However, recent modelling suggests green space expansion may slightly increase cold-related mortality in some European cities, underscoring the need for locally tailored strategies *(34)*. Health national adaptation plans guide countries in prioritizing and implementing health-focused adaptation strategies *(1,69)*.

As noted previously, there are multiple direct and indirect pathways mediating the adverse effects of climate change on health. Consequently, there are also multiple opportunities across sectors for integrating adaptation and mitigation solutions. Just as urban and health-system interventions can build resilience to climate threats, so too can adaptation in food systems: another critical determinant of population health. In the agricultural sector, a combination of climate-smart, conservation based, traditional and agroecological practices –such as no-till farming, crop rotation, biodiversification, improved fertiliser use and management, water harvesting and cover cropping – can support both adaptation and mitigation efforts for food and nutrition security *(47,70)*. Investment in developing climate-tolerant crop varieties is also essential, particularly those resistant to heat stress, pests and diseases or with increased nutrient content *(47,70)*. Policy support is crucial with regulations and incentives that encourage sustainable soil management and plant breeding, while discouraging harmful practices *(5,36)*.

Despite efforts across multiple sectors, adaptation faces challenges. The absence of universal metrics for measuring health adaptation outcomes limits the ability to evaluate success, particularly when compared to the clearer endpoints of mitigation strategies, such as emissions reductions. Poorly designed interventions may lead to maladaptation, exacerbating vulnerabilities, deepening inequalities or creating new risks, such as increased emissions from high-energy cooling systems or potential unintended heating effects from cool roofs *(71)*. Planting unsuitable trees in the wrong place can also increase heat exposure at night *(72)*. Engaging communities in designing, researching, implementing and evaluating adaptation solutions is critical to avoiding these pitfalls. Community involvement not only enhances the relevance and

effectiveness of interventions but also supports equitable outcomes and fosters trust in public health systems *(5,19,73)*. Adaptation efforts are likely to be most effective when aiming for "triple wins," addressing health, equity and environmental sustainability simultaneously.

3.2. Adaptation in health systems

Climate-resilient health systems require robust infrastructure, surveillance, and a trained workforce to face rising climate-health threats.

Effective adaptation within health systems requires a comprehensive approach, encompassing, amongst others, infrastructure improvements, enhanced disease surveillance and workforce capacity building: these three factors are expanded on below *(74)*.

Climate-resilient infrastructure

Adaptation begins with fortifying health system infrastructure to withstand climate-related shocks. Climate-proof hospitals and clinics, for example, are designed to maintain operations during extreme weather events, with features such as flood-resistant designs, enhanced ventilation, and renewable energy systems, including an objective to sustain critical functions during power cuts. Enhancing energy efficiency and transitioning to low-carbon energy sources in health-care facilities can significantly reduce GHG emissions, while integrating resilient power solutions, such as renewable energy and backup systems, can help ensure reliable electricity supply during emergencies *(19,75)*. Initiatives like the solarization of health-care facilities in southern Europe provide scalable models for integrating renewable energy into health infrastructure.

Surveillance and early warning systems

These systems are vital for addressing climate-sensitive diseases, including vector-borne illnesses like dengue and West Nile virus. In Europe, integrated early-warning systems have successfully predicted disease outbreaks by monitoring environmental conditions, such as temperature and precipitation patterns *(5,36)*. These efforts must be complemented by strengthening health service delivery, including health-care worker capacity building and risk communication, to manage the rising demand from climate-related health threats.

Workforce training and capacity-building

Health professionals are at the forefront of responding to climate-health challenges and require training to manage climate-related health risks effectively. This includes recognizing emerging disease patterns, treating heat-related illnesses and implementing sustainable practices within health-care settings. WHO's initiatives on climate literacy for health professionals have proven effective in building awareness and preparedness among health-care workers *(1)*.

3.3. Adaptation in urban settings

Urban adaptation must prioritize vulnerable populations, balancing climate action with equity, health and sustainable city planning.

Strategies must prioritize health equity, focusing on the needs of vulnerable groups disproportionately affected by climate change. Their heightened vulnerability stems from a combination of physiological, socioeconomic and environmental factors that amplify climate-related risks such as heat stress, air pollution and food insecurity *(2)*. Urban populations represent a unique "at-risk group" due to the compounded effects of urban heat islands, air pollution and dense living environments. While cities concentrate resources and health-care infrastructure, they also exacerbate vulnerabilities for certain groups, including low-income residents and outdoor workers. Carefully designed solutions with equitable access, such as urban greening – planting appropriate trees, creating parks and enhancing green roofs – can reduce heat stress, improve air quality and enhance mental health *(2)*. To achieve optimum effects, multispecies approaches to tree planting are required taking into account the local climate and avoiding allergenic species or those producing large amounts of volatile organic compounds that are precursors of tropospheric ozone. These interventions must also be balanced with competing urban and other land use priorities. For instance, compact city designs lower carbon emissions by promoting public transport and reducing urban sprawl but can result in reduced green space, negatively impacting environmental quality and health outcomes. Similarly, urban greening initiatives can inadvertently promote gentrification, exacerbating social inequities, highlighting the need for equitable and inclusive planning *(76)*.

The intersection of gender and socioeconomic status plays a significant role in determining climate action outcomes. Women, particularly in low-income households, are often primary caregivers and disproportionately bear the health and economic burdens of climate impacts. Tailoring adaptation solutions to address gender-specific vulnerabilities, for example in disaster response systems, is vitally important *(5)*.

3.4. Mitigation and health gains

Phasing out fossil fuels and promoting active transport, and more sustainable food systems can cut emissions while preventing diseases and saving lives.

As noted in the "Zero Regrets" paper *(1)*, from global assessments, *"Accelerated mitigation, if delivered with health considerations at its heart, can result in significant health co-benefits in the short term. Millions of lives could be saved each year by fast-tracking the transition to cleaner fuels, healthier diets and active modes of travel"*. A clean energy transition is central to both climate mitigation and public health. To reiterate, phasing out fossil fuels not only cuts GHG emissions but also significantly decreases air pollution *(8)*. Reducing $PM_{2.5}$ levels could save considerable health-care costs while improving life expectancy, especially in urban areas where pollution levels are highest *(77)*.

Evidence from the WHO Europe Region (from studies 2016–2020) indicate that 570 000 deaths are attributed each year to ambient air pollution and 154 000 deaths to household air pollution; 1 million deaths each year are attributed to physical inactivity; and 2.5 million deaths are attributed to unhealthy and unsustainable diets. These numbers are likely to be substantial underestimates for the Region as a whole.

Food systems offer major opportunities for both mitigation and health co-benefits. Across their entire life cycle, from production to consumption, food systems contribute to around 31% of Europe's GHG emissions, with animal-based foods responsible for the highest per capita emissions *(19)*. Shifting diets towards more plant-based foods while reducing high consumption of animal products can reduce GHG emissions and lower risks of noncommunicable diseases *(78,79)*. Fiscal measures, such as adjusting value-added tax to favour fruits and vegetables over meat and dairy, have been proposed to support this shift while improving public health and generating revenue *(80,81)*. Public procurement, including school meals, also presents a powerful policy lever to promote sustainable, nutritious diets *(82,83)*.

As discussed above for adaptation actions, tailoring mitigation efforts to address gender-specific vulnerabilities is a priority, for example, ensuring that active travel opportunities such as walking and cycling, as well as public transport, are made affordable, accessible and safe for women and girls. Promoting active transport reduces emissions while increasing physical activity, which in turn lowers the risk of noncommunicable diseases like stroke and diabetes *(84)*.

3.5. Mitigation in health-care systems

Health care must lead by example: reducing its carbon footprint through sustainable practices, innovation and prevention-focused care.

The health-care sector contributes about 5% of global GHG emissions, making mitigation essential for aligning with climate goals, while ensuring climate resilience *(4)* and potentially improving health service delivery. Sustainable procurement practices, including circular economy principles for pharmaceuticals and medical equipment, are one critical element of how to reduce emissions across the health-care supply chain. The European Region has a key role in advancing global supply chain sustainability, with growing initiatives such as centralized procurement systems and national standards promoting low-carbon, circular products in health care. While circular practices – like repair, reuse and responsible reprocessing – are being adopted in both high- and low-resource settings, lessons from contexts where resource efficiency has long been a necessity can foster further innovation *(75)*. Importantly, circular approaches in health care can align with infection prevention and control when supported by appropriate guidelines and systems *(85,86)*.

Energy efficiency measures, such as retrofitting hospitals with modern ventilation systems and transitioning to renewable energy sources, have proven effective in reducing emissions. Further, initiatives such as social prescribing (e.g. connecting patients with nature-based activities) and digital health tools (e.g. telemedicine) may

promote health and align well with broader sustainability goals while reducing demand for resource-intensive medical interventions and thus GHG emissions *(19)*. However, although much can be done in operationalizing policy for health systems reform at all levels, it should also be emphasized that effectively reducing carbon emissions from health services will depend substantially on reducing demand: that is preventing ill health. Therefore, primary care providers (and other health professionals) have an important role in promoting healthy, sustainable behaviours as well as addressing the health effects of climate change.

3.6. Policy implementation

Whole-of-government approaches and stronger accountability are key to embedding health in climate policy frameworks.

Effective solutions benefit from a "whole-of-government" approach, integrating health system strategies with, for example, urban planning, energy and agriculture policies. Collaborative governance frameworks, such as those emphasized during the COP29 Energy Community roundtable, highlight the value of regional partnerships *(87)*. However, scaling up these successes requires improved monitoring and accountability, and a stronger alignment between health and climate goals.

Countries can use the Roadmap for healthier people, a thriving planet and a sustainable future 2023–2030, which is part of the WHO Budapest Declaration *(12)*, to expedite the transitions needed to bring about sustainable communities. The Roadmap offers a set of actions Member States can implement to reduce the health consequences posed by climate change, environmental pollution and biodiversity loss. It also proposes steps to strengthen governance, human resources, financing and knowledge for health and the environment. The Budapest Declaration also comes with a regional alliance for health and climate – the so-called EHP Partnership for Health Sector Climate Action to galvanize climate action in the health sector. To foster change, the Partnership aims to accelerate the implementation of the Budapest commitments, sharing knowledge and solutions for low carbon and climate-resilient health systems.

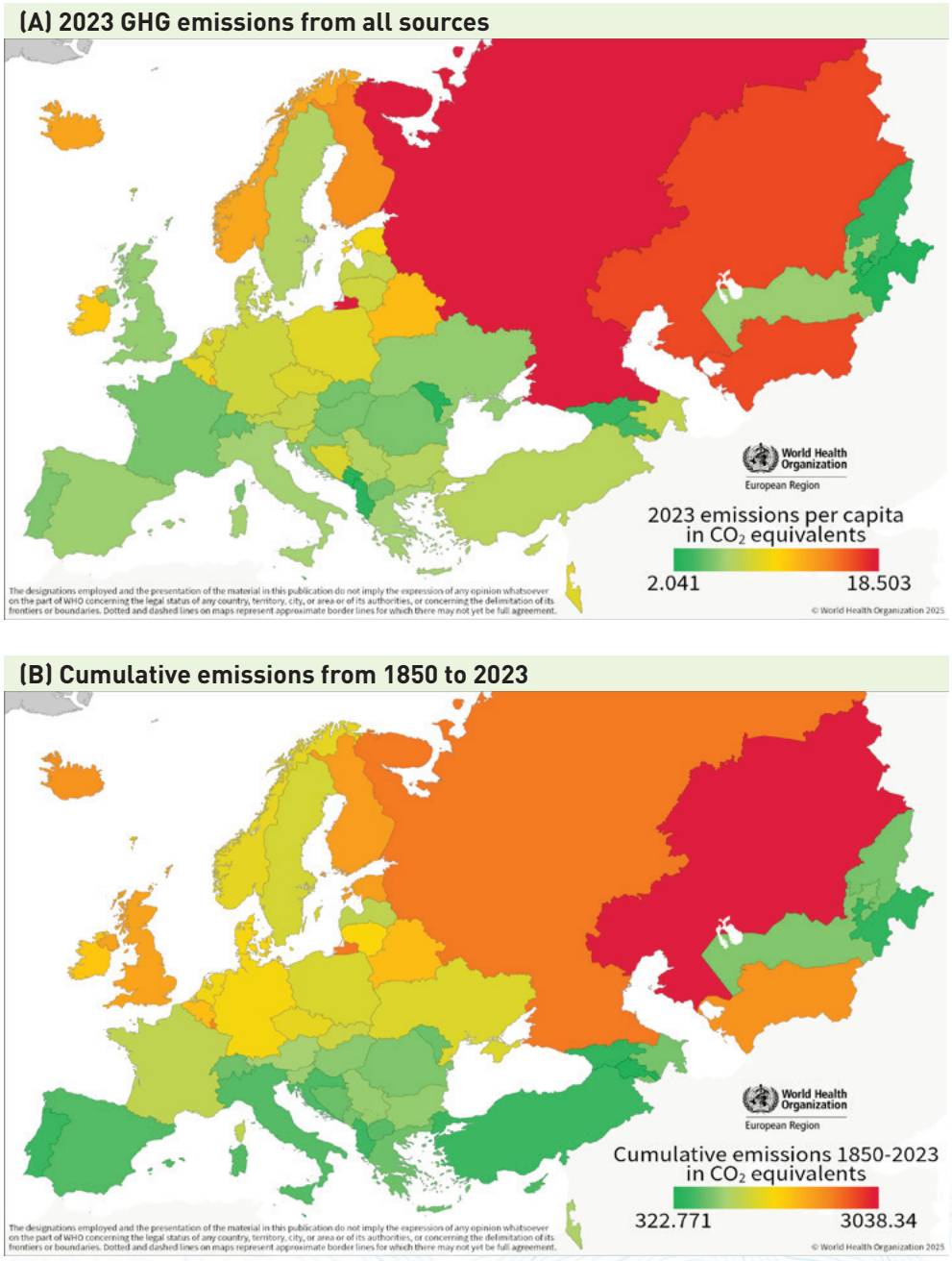
Despite some progress, health remains inconsistently integrated into key climate planning frameworks, including NDCs and LT-LEDS. Earlier rounds of NDCs showed increased mentions of health, but fewer than half of recently submitted NDCs include health-related priorities, indicating a need to revitalize momentum *(19,88)*. Moreover, although some of the WHO-UNFCCC country profiles, that help to provide the evidence base are relatively recent (for example, Iceland and Türkiye in 2022, and Bulgaria, Czechia, Malta and Slovakia in 2021), others represent an older analysis (201–2018), and insufficiencies in country documentation are compounded by variable mention in NDCs. LT-LEDS, similarly, often lack explicit health metrics or measurable co-benefits, limiting their effectiveness. Encouraging countries to embed actionable health targets within these frameworks, while ensuring coherence across NDCs, LT-LEDS and health national adaptation plans, could help maximize the potential of climate policies to deliver equitable, health-positive outcomes *(5,88,89)*.

3.7. Global collaboration for climate and health

The WHO European Region has a responsibility to lead in climate-health action while fostering global collaboration and equity.

The WHO European Region, as a major historical contributor to global GHG emissions (Fig. 11), holds a critical responsibility in advancing climate justice by supporting at-risk regions in addressing climate-health challenges.

Fig. 11. Map of per capita GHG emissions from European countries, reflecting historical contributions to climate change



Source: authors based on data from *(90)*.

Equally important will be fostering equitable knowledge transfer while addressing the "brain drain", which risks undermining the resilience of health-care systems in low and middle income countries when professionals migrate to wealthier European nations.

Cross-regional collaboration, such as the Transatlantic Dialogues on Climate and Health, further drive progress *(91,92)*. The new EHP Partnership for Health Sector Climate Action, together with the long-established European Environment and Health Task Force Working Group on Health in Climate Change, serve as powerful regional platforms to promote dialogue and cooperation in the WHO European Region on protecting health from the adverse effects of climate change. By embracing a collaborative and reciprocal approach to knowledge sharing, including through mechanisms such as the global Alliance for Transformative Action on Climate and Health *(93)*, countries could strengthen their own climate-health strategies while fostering equity and solidarity in addressing the shared challenges of climate change. It is also important that initiatives for the WHO European Region are well integrated with work by WHO at the global level, such as the Global Plan of Action on Climate Change and Health that is being developed *(94)*.

3.8. Mis- and disinformation

Misinformation is where the provider does not realise it is false and there is no intention to deceive; disinformation is knowingly false information, deliberately spread. Countering mis- and disinformation is critical to safeguard public trust and accelerate evidence-based climate and health policies.

Combating mis- and disinformation through robust evidence dissemination and targeted stakeholder engagement is increasingly critical in countering lobbying by vested interests and fostering political will. False information from vested interests, often termed "health-washing" (analogous to greenwashing), is increasingly used to defend commercial positions *(95)*, including in fossil fuel-producing regions of the WHO European Region. Evidence shows that such disinformation has influenced policy-makers and delayed climate action, with examples of coordinated efforts by elites to obstruct meaningful reforms while publicly adopting a green rhetoric *(96)*. Addressing these challenges will require not only evidence-based advocacy but also vigilance against deliberate misinformation campaigns that undermine public trust and policy development.

3.9. Financing health-climate strategies

Sustainable financing, fair carbon pricing and circular economy principles are vital to fund equitable health-climate solutions.

Approaches, such as the well-being economy, propose a reframing of economic priorities, shifting from a singular focus on economic growth to a broader emphasis on human well-being. Whether economic growth can be effectively decoupled from carbon emissions throughout the Region is uncertain. In some advanced economies

there has been partial decoupling where clean energy investments and efficiency gains have allowed gross domestic product growth while reducing emissions *(97)*. Some analysts have however suggested that absolute decoupling is infeasible *(98)*. Emerging discussions around concepts such as degrowth while still controversial, highlight the opportunities to align economic activities with planetary health, recognizing that excessive resource consumption exacerbates climate and health challenges *(99)*.

Climate finance mechanisms, including the Green Climate Fund *(100)*, are seen as critical to supporting adaptation and mitigation initiatives. However, barriers such as limited access to funds, bureaucratic complexity and inequitable distribution have hindered effective implementation, especially in low-resource settings. Additionally, debt relief including debt swaps for climate and nature protection *(101)*, could be crucial to freeing up resources for climate action, particularly in low-resource settings, where unsustainable debt burdens hinder the capacity to respond to climate crises and invest in resilience-building measures. Recent preliminary findings from the Organisation for Economic Co-operation and Development and the United Nations Development Programme indicate that investing in ambitious climate action can foster more inclusive and resilient development; for example, enhanced NDCs could help prevent projected gross domestic product losses of at least 3% by 2050 and 13% by 2100 *(101)*. While such estimates are based on conventional growth models, they underscore the economic risks of inaction, even as broader debates continue on how best to define and measure sustainable progress.

Incorporating circular economy principles into health-climate financing frameworks, offers a pathway to reduce waste, optimize resource use and lower emissions. By transitioning health-care systems towards sustainable procurement and waste management practices, significant cost savings and environmental benefits could be realized. Taxation and carbon pricing represent additional tools for mobilizing resources while addressing emissions, and the options warrant further consideration. Redirecting subsidies from fossil fuels to clean energy and health-promoting initiatives could deliver substantial health and equity co-benefits *(19)*. Fair carbon pricing mechanisms could further incentivize decarbonization in health-care systems while generating revenue for health-climate adaptation and mitigation measures *(16)*.

Recent developments, including international discussions on loss and damage financing and the anticipated recommendations from the International Court of Justice on State obligations for climate change, could reshape governance frameworks in 2025, presenting new opportunities for integrating health into climate finance. Additionally, ongoing European climate-health litigation may set precedents for financing accountability *(102)*. In tackling the challenges to deliver equitable and effective outcomes, there are increasing opportunities to prioritize access to climate funds, combined with robust monitoring of financial flows, and inclusion of health in future climate finance frameworks.

4. Key considerations and next steps

The update of the WHO Regional Office for Europe´s "Zero Regrets" paper between the first (2021) and second (2023) editions aligned with ongoing political attention to climate change and health issues, and the emerging specification of what opportunities might be pursued at global, regional and national levels. However, during this period (2021–2023), efforts to mitigate climate change remained inadequate and the adverse effects on health increased. The climate change crisis has further worsened since 2023. A similar faltering in action on policy priorities has been seen across the 2030 Agenda for Sustainable Development *(11)* where the United Nations Economic Commission for Europe (whose constituency, with the exception of North America, parallels the WHO European Region) recently found almost no change in SDG progress in the previous two years *(103)*.

What then should be done within the framework of "people, place and planet" as propsed in the WHO COP29 special report on climate change and health *(16)*? While the present technical brief is not intended to be prescriptive, its analysis underpins the "Zero Regrets" paper's strategic "asks" for health-oriented climate action *(1)*: (i) moving from awareness to implementation; (ii) monitoring, quantifying and assessing; and (iii) leading and communicating. The mounting adverse health impacts of climate change underscore the urgency for finding and implementing practical and scalable solutions for integrating health into climate and broader development policies and for ensuring that climate considerations are embedded in health system planning. Better integration of rigorously evaluated mitigation and adaptation actions can help to build sustainability and resilience. Strengthening these efforts necessitates prioritizing health in local, national and regional policies and practice, ensuring that health outcomes are central to planning and implementation. Alignment with global health goals, such as universal health coverage, and intersectoral policies and agreements, including energy, agriculture and transport, are also essential to achieving a whole-of-government approach. Furthermore, new action can be aligned with and build on previous work, for example by the Pan-European Commission on Health and Sustainable Development (that focused on pandemics) *(104)*. Fostering political will benefits from articulating clear, robust, evidence-based narratives that connect health and climate goals and building public pressure by engaging stakeholders across all levels of governance. By strengthening collaboration across regions, sectors and disciplines, and catalysing discussion and action on cross-cutting themes, as outlined in Table 1, and by sharing and scaling up lessons learned from innovative initiatives already underway, the WHO European Region can help lead the global transformative efforts to build healthy, resilient, sustainable and equitable societies in the face of climate change.

Table 1. Cross-cutting issues, knowledge gaps and implications: potential areas for developing and implementing climate-health recommendations for "people, place and planet".

THEME	OBJECTIVES FOR FURTHER DISCUSSION
Attribution and quantification of climate change effects	Clarifying priorities and methodologies for determining current and projected health impacts
Economics reframing	Including: decoupling GHGs from economic growth; cost-benefit assessment for mitigation and adaptation; financial initiatives to promote health and equity in climate policies. Developing and implementing metrics to assess human progress that do not exclusively focus on gross domestic product
Governance reforms to achieve health in a net zero economy	Achieving health in all policies, addressing synergies, trade-offs and new approaches (e.g. a circular economy) plus examining other governance mechanisms that can support change at scale
Community involvement	Engaging with stakeholders and all citizens and focusing on vulnerable groups for prioritization, research design and translation to policy, innovation and practice
Countering mis- and disinformation as part of the effective communication of climate health risks and the health benefits of climate action	Collaboration to foster political will and counter lobbying by vested interests
Climate-smart technologies	Identifying and sharing the experience of implementation (e.g. for decarbonization, early-warning systems, and sustainable food and nutrition security) including regulation and interaction with demand-side interventions and opportunities arising from new transdisciplinary approaches (e.g. the application of artificial intelligence to climate and health challenges).
Responsibilities to act	Recognizing opportunities to integrate action at science-policy interfaces at local, national and continent-wide levels within a planetary health framework

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Annex 1.
Methodological detail

In bringing together evidence for the technical brief, priority has been given to the citation of systematic reviews combined with previous experience from transdisciplinary networks for assessing global evidence. When possible, in the time available, to review primary research literature, this technical brief has aimed to follow the principles for Cochrane rapid review guidance for knowledge *(1)*.

One key consideration in interpreting the literature is the extent to which health effects can be directly attributed to climate change. The growing field of health impact attribution aims to establish estimates of risk relationships between climate exposures and health outcomes so as to capture the burden of disease causally linked to anthropogenic climate change, relying on the science of detection and attribution *(2)*. The process of deriving health attribution involves sophisticated statistical models to show that in the absence of climate change the burden of disease would decline, that is the excess disease burden is directly attributable to human-caused climate emissions. Several stages of rigorous analysis are required to conduct health impact attribution, the first of which aim to detect long-term changes in climate and differentiate this from the natural weather variability that occurs over shorter timescales. The next steps involve distinguishing the severity, frequency, or duration of the climate hazard under factual and counterfactual scenarios, in which the latter scenario will exclude human-caused contributors (radiative forcings) such as greenhouse gas emissions. The final step of health impact attribution applies established climate-health causal relationships to quantify the excess disease burden that can be attributed directly to anthropogenic climate change *(3)*.

For example, a study published in 2021 evaluated the burden of heat-related deaths to human-caused climate change applying health impact attribution methods to assess a large database of temperature and mortality case records from 732 worldwide locations *(4)*. The magnitude of heat-related deaths attributable to climate change had a higher-than-average burden in southern and eastern European countries and, globally, an overall estimated 37% of all heat-related deaths were attributable to anthropogenic climate change.

The complexity and computationally-intensive nature of attribution methods in combination with constraints on data availability has limited most climate-health research to epidemiological impact assessments. A recent report assessing the global literature found 13 studies that generated estimates of disease burdens attributable to anthropogenic climate change *(3)*. Critical limitations of health attribution analysis include the absence of long-term health records, particularly for outcomes with imprecise case definitions (e.g. some mental health conditions *(5)*) and inaccessible or missing data in some regions. A key area for method development relates to handling statistical uncertainty of climate-health risk relationships and compounding uncertainty in the multiple climate models used to project climate trends. The science

of health impacts attribution is advancing rapidly and improving understanding of the magnitude and breadth of social impacts of climate change. Findings from attribution studies may also accelerate litigation by substantiating loss and damage claims from climate justice communities.

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