Health Canada Santé Canada

World Health Organization

CLIMATE CHANGE AND HEALTH

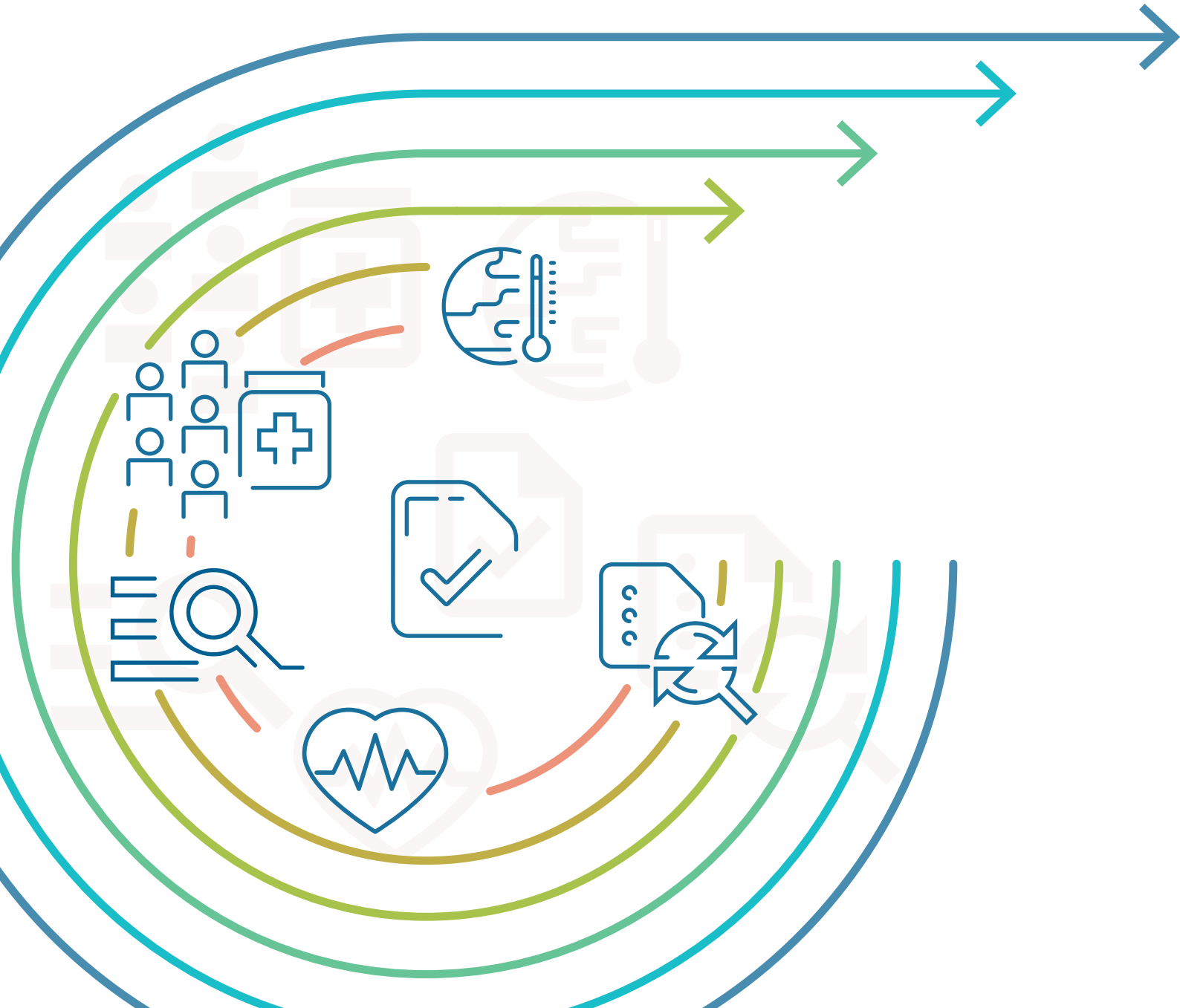
Vulnerability and Adaptation Assessment

Health Canada Santé Canada

World Health Organization

CLIMATE CHANGE AND HEALTH

Vulnerability and Adaptation Assessment



Climate change and health vulnerability and adaptation assessment

ISBN 978-92-4-003638-3 (electronic version)
ISBN 978-92-4-003639-0 (print version)

Editing, design and layout by Inis Communication

Contents

Preface to the second edition

In 2013 the World Health Organization (WHO) published the report *Protecting health from climate change: vulnerability and adaptation assessment*. The aim was to provide basic and flexible guidance on conducting national or subnational assessments of current and future vulnerability (the susceptibility of a population or region to harm) to the health risks of climate change, and of policies and programmes that could increase resilience, taking into account the multiple determinants of climate-sensitive health outcomes.

That guidance has been a very useful tool, applied to more than 50 countries and settings, and has helped countries to prepare their health contributions to United Nations Framework Convention on Climate Change national adaptation plans.

Since the launch of the guidance, WHO, technical partners such as Health Canada, and countries have learned much in terms of its applicability in different countries, at national and local levels. At the same time, knowledge on climate change and health has increased.

WHO, the Pan American Health Organization and Health Canada have produced this updated version, which aims to better support countries in their assessments by proposing a simpler tool that incorporates all lessons learned.

Acknowledgements

This document is based on, and updates, the World Health Organization (WHO) 2013 report *Protecting health from climate change: vulnerability and adaptation assessment*. It represents the work and contributions from experts in WHO, the Pan American Health Organization (PAHO) and Health Canada. WHO extends its gratitude to Health Canada for financial and technical support in developing this document.

The document was written by Kristie Ebi (University of Washington), Peter Berry (Health Canada), Carlos Corvalan (University of Sydney), Aderita Sena (WHO), Marielle Verret (Health Canada), Elena Villalobos Prats (WHO), Laura Scheske (World Meteorological Organization), Joy Shumake-Guillemot (World Meteorological Organization), Lucia Fernandez Montoya (World Meteorological Organization and WHO), Daniel Buss (PAHO), Anwar Mendez (PAHO) and Diarmid Campbell-Lendrum (WHO).

WHO extends its thanks to the following reviewers and contributors: Timothy Bouley (BioFeyn), Sally Edwards (PAHO), Sherilee Harper (University of Alberta), Dorota Jarosinka (WHO Regional Office for Europe), Vladimir Kendrovski (WHO Regional Office for Europe), Mary Manandhar (WHO), and Rebekka Schnitter (Health Canada). Case study contributions were received from: Esther Onyango (WHO), Amy Savage (WHO), Arthur Wyns (WHO), Mazen Malkawi (WHO Regional Office for Eastern Mediterranean), Mona Khaleghy Rad (WHO Country Office, Iran), Mohammad Rahimi (Semnan University, Iran), Fatima Thneibat (Ministry of Health, Jordan), Rachid Wahabi (Ministry of Health, Morocco).

Abbreviations

GIS	geographical information systems
HNAP	health national adaptation plan
IPCC	Intergovernmental Panel on Climate Change
M&E	monitoring and evaluation
NAMA	nationally appropriate mitigation actions
NAP	national adaptation plan
NDC	nationally determined contributions
PAHO	Pan American Health Organization
RCP	representative concentration pathway
UNFCCC	United Nations Framework Convention on Climate Change
V&A	vulnerability and adaptation assessment
WHO	World Health Organization

Glossary

Adaptation	Adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects.[a]
Adaptive capacity	Ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.[a]
Capacity assessment	Process by which the capacity of a group, organization or society is reviewed against desired goals, where existing capacities are identified for maintenance or strengthening, and capacity gaps are identified for further action.[b]
Capacity development	Process by which people, organizations and societies systematically stimulate and develop their capacities over time to achieve social and economic goals. The concept extends the term of capacity-building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning, various types of training, and continuous efforts to develop institutions, political awareness, financial resources, technology systems and the wider enabling environment.[b]
Climate	Average weather (in a narrow sense) or (more rigorously) statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.[a]
Climate change	Change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean or variability of its properties that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, or persistent anthropogenic changes in the composition of the atmosphere or land use. Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.[a]
Climate change hazard	Process, phenomenon or human activity that may cause loss of life, injury or other health impact, property damage, social or economic disruption, or environmental degradation.[b]

Climate change risk	Potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure.[a]
Climate projection	Simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission, concentration or radiative-forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic or technological developments that may or may not be realized.[a]
Climate-resilient pathways	Iterative processes for managing change within complex systems to reduce disruptions and enhance opportunities associated with climate change.[a]
Climate variability	Variations in the mean state and other statistics (e.g. standard deviations, occurrence of extremes) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).[a]
Co-benefits	Positive effects that a policy or measure aimed at one objective might have on other objectives, thereby increasing the total benefits for society or the environment. Co-benefits are often subject to uncertainty and depend on local circumstances, implementation practices and other factors. Co-benefits are also known as ancillary benefits.[a]
Coping capacity	Ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term.[a]
Disaster	Serious disruption of the functioning of a community or society at any scale due to hazardous events interacting with conditions of exposure, vulnerability or capacity, leading to one or more human, material, economic or environmental losses or impacts.[b]
Disaster risk	Potential loss of life, injury, or destruction or damage of assets that could occur to a system, society or community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.[b]
Disaster risk management	Process for designing, implementing and evaluating strategies, policies and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life and sustainable development.[a]
Early warning system	Set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss.[a]

Emission scenario	Plausible representation of the future development of emissions of substances that are radiatively active (e.g. greenhouse gases, aerosols) based on a coherent and internally consistent set of assumptions about driving forces (e.g. demographic and socioeconomic development, technological change, energy and land use) and their key relationships.[a]
Equity	Principle of fairness in burden-sharing. Equity is a basis for understanding how the impacts and responses to climate change, including costs and benefits, are distributed in and by society in more or less equal ways. It is often aligned with ideas of equality, fairness and justice and applied with respect to equity in the responsibility for, and distribution of, climate impacts and policies across society, generations and gender, and in the sense of who participates and controls the processes of decision-making.[a]
Exposure	Presence of people, livelihoods, species or ecosystems, environmental functions, services or resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.[a]
Extreme weather event	Event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of "extreme weather" may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g. drought or heavy rainfall over a season).[a]
Hazard	Potential occurrence of a natural or human-induced physical event, trend or physical impact that may cause loss of life, injury, other health impact, or damage to or loss of property, infrastructure, livelihoods, service provision, ecosystems or environmental resources.[a]
Health	State of complete physical, mental and social well-being, and not merely the absence of disease or infirmity.[c]
Health systems	Ensemble of all public and private organizations, institutions and resources mandated to improve, maintain or restore health and incorporate disease prevention, health promotion, and efforts to influence other sectors to address health concerns in their policies.[d]
Human system	Any system in which human organizations and institutions play a major role. Often, but not always, the term is synonymous with society or social system. Agricultural systems, urban systems, political systems, technological systems and economic systems are all human systems in the sense applied in the context of the Intergovernmental Panel on Climate Change report.[a]
Impacts	Consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.[a]

Mitigation measures	In climate policy, technologies, processes or practices that contribute to mitigation (e.g. renewable energy technologies, waste minimization processes, public transport commuting practices).[a]
Monitoring and evaluation	Mechanism put in place at national to local scales to monitor and evaluate efforts to reduce greenhouse gas emissions or adapt to the impacts of climate change with the aim of systematically identifying, characterizing and assessing progress over time.[a]
Resilience	Ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.[b]
Risk assessment	Qualitative or quantitative scientific estimation of risks.[a]
Risk management	Plans, actions, strategies or policies to reduce the likelihood or consequences of risks or to respond to consequences.[a]
Scenario	Plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. Scenarios are neither predictions nor forecasts but are useful to provide a view of the implications of developments and actions.[a]
Uncertainty	State of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many sources, including imprecision in data, ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a probability density function) or by qualitative statements (e.g. reflecting the judgement of a team of experts).[a]
Vulnerability	Conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.[b]

[a] Matthews JBR. Annex I: glossary. In: Masson-Delmotte V, Zhai P, Pörtner H-O, et al., editors. Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above preindustrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: Intergovernmental Panel on Climate Change; 2018.

[b] A/71/644. Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. In: Seventy-first United Nations General Assembly, New York, 1 December 2016.

[c] Constitution of the World Health Organization. Geneva: World Health Organization; 1946.

[d] The Tallinn Charter: health systems for health and wealth. Copenhagen: World Health Organization Regional Office for Europe; 2008.

Introduction

Climate variability and change are affecting human health and health systems, increasing climate-sensitive diseases and health outcomes, and damaging health care facilities from sea-level rise, storm surges, and extreme weather events such as flooding, drought and heatwaves *(1–4)*. Between 2005 and 2019, an average of 412 health facilities were damaged or destroyed each year by climate-related disasters – and such impacts are increasing *(5)*.

Climate change over the next few decades is projected to alter the geographical range and numbers of cases of injuries, illnesses and deaths from climate-sensitive health outcomes, and to affect the functioning of public health and health care systems. If no additional actions are taken, substantial increases in morbidity and mortality are projected for a wide range of health outcomes over the coming decades *(6, 7)*.

Vulnerable populations and geographical regions will be affected differently, with increases in poverty and inequities linked to climate change. Until the middle of the twenty-first century, non-climatic factors such as the key determinants of health (e.g. health services, income and social status, education, social support systems, age, gender) can have a strong or even dominant effect on the burden of climate-sensitive health outcomes, either independently or by modifying climate effects.

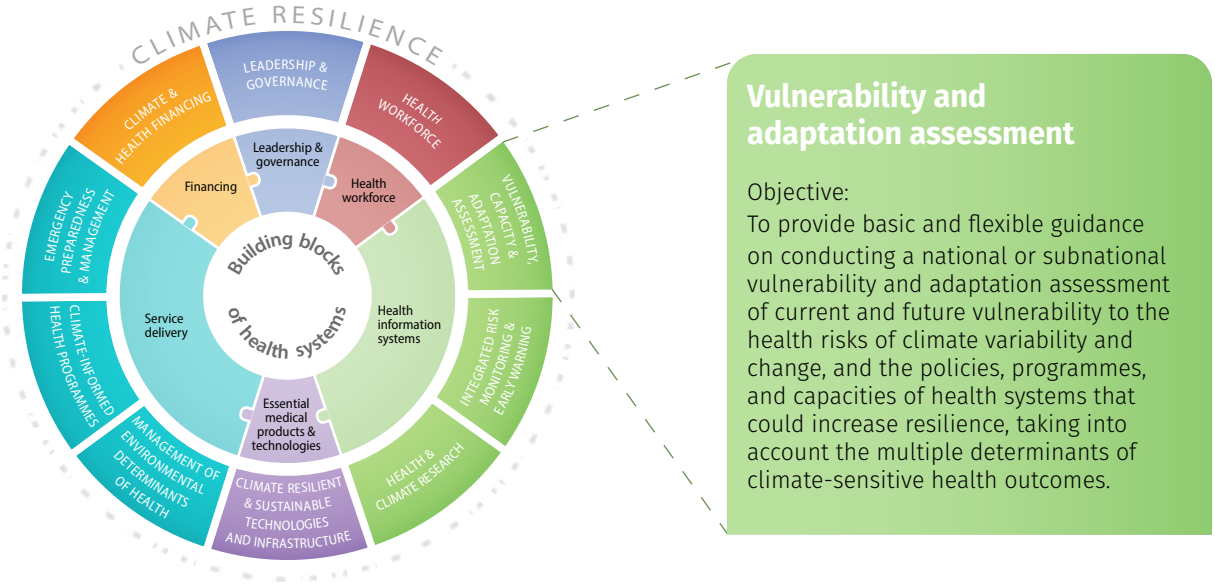
A key driver of population health will be the degree of success or failure of current policies and programmes to reduce climate-sensitive diseases and health outcomes. Understanding the strengths and weaknesses of the health system and specific programmes to manage climate change impacts and surprises is of critical importance to plan modifications needed to increase the resilience of health systems.

The World Health Organization (WHO) Operational Framework for Building Climate-resilient Health Systems highlights important components and resources necessary to ensure health system functioning and resilience (Figure 1). This can be used to inform the planning and conduct of climate change and health vulnerability and adaptation (V&A) assessments *(8)*.

A V&A assessment is a participatory process. It is a tool that allows countries to evaluate which populations and specific geographies are most vulnerable to different kinds of health effects from climate change; to identify weaknesses in the systems that should protect them; and to specify interventions to respond.

All climate-sensitive diseases and health outcomes are current causes of morbidity and mortality, although perhaps new or emerging in specific regions; therefore, building climate-resilient health systems to explicitly take climate change into account should enable reductions in most of the projected increases in morbidity and mortality. Policies and programmes designed to address the health risks of climate change should be incorporated into existing programmes within and outside health systems to ensure the efficient use of financial and human resources. At the same time, flexibility and innovation will be needed in approaches to protecting health, as the future is inherently uncertain, with many unknowns about the rate and pattern of climate change and development pathways, including changes in a wide range of social, technological and economic factors.

Figure 1. Vulnerability and adaptation assessment in the context of the World Health Organization Operational Framework for Building Climate-resilient Health Systems



Source: Operational framework for building climate-resilient health systems. Geneva: World Health Organization; 2015.

The term "risk" is often used to refer to the potential for adverse consequences of a climate-related hazard. Risk results from the interaction of vulnerability of the affected system, its exposure over time to the hazard, the climate-related hazard, and the likelihood of its occurrence *(9)*.

The primary policy responses to managing the health risks of climate change are mitigation (reduction of human influence on the climate system) and adaptation (interventions designed to prevent avoidable impacts and minimize resulting health burdens). Mitigation and adaptation policies are not mutually exclusive. Co-benefits to human health can result from actions to reduce greenhouse gas emissions *(10)*, and adaptation measures can lead to reduced emissions, such as when a hospital installs low-carbon energy sources to reduce power disruptions during disasters. Although there are uncertainties about the rate and magnitude of future climate change, failure to invest in adaptation and mitigation will leave communities and nations poorly prepared, increasing the probability of more severe adverse consequences *(11)*.

V&A assessments build on the core principles of risk assessments, taking into consideration the unique challenges presented by climate variability and change, to provide policy-relevant information for maintaining and improving health systems in a changing climate.

To effectively manage the health risks of climate change, health systems need an iterative risk management approach to strengthen core functions of health systems and to establish a process to regularly modify health risk management activities to prepare for and respond to ongoing changes in the number of injuries, illnesses and deaths related to climate-sensitive diseases and health outcomes.

Identifying risk is the first step in identifying, assessing, prioritizing and managing threats to health. Policies and programmes will need to go beyond addressing current vulnerabilities to protect against health risks from future, possibly more severe climate change, including cumulative or catastrophic events.

Decision-makers in health systems and in sectors relevant to health need timely and robust information about options for modifying current or implementing new policies and programmes. These choices will need to evolve as the context for adaptation continues to change with changing demographics, technologies, socioeconomic development and climate conditions. Conducting a risk assessment is a key to risk management. These assessments synthesize scientific evidence into policy recommendations to protect health.

In summary, V&A assessments aim to provide an improved understanding of climate-related risks to health and relevant and actionable recommendations for policy-makers on how they can strengthen health systems and increase the resilience of populations vulnerable to the impacts of climate change.

V&A assessments are not only about understanding the potential implications of future climate change. They are about assessing vulnerability factors that interact with climate. Vulnerabilities can be modified through public health and related interventions to decrease existing risks to health. V&A assessments also make important contributions to the global climate change and health agenda and help to build future capacity of the health sector to contribute to efforts to address climate change.

Box 1. Quality criteria for health national adaptation plans

A health national adaptation plan (HNAP) is a plan led by the Ministry of Health as part of the national adaptation plan (NAP) process.

The HNAP sets out a range of actions to address the health impacts of climate change and build climate-resilient health systems at all levels of planning. It contributes to comprehensive health adaptation planning to respond to the health risks of climate change. It is based on the best available evidence and is informed by a comprehensive V&A assessment.

WHO has identified six key criteria to support countries in developing HNAPs:

- Leadership and enabling environment: leadership by the Ministry of Health and active engagement of the health sector in all aspects of the HNAP development process is crucial and provides a strong foundation for effective health adaptation planning. A comprehensive V&A assessment provides evidence on vulnerabilities and adaptive capacities of health systems and health care facilities, which can inform health planning and programming.
- Cross-sectoral coordination and policy coherence: it is crucial that health is protected and promoted not only by the health sector but also by other health-determining sectors such as food and agriculture, energy, urban planning, and water, sanitation and hygiene. The active involvement of these sectors in HNAP development, including the V&A process, is likely to contribute to a more effective HNAP.
- Comprehensive coverage of climate-sensitive health risks: one of the steps in the NAP process is conducting a V&A assessment at sector, subnational, national and other levels. A comprehensive V&A assessment covering a wide range of climate-sensitive health risks is critical for ensuring the HNAP addresses health risks of concern in a specific context.
- Comprehensive coverage of adaptation options and actions: the HNAP is part of a long-term process of adaptation planning. A comprehensive range of adaptation options for medium- and long-term timeframes should be included in the final plan. Taking a systematic approach to addressing climate change in health should consider climate-sensitive health risks, resilience of health systems, and health-promoting adaptation options in relevant climate-sensitive health sectors. This should be informed by the climate change and health V&A assessment.
- Resourcing: a budget and human resources estimation for adaptation actions outlined in the HNAP is crucial for effective planning and implementation. A resource mobilization strategy to bridge funding gaps can be used to plan for medium- and long-term resourcing requirements and to seek external funding. When the HNAP is developed before the V&A assessment, specific resources should be allocated for the conduct of iterative V&A assessments.
- Monitoring, evaluation and reporting: the HNAP includes a comprehensive monitoring, evaluation and reporting plan to assess progress in HNAP implementation and potentially the impact of adaptation actions. V&A assessments establish the baseline and can be used to iteratively assess outcomes of HNAP implementation.

The application of these criteria is informed by the evidence gathered in V&A assessments and is therefore adaptable to dynamic country contexts, uncertain and changing climatic conditions, and new knowledge and technologies.

Source: Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021.

Objectives

This document is designed to provide basic and flexible guidance on conducting a national or subnational V&A assessment of current and future vulnerability to the health risks of climate variability and change, and the policies, programmes and capacities of health systems that could increase resilience, taking into account the multiple determinants of climate-sensitive diseases and health outcomes.

The assessment outcome provides information required by decision-makers for the effective management of the health risks of a changing climate, such as:

- the magnitude and pattern of likely health risks attributable to climate change over the short and longer term;
- potentially severe or catastrophic impacts to individual health and to health systems when capacity to respond is overwhelmed;
- opportunities to collaborate with decision-makers outside the health sector to achieve large health co-benefits from climate action;
- potential cost savings and other benefits of implementing such policies and programmes.

A V&A assessment helps build capacity within and outside the health sector to prepare for and identify changing risks, and to evaluate the effectiveness of ongoing and proposed policies and programmes. This contributes to the generation of knowledge in understanding the health impacts of climate change and developing approaches and options for action.

These policies and programmes should consider both rapid climate change over the next few decades and longer-term changes in the means and extremes of meteorological variables.

This guidance does not address the tasks required to conduct an assessment of the positive and negative health effects associated with climate change mitigation measures, although this is as important as conducting a V&A assessment.

In addition to providing the foundational information for informing action aiming to address the health impacts of climate variability and change at any level, conducting a V&A assessment is one step in developing the HNAP *(12, 13)*. The elements of developing the HNAP are to lay the groundwork; undertake preparatory elements; develop implementation strategies; and report, monitor and review activities towards protecting health. These are broadly related to the phases of a project cycle (identification, formulation, implementation, monitoring and evaluation).

A national or subnational V&A assessment provides public health officials with robust information to strengthen health systems and communities in high-priority areas such as *(14)*:

- enhancing service delivery (e.g. during and after climate-related hazards such as severe storms);
- seeking adequate funding and resource allocations to support health adaptation efforts;
- informing actions to maintain, upgrade, site and build new health infrastructure such as hospitals and other health care facilities (e.g. in areas of permafrost melt or flood risk);
- preparing the health workforce by providing information and tools so they can protect their own and their clients' health when disasters strike;
- developing and implementing health information systems (e.g. monitoring and surveillance systems, syndromic surveillance systems) to track illnesses, injuries and deaths and to inform early warning systems that protect health (e.g. linked to meteorological information);

- working with decision-makers outside the health sector to maximize co-benefits to human health and to health systems from properly designed adaptation and greenhouse gas mitigation measures;
- determining the effectiveness of adaptation options taken by health authorities and partners outside the health sector to support iterative decision-making;
- providing the data and information needed to develop a health adaptation strategy, with high-priority adaptation options and with a monitoring and evaluation plan.

Background on health risks of climate variability and change

Climate change can affect health through the following pathways (Figure 2) *(13)*:

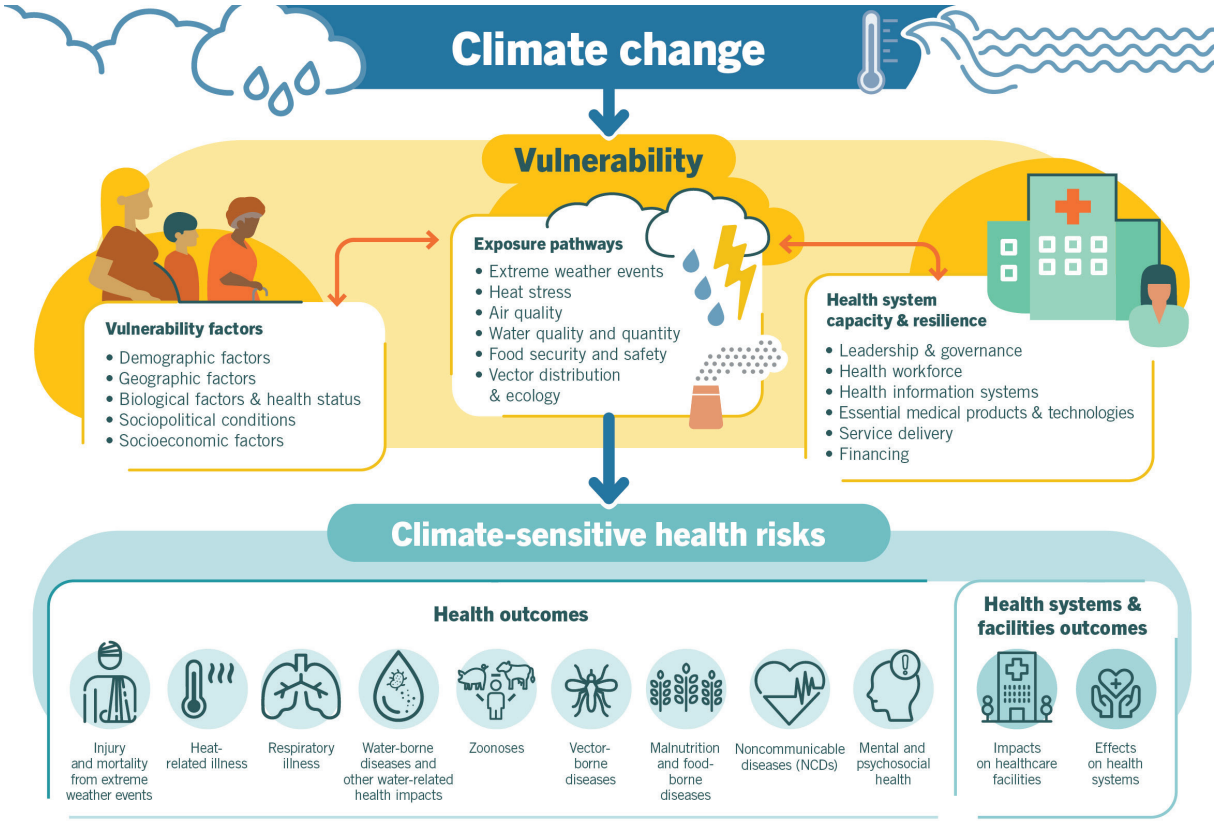
- changes in the frequency and intensity of extreme weather and climate events (e.g. heat, windstorms, flooding, drought);
- effects mediated through natural systems, such as changes in the geographical range and incidence of infectious diseases (e.g. water-, food- or vector-borne diseases) or health outcomes associated with poor air quality (e.g. high concentrations of ozone, particulate matter, dust, wildfire smoke, aeroallergens);
- effects heavily mediated by human systems (e.g. occupational impacts, undernutrition, conflict, migration, mental stress such as eco-anxiety).

Changes in the mean and variance of weather and climate variables can independently and jointly influence the burden of climate-sensitive diseases and health outcomes.

For example, rising mean temperatures can create conditions conducive to the geographical spread of vector-borne diseases such as malaria. Heavy precipitation events can wash away breeding grounds, resulting in short-term reductions in the number of malaria-transmitting *Anopheles* mosquitoes in endemic areas, but can also provide mosquito breeding habitats in places where mosquitoes and malaria were previously uncommon, increasing morbidity and mortality in populations that have not previously been exposed and have low immunity *(1)*.

These changes are dynamic and complex and can lead to unanticipated health risks and surprises for geographical regions and populations. As changes continue, and with shifts in the key determinants of health, population health status, population ageing and health system capacity, thresholds may be crossed that could result in large increases or decreases in the incidence of climate-sensitive diseases and health outcomes.

Figure 2. Major health risks associated with climate change



Source: Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021.

Health systems in many countries face a range of climate-sensitive diseases and health outcomes that need to be addressed to protect population health (Table 1). An increasing number of detection and attribution studies show that climate change is causing specific health impacts *(15)*.

Table 1. Selected climate-sensitive diseases and health outcomes and current burden of disease

Health outcome	Current distribution	Population at risk	Annual morbidity or mortality
High ambient temperature morbidity and mortality	Worldwide	All people, particularly older people	0.4% of mortality in 384 locations in 13 countries attributed to heat[a] 54% increase in heat-related mortality in people aged over 65 years in past 20 years[b]
Ozone-related mortality	Primarily urban areas worldwide	Older adults Children People with respiratory diseases	About 1 million adults aged over 30 years annually[c]
Diarrhoeal disease mortality	Primarily tropical regions	Children with limited access to safe water and improved sanitation	Annually 525 000 deaths among children aged under 5 yearsand 1.7 billion cases of childhood diarrhoeal disease[d]
Malaria	Tropical regions	50% of world population	In 2019, 229 million cases and 409 000 deaths[e]
Dengue	Tropical regions, spreading into temperate regions	50% of world population	400 million cases per year; 2019 was the year with the highest number of reported cases ever[f]
Lyme disease (borreliosis)	Temperate forested regions through North America, Europe and northern Asia	Most common tick-borne disease in northern hemisphere	More than 360 000 cases in Europe in past two decades[g]
Undernutrition	Africa, Latin America and Asia	Primarily children	149 million children aged under 5 years stunted and 45 million wasted in 2020[h]

[a] Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet. 2015;386(9991):369–375.

[b] Lancet (editorial). No healthy l ongevity without a healthy planet. Lancet. 2021;2(1):E1.

[c] Malley CS, Henze DK, Kuylenstierna J, et al. Updated global estimates of respiratory mortality in adults ≥30 years of age attributable to long-term ozone exposure. Environ Health Perspect. 2017;125(8):087021.

[d] Diarrhoeal disease. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease).

[e] Malaria. Geneva: World Health Organization; 2021 (https://www.who.int/news-room/fact-sheets/detail/malaria).

[f] Dengue and severe dengue. World Health Organization; 2021 (https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue).

[g] Lyme borreliosis in Europe. Copenhagen: World Health Organization Regional Office for Europe; 2014 (https://www.ecdc.europa.eu/sites/portal/files/media/en/healthtopics/vectors/world-health-day-2014/Documents/factsheet-lyme-borreliosis.pdf).

[h] Malnutrition. Geneva: World Health Organization; 2021 (https://www.who.int/news-room/fact-sheets/detail/malnutrition).

The impacts of climate change on health can be relatively immediate or delayed. Delayed effects include reductions in worker productivity and mental health impacts following extreme weather and other climate events *(2)*; increased childhood undernutrition due to reduced agricultural yields following drought or excessive flooding *(6)*; and decreased nutritional quality of food due to higher atmospheric carbon dioxide concentrations *(16)*.

Cascading effects from extreme events or from climate events combined with other health emergencies (e.g. infectious disease outbreaks such as COVID-19) can overwhelm health and social services. The overall health burden of climate change is almost certainly underestimated because of the complexity of the causal pathways between climate-related hazards and health outcomes and a lack of robust surveillance and monitoring systems in many countries:

- Risks are projected to increase with warming of 1.5 °C and higher for heat-related morbidity and mortality, ozone-related mortality and some vector-borne diseases, particularly in Africa and Asia. Undernutrition is projected to increase with warming of 1.5 °C and higher *(7)*. One study modelled the health effects associated with expected reductions in food availability and projected a net increase of 529 000 deaths globally by 2050 due to climate change *(17)*.
- A study of 23 countries suggested that under a scenario of high greenhouse gas emissions, a 3–12% net increase in temperature-related mortality could be expected to occur without further adaptation from the period 2010–2019 to 2090–2099 *(18)*.
- Climate change could increase the number of people living in extreme poverty by 100 million by 2030 without concerted efforts to include climate-resiliency initiatives in development practices *(19)*.
- The likelihood of crossing thresholds important to health outcomes increases substantially with warming of 3 °C and above, leading to potentially significant increases in the burden of disease attributable to climate change.

Many impacts on human health and health systems from climate variability and change can be reduced or avoided through well-designed adaptation measures *(20)*. Nevertheless, health risks of climate change are and will continue to be distributed inequitably, with sensitive populations and regions affected differently. Some population groups (e.g. older adults, people with chronic illnesses, people with mobility challenges, poor people, isolated people, Indigenous Peoples, some occupational groups, and overlaps of these) will experience a disproportionate share of the impacts because of heightened physiological sensitivities, greater exposure, or less capacity to take protective action *(1)*. Often these groups have less decision-making power by being deliberately excluded or discriminated against.

Low- and middle-income countries face more severe impacts because of current vulnerabilities, including underlying levels of disease, limited infrastructure and services, weak economies, and poorly informed governance and decision-making processes.

Health facilities and services are critical for the treatment and care they provide to people exposed to climate hazards, for contributing to community resiliency efforts, and for reducing greenhouse gas emissions. A global survey of 814 cities found that 67% of respondents expect climate change to seriously impact their public health assets and infrastructure *(3)*. Separate WHO guidance is available for assessing climate resilience and environmental sustainability in health care facilities *(21)*.

Framework for assessing vulnerability and adaptation

A central goal of a V&A assessment is to provide policy-relevant information to inform interventions to increase the resilience of health systems to climate variability and change. This information supports efforts to proactively and effectively manage risks, taking into account key exposures, vulnerabilities and capacities.

A V&A assessment considers climate change along with all factors that can interact with climate to increase or decrease risk. Specifically, the magnitude and pattern of the health risks of climate change are a function of:

- interactions between exposures to climate change-related alterations in weather patterns;
- who or what is exposed to those changes;
- vulnerabilities of the exposed human and natural systems that are relevant for the incidence and geographical range of climate-sensitive health outcomes;
- capacities of the health systems jointly with other sectors to manage risks.

Hazards

Climate change hazard is defined as the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, other health impacts, or damage or loss of property, infrastructure, livelihoods, service provision, ecosystems or environmental resources *(9)*.

Climate hazards include floods, storms, sea-level rise, droughts, heatwaves, wildfires, cold waves, and other climate phenomena that may result in exposure to human populations and health infrastructure and services. The frequency and intensity of extreme weather events, and changes in mean temperature, precipitation and other weather variables affect the frequency, intensity and duration of hazards.

Exposures

Exposures are defined as the presence of people; livelihoods; species or ecosystems; environmental functions, services or resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected by a climate-related hazard *(9)*.Exposures include changes in the frequency and intensity of extreme weather events, and changes in mean temperature, precipitation and other weather variables that have consequences for health determinants and disease transmission pathways.

An assessment needs to consider how climate change has altered or likely will alter the weather and climate hazards to which a population is exposed; whether exposures are likely to change with increasing climate change; and the characteristics of individuals and populations that can increase their risk when exposed to the hazard. This information is needed to identify how modifying current or introducing new programmes could reduce the burden of climate-sensitive diseases and health outcomes now and in the future.

It is important to consider the full range of options for reducing health risks, including those that could be taken by other actors. For example, the health risks of increasing ambient temperatures can be exacerbated by urban heat islands; these risks could be reduced by altering the built environment to reduce heat retention at night, changing land-use planning to increase the amount of green space, and modifying building codes to encourage the use of white roofs.

Vulnerabilities

Vulnerability to climate change is defined as the propensity or predisposition to be adversely affected by a climate risk *(9)*. Vulnerability of a population or location is the summation of all factors that increase susceptibility or sensitivity and that reduce risk. In combination, these factors ultimately determine whether a subpopulation or subnational region experiences adverse health outcomes *(22)*.

The vulnerability of a location can be due to factors such as the baseline climate, including the expected magnitude and frequency of extreme weather events, and geographical circumstances, such as coastal or urban settings that expose populations differentially to hazards.

Adverse health outcomes from flooding, for example, are a consequence not only of heavy precipitation but also of infrastructure and land-use choices over previous decades, the effectiveness of emergency risk management programmes, and other factors.

Population vulnerability is also a function of the effectiveness and coverage of the health system and related institutions, reflected in the quality of policies and programmes such as surveillance and control programmes, and baseline morbidity and mortality conditions. Population characteristics such as demographic structure, prevalence of pre-existing medical conditions, and acquired factors such as immunity and genetic factors are important baseline vulnerability conditions *(22)*.

Other demographic and socioeconomic factors, including population density, social capital and distribution of resources, also play a critical role in determining vulnerability, often interacting with biological factors such as nutritional status that lead to differences in the ability to adapt or respond to exposures or early phases of illness.

Therefore, multiple and often overlapping sources of vulnerability need to be considered when assessing current and likely future vulnerabilities that affect health outcomes. Similarly, it should not be assumed that all subgroups within a population are equally vulnerable. It may be important to consider not only current vulnerabilities and the current burden of specific health outcomes, but also systems that are or could be affected by climate change.

For example, undernutrition is a consequence of local and regional crop yields that are affected by soil quality, temperature and precipitation patterns, and the vulnerability of the food production system to trade policies, individual and community access to an adequate and diverse diet due to income disparities, conflict, institutional failures and other pressures.

Health system capacity

As a determinant of vulnerability, adaptive capacity is the capability of individuals, communities and institutions such as health systems to effectively adjust to climate hazards, or prepare for, respond to and cope with the consequences of climate variability and climate-related health risks *(23)*. Information about climate change impacts on health systems and human health is needed to build or increase adaptive capacity for supporting action plans to strengthen health adaptation strategies *(13, 23)*.

Prioritization of the adaptation options should be based on the information from V&A assessments. Health adaptation actions must be developed and implemented through iterative decision-making, including health authorities, all relevant health sectors at different levels, partners outside the health sector, civil society and communities *(14)*.

Social, political, economic, geographical, biological and demographic factors are collectively determinants of health, and some groups of people may be disproportionately disadvantaged. It is essential to consider differences and inequalities at the local level, and to build equity into health actions to promote vulnerability reduction. Adaptive capacity strategies increase the opportunity for people, communities and institutions to participate meaningfully and equally in the resilience-building process *(23)*.

Using this guidance to conduct a vulnerability and adaptation assessment

The steps to be conducted in a particular V&A assessment depend on the interests of the Ministry of Health, working with other government sectors and nongovernmental stakeholders, and taking into consideration national and subnational interests and concerns with respect to climate change.

For example, the primary concern may be to enhance preparedness for extreme weather events. In this case, the focus would likely be on describing vulnerability and identifying policies and programmes to improve health system preparedness and increase community resilience (i.e. ability to adapt), often in collaboration with other departments and ministries involved in disaster risk management.

Other assessments may be broader in scope. These may investigate a broader range of health concerns associated with climate change and may project health impacts under different climate and socioeconomic development scenarios. The ultimate goal is to provide policy-relevant and actionable information that can be used to facilitate risk management over the coming decades in a changing climate.

Depending on the resources and time available, the first V&A assessment may not be comprehensive but instead may provide a scan of impacts and vulnerabilities related to climate change. This is appropriate because it is important to simply get started, begin to understand the key climate change and health concerns, investigate data sources, build partner networks for an assessment, and raise public awareness.

Increasing climate change impacts and ongoing country development mean that assessment is an iterative process. The results of an assessment should provide a baseline of information that will need to be updated in the future. The proposed steps may be implemented in the order presented, or only selected steps may be undertaken to meet the needs of the health system or population being considered.

The components of a comprehensive V&A assessment of climate change and health are as follows (Figure 3):

Step 1: getting started – plan the assessment:

Step 1A: establish a project team and management plan, including representatives from other departments and ministries.

Step 1B: identify the questions to be addressed and the policy context.

Step 1C: define the health risks, outcomes, geographical region and time period that will be the focus of the assessment.

Step 1D: establish a stakeholder process, including populations that could be affected by climate change.

Step 1E: identify information and data to inform the assessment.

Step 1F: develop a communication plan.

Step 2: vulnerability assessment – describe the current burden of climate sensitive health outcomes and vulnerabilities to climate variability and recent climate change:

Step 2A: identify, describe and prioritize key climate-sensitive health outcomes.

Step 2B: analyse the relationships between current and past weather and climate conditions and health outcomes.

Step 2C: identify trends in upstream drivers of climate-sensitive health outcomes and the geographical distribution of risks.

Step 2D: identify vulnerable populations and geographical regions.

Step 2E: document baseline information for monitoring changes in future vulnerability and evaluating adaptation options.

Step 3: capacity assessment – assess the capacity of health and health-relevant systems:

Step 3A: identify the policies, programmes and infrastructure to manage current and future health outcomes.

Step 3B: assess the current capacity of the health system to address the risks of climate sensitive health outcomes.

Step 3C: assess the current actions of other sectors that affect the risks of climate-sensitive health outcomes.

Step 4: future risk assessment – qualitatively or quantitatively project the health risks of climate change:

Step 4A: describe how current health risks could change under diverse scenarios of climate change and development.

Step 4B: estimate the possible additional burden of adverse health outcomes due to climate change.

Step 5: adaptation assessment – identify and prioritize policies, programmes and actions to address current and projected health risks:

Step 5A: identify additional population health and health care policies and programmes to prevent or reduce projected health burdens.

Step 5B: prioritize health system adaptation policies and programmes to reduce likely future health burdens.

Step 5C: identify human and financial resources for implementation of identified policies and programmes and potential challenges to be addressed.

Step 5D: estimate the costs of action and inaction.

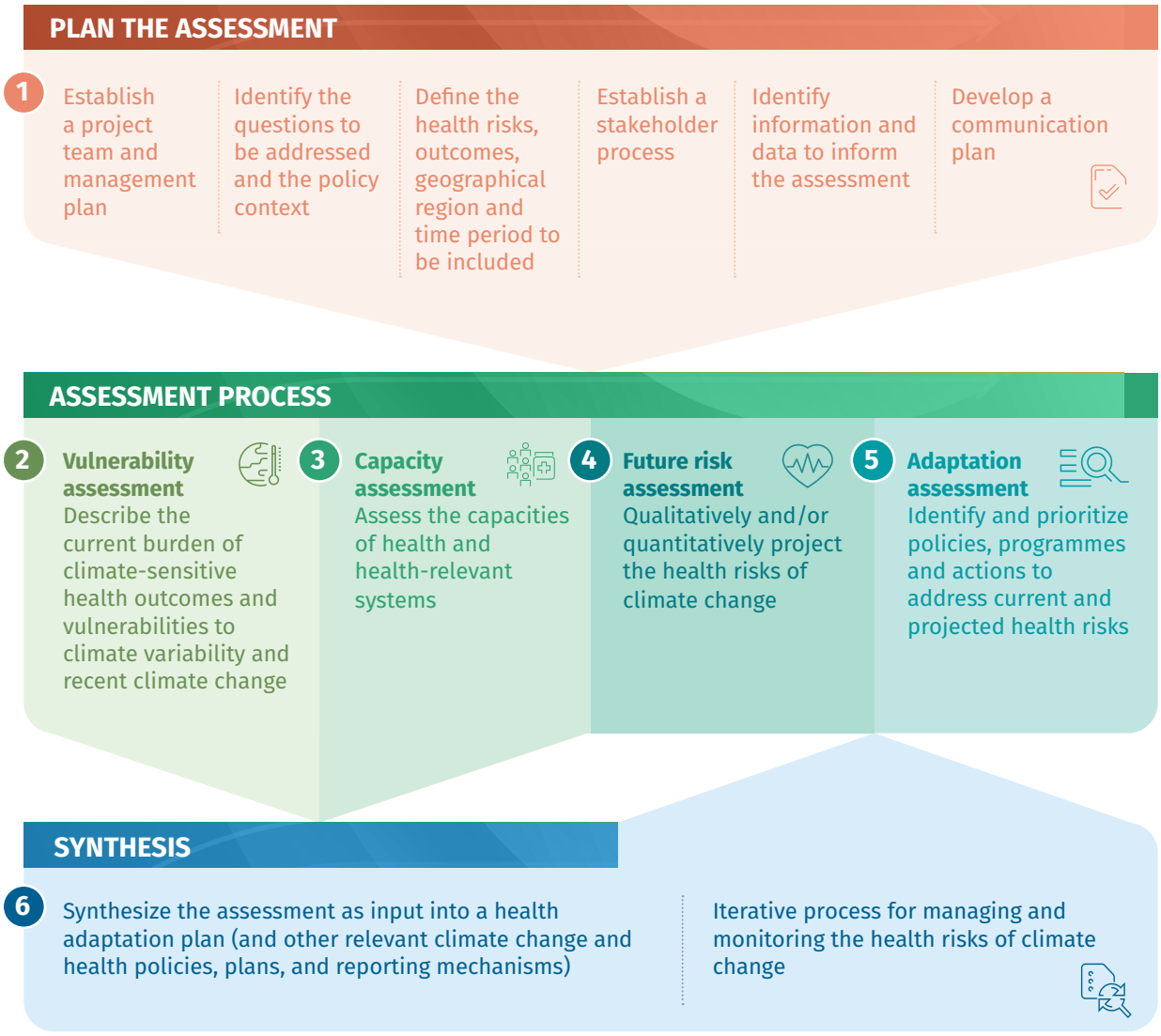
Step 5E: identify actions to reduce the potential health risks and maximize health co-benefits of adaptation and greenhouse gas emission mitigation policies and programmes implemented in other sectors.

Step 6: synthesize the assessment as input into relevant climate change and health policies, plans and reporting mechanisms:

Step 6A: synthesize the knowledge and understanding gained as input into a health adaptation plan.

Step 6B: establish an iterative process for managing and monitoring the health risks of climate change and climate resilience of health systems.

Figure 3. Conducting a climate change and health vulnerability and adaptation assessment



Vulnerability and adaptation assessment steps

STEP 1

GETTING STARTED
plan the assessment

A Ministry of Health, other health organization or local government may decide to undertake a V&A assessment to better understand the extent to which population health and health systems are already being affected by climate change and to prepare for and reduce future risks.

Alternatively, the ministry or organization may be requested to undertake an assessment by the national climate change team to inform national adaptation planning, or an assessment may be an element of an externally funded project to increase resilience to climate change.

Some regions and countries have policy processes that overlap with or encompass the links between climate change and health, such as regional health and environment ministerial processes or national environmental health action plans.

Regardless of the source of the request, the mandate for the assessment and the time and resources available to the project team will inform the scope of the assessment.

Before an assessment is initiated, key aspects of the assessment process should be framed and scoped. The project leads should take steps to:

- identify the most pressing health risks of climate change for focus in the assessment;
- define the scale of the assessment (national, subnational, state, province);
- determine how the assessment will be managed;
- establish a workplan that includes a timeframe, key information sources, context-specific adaptation needs, stakeholder participation, and a communication plan for informing stakeholders.

This information will assist in deciding who should be part of the project team (e.g. participants with certain expertise or from a chosen geographical area). Assessments can take several months to a few years, can involve a few to many scientists and stakeholders, and can have small or large budgets.

The workplan should be developed to reflect the desired timeframe and available resources for the project.

Step 1A: establish a project team and management plan, including representatives from other departments and ministries

The entity calling for the assessment will generally specify an organization to lead the assessment. This organization may be a department within the Ministry of Health, a university department, a nongovernmental organization or another group. Leadership by the Ministry of Health is fundamental to the success of a climate change and health V&A assessment.

Whoever is charged with conducting the assessment establishes a project team and management plan. This step identifies the core members of the project team, who will establish the scope and goals of the assessment and oversee the process of conducting the assessment.

Due to the broad scope of climate change risks to health, members of the project team need expertise and experience in assessing the health risks of climate variability and change to provide insights and linkages across sectors and departments. Key aspects to consider include which departments within the Ministry of Health should be represented on the team and which other institutions or agencies should be involved.

The size of the project team will be determined to some extent by the available resources and timeframe for the assessment. If, for example, the focus is on vector-borne diseases in a particular subnational region, the project team could include entomologists, public health specialists, representatives of the health care system, meteorologists, and officials in related areas. If the assessment aims to use quantitative methods to analyse the relationship between current and past weather or climate conditions and health outcomes, and to project future health risks and impacts of climate change, the team may include experts on statistics and epidemiology.

Engagement outside the Ministry of Health is necessary to facilitate collaboration with health-determining sectors, including access to data and insights to increase health system resilience to climate change.

The management plan should include the assessment timeline, roles, responsibilities and budget.

When identifying potential project team members, the following should be considered:

- officials from local authorities whose activities can affect the burden and pattern of climate-sensitive health outcomes (e.g. water authority, vector control unit, solid waste management);
- representative health care providers who would diagnose and treat any identified cases of climate change-related diseases or other health outcomes;
- core members of the project team who stay for the entire project as researchers or advisors;
- people working on issues relevant to the mandate of the assessment in other departments or organizations (e.g. experts in disease transmission or disaster risk management);
- people working or regularly interacting with populations of concern (e.g. Indigenous leaders, community leaders, social workers, anthropologists, nongovernmental organization representatives);
- communication experts who can discuss how to present the assessment results in ways that inform and empower the public to take appropriate behavioural adaptation actions;
- people with targeted expertise (e.g. climatologists, gender specialists, entomologists);
- modelling or mapping experts who are engaged early on and have sufficient resources.

Step 1B: identify the questions to be addressed and the policy context

The Ministry of Health lead department sets clear objectives for the V&A assessment in collaboration with stakeholders, based on human and financial resources availability, capacity levels, strategic goals and other criteria.

The objectives relate to providing decision-makers within the health system and in health-important sectors, key stakeholders and the public with the information needed to reduce health risks from current climate variability and prepare for future climate change.

The questions to be addressed support these objectives and should be informed by the needs of policy- and decision-makers in the Ministry of Health or local health department. New Ministry of Health priorities, programmes or projects could also shape the objectives, such as investments targeted towards strengthening the climate resiliency of health care facilities or the integration of climate or weather information in surveillance systems.

Questions that can assist health authorities in preparing for climate change impacts and that can be addressed in a V&A assessment include the following:

- What health risks and outcomes are sensitive to weather and climate?
- What climate-sensitive health risks and outcomes are of greatest concern for stakeholders and the public?
- What is the current burden of climate-sensitive health outcomes?
- What subnational areas and populations in the country are the most vulnerable to climate variability and climate change?
- What factors other than weather and climate determine vulnerability of populations and health systems?
- How effective are current policies, programmes and activities in managing climate-sensitive health risks and outcomes?
- How is the burden of climate-sensitive health outcomes likely to change over the coming decades, irrespective of climate change?
- What are the likely health impacts of climate change over the next several decades and over the longer term?
- How is the health system (including other systems such as Indigenous and informal health systems) currently being impacted by climate change?
- How well is the health system prepared for changes in demand due to changes in geographical distribution, incidence or timing of climate-sensitive health outcomes?
- What additional public health interventions will likely be needed for effective risk management?
- What are the estimated costs and benefits of the proposed adaptation measures?
- What interventions are needed in other sectors to protect public health?
- How might climate change affect health equity, and how will special vulnerabilities of groups such as Indigenous Peoples, pregnant women and poor rural communities be considered in the assessment?

The assessment objectives influence the questions to be answered and the activities undertaken during the assessment process that constitute the final workplan. For example, an assessment may focus on a subset of climate-sensitive health outcomes or on particular vulnerability factors (e.g. rural and urban communities or northern communities).

Documenting the choices made in identifying the project objectives and key questions to be answered reinforces the legitimacy of the process and informs subsequent V&A assessments.

An overview of the policy context should be described, including existing policies and programmes relevant to climate change, health and critical health determinants, such as water, sanitation, food security, disaster risk management and land management – for example, the national priorities with respect to climate change (as described in the national climate change plan or the national determined contribution) and with respect to health (as described in the Ministry of Health 5- or 10-year plan).

The description should include the influence of civil society and nongovernmental organizations – for example, in reaction to experienced impacts of extreme events such as floods or droughts, which can prompt concern over the effects of longer-term climate change.

When developing the workplan, it is important to consider the extent to which all steps in a V&A assessment are necessary to provide information needed by decision-makers to increase knowledge, awareness and preparedness of climate change impacts on health. Time, financial resources, new priorities or health emergencies may limit the ability to conduct a full assessment with all steps.

The team should note any steps that it decides not to implement. Reasons for not undertaking a certain step and plans for doing so in the future should be included in the final report to inform the framing and scoping of subsequent assessments.

Step 1C: define the health risks, outcomes, geographical region and time period that will be the focus of the assessment

The choice of which climate change health risks and outcomes to include in the assessment determine the expertise and experience needed in the project team, the types of stakeholders involved, and the key audience for the results. In some cases, all climate-sensitive health outcomes will be considered in the assessment; in other cases, the focus will be on specific outcomes such as infectious diseases or the health impacts of extreme weather events.

The assessment can start from the perspective of specific shifts in weather patterns due to climate changes (i.e. exposures) and determine their possible consequences, or from the perspective of current climate-sensitive health outcomes (e.g. increase in observed health impacts or vulnerabilities) and determine how risks could change with climate change. The geographical scale could be national or subnational.

The resources and timeline for the assessment influence the numbers of health outcomes and subnational regions included. When only certain health outcomes and subnational regions are included, it can be useful for the project team to agree which are of higher priority. Current Ministry of Health priorities, recent disease outbreaks or public concerns may lead to the selection of a subset of climate-sensitive health outcomes and subnational regions for inclusion or prioritization.

Given that some V&A methods, data sources and analysis tools may be new to health authorities, some begin by focusing on one health issue or subnational region that has the most data available or opportunities for expert participation, and then use this as a learning experience and template to complete other analysis. V&A assessments are conducted iteratively, and so other health outcomes and subnational regions can be included in the next assessment.

The project team decides on the time periods related to current and future climate change risks to be considered in the assessment and includes these in the workplan. The time periods should balance the needs of decision-makers, who are often focused on health system planning and operations over the next 5–10 years, with the need to understand how climate change could affect health risks over decades or longer.

A particular challenge is considering how other factors that could affect vulnerability to climate change risks to health are likely to change over time, such as demographics, urbanization, land use, environmental changes or socioeconomic development. The longer the projection, the more uncertain the changes in these and other factors.

The choice of time period will depend on the focus of the assessment. For example, if one objective of the assessment is to determine health care infrastructure impacts, vulnerabilities and adaptation needs, then a longer time period would be more appropriate. New buildings typically last for many decades, and it would be helpful to know whether certain locations for siting them may be at higher risk of increased impacts from future extreme weather events such as floods. The choice of time period will also depend on availability of data on projected changes.

Projections of changes in climate and other factors are available from the Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre *(24)* and often from regional and national climate centres and agencies. The United Nations Department of Economic and Social Affairs has national-level demographic projections to 2050 for all countries *(25)*. WHO has current estimates and projections of expected disease burden *(26)*.

Because of the inertia in the climate system, current atmospheric concentrations of carbon dioxide and other greenhouse gases have committed Earth to several more decades of climate change, irrespective of the rate and extent of future reductions in greenhouse gas emissions. Therefore, projections for the next several decades – useful for analysis of health risks – do not need to take into account emissions of greenhouse gases under different plausible futures, such as representative concentration pathways (RCPs). Projecting possible health risks of temperature and precipitation changes in these time periods should, however, take into account changes in demographics (e.g. population ageing), health system development, technology development, economic growth and other confounding factors (see Step 4).

Longer-term projections past the middle of the twenty-first century need to take into account different emission pathways in addition to changes in the important confounding factors over time. Possible time periods for projections to support analysis of future health risks are the middle and the end of the century. The time periods chosen will support the objectives of the assessment by being relevant for decision-makers, taking into account that climate change will continue to affect health systems for decades. Policy-makers may be focused on the next 5–10 years, but climate change will affect health system infrastructure until the end of the century.

Step 4 describes qualitative and quantitative approaches to constructing possible future pathways that could affect the extent to which climate change or development affect the magnitude and pattern of future health risks.

Step 1D: establish a stakeholder process, including populations that could be affected by climate change

Assessing the health risks of climate change and identifying possible policies and programmes to increase resilience need to be informed through engagement (e.g. workshops, surveys, expert solicitation, focus groups) with representatives from all groups engaged in or concerned with the prevention and management of the health impacts of climate change, including within the Ministry of Health, universities, nongovernmental organizations, national and subnational emergency preparedness committees, and the populations most affected by climate change.

Community, subnational and national climate change initiatives and those focused on managing climate-sensitive health risks may be helpful in identifying appropriate stakeholders. Users of the V&A assessment results should be included in the stakeholder list to ensure their perspectives are included throughout the process.

The project team establishes a process for gathering and incorporating stakeholder input into the design, implementation and conduct of the assessment through the various steps and for communication of the results. The stakeholders can later help translate the identified action needs into concrete measures.

Two stages of stakeholder involvement may be required. At the initial stages of project scoping and workplan development, the stakeholder group will probably be small to support identification of the assessment objectives and additional stakeholders needed. Following initial scoping activities, the core project team may need to expand to support and inform the completion of the assessment steps, and a broader, diverse group of stakeholders should be engaged throughout the assessment.

It is important to include representatives of institutions that will be important contributors of data or analytical skills, that will implement the identified policies and programmes, and that may be affected by such policies or climate change impacts.

The roles and responsibilities of the stakeholders should be clear to all participants. The assessment process is an opportunity to develop an ongoing network of partners engaged in or concerned about the health risks and impacts of climate change.

For national assessments, countries typically hold at least one stakeholder meeting with representatives from all ministries, nongovernmental organizations, universities, community leaders and other relevant groups. The assessment goals are presented and discussed, and input is sought on high-priority issues that need to be addressed, including subnational regions and vulnerable populations.

Ideally, stakeholders represent the programmes that deal with the health outcomes, organizations and institutions that are knowledgeable about climate change and development plans, subnational and national policy-makers, and the most vulnerable groups. For example, if waterborne diseases are a high-priority issue, stakeholders could include representatives from:

- the WHO country office;
- the Ministry of Health;
- the Ministry of the Environment (if it deals with climate change or water management);
- the Ministry of Finance (if it oversees infrastructure development and planning);
- water managers;
- scientists involved in water-related issues;
- community leaders, Indigenous leaders and others who understand changing patterns of water use and misuse, and their impacts on communities;
- representatives of other international organizations;
- nongovernmental organizations in the region working on issues related to waterborne diseases.

The output from the initial stakeholder meeting includes further specification of the content and process of the assessment, and details of how to ensure active and sustained stakeholder dialogue throughout. If required, users can consult current literature on stakeholder engagement, including planning approaches, the role of facilitators, and principles of effective consultation.

Step 1E: identify information and data to inform the assessment

The project team begins the process for collecting documents and data relevant to the objectives and questions of the assessment, including peer-reviewed literature, white papers and other documents, and copies of policies and programmes to manage the climate-sensitive health outcomes. Health data should be available from the Ministry of Health and subnational health authorities. It is important to have as long a data series as possible, so it can be helpful to determine whether there are data on paper records that could be digitized for use in the assessment.

The national hydrological and meteorological services will have data on weather and climate, although a memorandum of understanding may be needed to access these – this process should be started as soon as possible.

Data from other ministries and organizations could be valuable, such as data on flood or drought zones, demographic and urbanization trends, and land-use management.

Identifying a subgroup of the project team including relevant stakeholders to locate the data and documents could be helpful.

Sources of quantitative and qualitative information may include the following:

- Peer-reviewed literature: there are many publications on potential changes in health risks to vulnerable populations from climate hazards, including projections of changes in precipitation and temperature in the coming decades and maps of the current and projected ranges of the vectors that cause malaria, dengue and Zika.
- Grey literature: this may describe the current burden of climate-sensitive diseases and management approaches for the health outcomes of concern. Assessments that have been done for other sectors could provide valuable insights into climate exposures that impact health.
- Community reports: these can provide information on a range of key vulnerability factors, such as relevant health reports and associated datasets, and ethnographic and anthropological documents relating to a specific location or population group.
- Health data: these may be obtained from national health authorities and from specific local surveillance systems established as part of specific projects. Data may include information about the prevalence of climate-sensitive diseases and the causes of morbidity and mortality.
- Vulnerability factor data: these may be obtained from environmental health departments, demographic surveillance systems, national statistical institutes, the Ministry of Agriculture, national water management services, the Ministry of Gender, the Ministry of Social Development, and others. Data include information about current levels of population exposure factors (e.g. lack of access to improved water and sanitation), sensitivity (e.g. number of marginalized people, ethnic minorities, percentage of older people, poverty, lack of access to education), coping capacity (e.g. local heat early warning systems, emergency response plans, disaster risk management), and future projections (e.g. population growth, ageing, urbanization).
- Climate data: national meteorological services are usually the main providers of these data. Historical climate data, trends in temperatures and rainfall data, seasonality analysis, occurrence and intensity of extreme weather events, future climate projections and other relevant climate indicators may be available.

Step 1F: develop a communication plan

Plans for communicating the assessment process and results should be formulated at the start of the V&A assessment to ensure all opportunities are identified to effectively communicate identified risks to decision-makers responsible for protecting health, and to those who could be affected.

The credibility and legitimacy of the assessment results will be increased if stakeholders and the intended end-users are kept engaged and informed of project progress.

The audience for the assessment, such as departments within the Ministry of Health and the team responsible for the national communication to the United Nations Framework Convention on Climate Change (UNFCCC), and the mechanisms for communicating the results need to be identified. For example, the results could be presented in a report aimed at the appropriate officials and programmes within the Ministry of Health, with an executive summary to inform the national communication.

Communication mechanisms and products developed to share the results may be similar to those developed by the Ministry of Health for other projects and could include executive summaries, infographics, decision-maker briefs, presentations, podcasts, newsletters, social media and visual digital media.

Well-developed and implemented communication activities are needed to ensure the inputs and findings of the V&A assessment are relevant to decision-makers, which will increase the chance that they will be used to manage climate risks. Full and effective implementation of the communication plan supports preparedness and response activities in communities and empowers them in efforts to strengthen or increase their resilience to climate risks to health.

Equally important are communities' inputs to decision-making, and their engagement in adaptation actions, which should include approaches and plans for documenting good practices and lessons learned for scaling up *(27)*.

In general, communication plans should include a summary of the assessment process, a list of target audiences and information needs, planned communications products, mechanisms for delivery, a timeline for execution, stakeholder participation, and a summary of high-priority policies and programmes recommended. A useful reference is the UNFCCC Strategic plan *for stakeholder engagement, communications and resource mobilization (28)*.

Box 2. Benefits of Indigenous partnerships and knowledge in vulnerability and adaptation assessments

Indigenous Peoples are often at higher risk to the health impacts of climate change because of greater exposures to climate hazards (e.g. thawing permafrost and unpredictable weather in the Arctic), higher sensitivity to health impacts (e.g. higher background rates of climate-sensitive diseases), and less capacity to take adaptation measures at the community and individual levels (e.g. reduced access to health services, colonial legacies).

Climate change and health V&A assessments should include analysis of current and projected health impacts on Indigenous Peoples and adaptation options that respond to local, cultural and spiritual needs of specific communities.

Indigenous knowledge and western science can be used in V&A assessments to help public health officials plan for climate change impacts. Indigenous knowledge is the "understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings. It is passed on from generation to generation, flexible, and adaptive in changing conditions, and increasingly challenged in the context of contemporary climate change" *(29)*.

Assessments benefit from Indigenous knowledge through the inclusion of observations of climate change and its effects on health, providing a rigorous and rich form of evidence. V&A assessments can be served through the consideration of current adaptations being led by Indigenous Peoples, as many communities are already responding to observed changes. Key experiences and lessons learned can be used by the assessment team.

Many V&A assessments have been completed in countries that use Indigenous knowledge and western science or only Indigenous knowledge. Conceptual frameworks can guide the use of Indigenous knowledge in such studies. Rigorous and meaningful integration of Indigenous knowledge and western science requires an openness to diverse ways of knowing and using these complementary or contrasting perspectives to understand and plan for climate change impacts on health.

The meaningful, ethical and robust use of Indigenous knowledge in V&A assessments requires several elements, including:

- meaningful engagement that goes beyond consultation, such that Indigenous Peoples are included in or lead all V&A assessment steps;
- making V&A assessment processes and products useful, meaningful and accessible to Indigenous Peoples and their organizations;
- sharing V&A assessment information and findings within the context of concerns and interests identified and defined by Indigenous Peoples;
- acknowledging the intellectual property of Indigenous knowledge, such that it is protected and validated by Indigenous Peoples themselves and not appropriated by non-Indigenous Peoples;
- recognizing and crediting Indigenous contributions in the final products, publications and other outputs;
- adopting a strength-based approach to guide the work that avoids portraying Indigenous Peoples as inherently vulnerable "victims" of climate change or "heroic" groups whose Indigenous knowledge can be taken and appropriated for finding solutions elsewhere;
- committing to using Indigenous knowledge in climate health decision-making based on results of the V&A assessment, which enables the incorporation of relevant priorities and local context into adaptation and mitigation.

The Climate and Traditional Knowledges Workgroup provides information about actions for agencies, researchers and Indigenous knowledge-holders that maybe useful for V&A assessments *(30)*.

STEP 2

VULNERABILITY ASSESSMENT
describe the current burden of climate-sensitive health outcomes and vulnerabilities to climate variability and recent climate change

In this step, the V&A assessment begins by describing the current burden of climate-sensitive health outcomes and current vulnerabilities and works towards establishing a baseline for further analyses and assessments (including the assessments of future risks detailed in Step 4).

This description can be a qualitative or quantitative summary of the current distribution and burden of climate-sensitive health outcomes by vulnerable population or geographical area and will establish the vulnerability baseline.

Step 2A: identify, describe and prioritize key climate-sensitive health outcomes

Documents and data collected in the previous step should be analysed and synthesized to describe the current distribution and burden of climate-sensitive health outcomes. The synthesis can include experiences and insights from departments within the Ministry of Health (e.g. experience from a dengue control programme that the burden of dengue has been increasing in recent years).

Data sources for further analyses should be identified. The synthesis should take into account knowledge about the burden of climate-sensitive health outcomes in neighbouring countries or regions, such as increasing or decreasing outbreaks of climate-sensitive infectious diseases along a border. If the available information is insufficient for further quantitative assessment of the health outcome or for understanding sensitivities to climate variables, interviews with subject matter experts can help fill knowledge gaps and inform future analyses of vulnerabilities.

The synthesis is needed to establish a baseline for further analyses and assessments. This synthesis can be a qualitative or quantitative summary.

Unless the V&A assessment will be comprehensive, the list of climate-sensitive health outcomes should be prioritized to identify which to include. Prioritization can be based on Ministry of Health priorities, concerns expressed by the public (e.g. recent outbreaks of dengue), or a qualitative assessment of the strength of association between climate change and a health risk and outcome (e.g. weak, moderate, high) and the possible impact of an event or outbreak (e.g. limited, moderate, high). The timeframe over which the event or outbreak could occur is also valuable to capture, as risks not of concern until later in the century could be postponed for later consideration.

Step 2B: analyse the relationships between current and past weather and climate conditions and health outcomes

Understanding the relationships between health outcomes and weather and climate patterns is essential when assessing the risks posed by climate change to population health. These analyses should aim to be at the geographical scale and level of detail most suitable for decision-makers, taking into consideration the type and quality of evidence.

Data on seasonal and historical trends of key climate hazard variables may include maps of weather and climate conditions and impacts such as location and dates of floods, droughts, hurricanes, wildfires, sea-level rise, rainfall and temperature patterns. This information can be used to understand exposure of individuals and communities to potentially threatening climate hazards. If relevant to the targeted health outcomes, this step can document how the geographical range, intensity, duration and return periods of particular weather events have changed over recent decades.

Quantitative data are not necessary to describe these relationships. The burden of the chosen health outcome can be estimated using expert judgement and described in relative terms (e.g. high burden of endemic malaria in one district but medium risk in another district).

National data are available from the WHO Global Health Observatory *(31)*. Information may also be available from national datasets and from climate and health risk maps and surveys conducted by nongovernmental organizations, universities and others. Observed seasonal epidemiological trends and disease outbreaks associated with weather anomalies over time can be good indicators of the sensitivity of the outcome to meteorological conditions (e.g. incidence of disease during dry and wet seasons).

Quantitative approaches for analysing relationships between weather variables and climate-sensitive health outcomes are available *(32, 33)*.

Health and weather data availability, and reliability, cost, spatial and temporal resolution and comparability of data need to be addressed during the assessment. At a minimum, analyses should be conducted of the relationships between health data and core weather variables, such as temperature, precipitation, relative humidity, and extreme weather events and patterns.

Health data are generally available from ministries of health, and weather data from national meteorological and hydrological services. In some countries, accessing these data is challenging because some meteorological services and other data sources charge for data, limiting the scope of the analyses. Stakeholder participation from data owners can help facilitate access.

Some sources of current and historical meteorological data relevant for health decisions are the World Weather Information Service of the World Meteorological Organization *(34)*, and the International Research Institute for Climate and Society and Lamont-Doherty Earth Observatory Climate Data Library *(35)*.

The time periods and geographical and temporal resolution of weather and health data often do not match perfectly. There should be consultations with relevant disciplinary experts on the choices for the scale of analysis. For example, if health data are available at the hospital level or the level of a census tract, and the catchment area includes several weather stations, then the weather data may need to be aggregated to the level of the health data.

Weather patterns can change over geographical regions; caution should be applied when analysing health outcomes if the weather data have been measured at some distance and with a difference in altitude from the population being described.

The robustness of the conclusions that can be drawn should be considered if the time series for the health or weather data are short. Often health data are available for only a few years; they are rarely available for decades or longer. Climate change occurs over decades or longer; analyses over shorter timescales can provide information on possible risks associated with weather patterns but cannot attribute how climate change has affected the geographical range or incidence of a particular health outcome.

Where data are available over several decades, a valuable analysis is to determine whether there is a trend in a health outcome and to assess whether some or all of the change can be attributed to climate change. This requires other drivers of the health outcome to be included in the analysis.

Step 2C: identify trends in upstream drivers of climate-sensitive health outcomes and the geographical distribution of risks

Spatial mapping is a valuable approach for describing the geographical distribution of current or projected future vulnerabilities and hazards. A geographical perspective can integrate, visualize and analyse health and environmental data used or produced during the assessment. Maps also serve as important communication tools for explaining assessment results.

A geographical perspective and the use of geographical information systems (GIS) offer opportunities to show current distributions of, for example, vulnerable populations and the spatial relationship to disease vectors, river basins prone to flooding, health care facilities, and other important variables of interest to public health officials. Vulnerability and risk identification programmes often use GIS as one of their principal tools.

Several GIS software packages are publicly available. A variety of potentially relevant environmental, climate and sociodemographic data are available through web-based sources, such as the R Project *(36)*, QGIS *(37)*, the Centers for Disease Control and Prevention Map feature in Epi Info *(38)* and ArcGIS Online *(39)*.

The area investigated depends on the purpose and objective of the investigation. Spatial resolution of the assessment is influenced by available data. Grids, natural areas or administrative units usually serve as spatial resolution.

Where feasible and required, associations between the hazards and the incidence, seasonality and geographical range of the climate-sensitive health outcomes under consideration can be analysed using epidemiological methods. There will be more confidence in analyses conducted using longer, larger, good-quality and documented health datasets.

It is important to understand the extent to which exposures not related to climate change do or could affect human health. Assessments should consider how key health determinants such as poverty, the availability and quality of water and food, and population density and dynamics (e.g. migration) could affect relationships between weather patterns and climate-sensitive health outcomes. Analyses should focus on understanding these trends scaled to the area of interest.

To analyse the relationships in the temporal trends of climate hazards and the affected health outcomes, time series with at least 10 years of data are recommended. Plotting and mapping may prove useful as an initial step for identifying patterns, particularly when only limited data time series are available.

In the analysis, it is important to consider factors that could influence any observed trends, such as changes in disease control programmes, disease case definitions, and changes in land use. It is important to account for vulnerability factors that act as mediating agents between climate change and sensitive health outcomes (e.g. population growth, people living in low-lying areas, people living on subsistence agriculture, people with access to improved water and sanitation systems).

Step 2D: identify vulnerable populations and geographical regions

Although climate change affects all populations and geographical regions, some are more vulnerable to weather and climate, which means they could experience greater harm if not prepared. A source of vulnerability for many population groups is inequitable distribution of resources, which affects the ability to adapt. In many situations, climate change will increase inequity *(1)*.

This step identifies populations and subnational regions with increased or decreased vulnerability to weather, current climate variability, and recent climate change. Examples include the following:

- People living on a flood plain are at risk during flooding. People with less ability to escape floodwaters and their consequences (e.g. children, older people, infirm people, people with disabilities, people living in substandard housing along riverbanks) are at even higher risk.
- Adults with chronic respiratory disease, people with asthma, children and outdoor workers are at increased risk during episodes of poor air quality.
- People living in areas of land-use change such as deforestation, coastal development or urbanization may be affected by changed distribution of infectious diseases.

Certain health conditions affect specific subpopulations to a greater or lesser extent, as a result of differences in exposures and sensitivity. Examples of some of the most important relationships are given in Table 2.

Table 2. Subpopulations vulnerable to climate-sensitive health outcomes

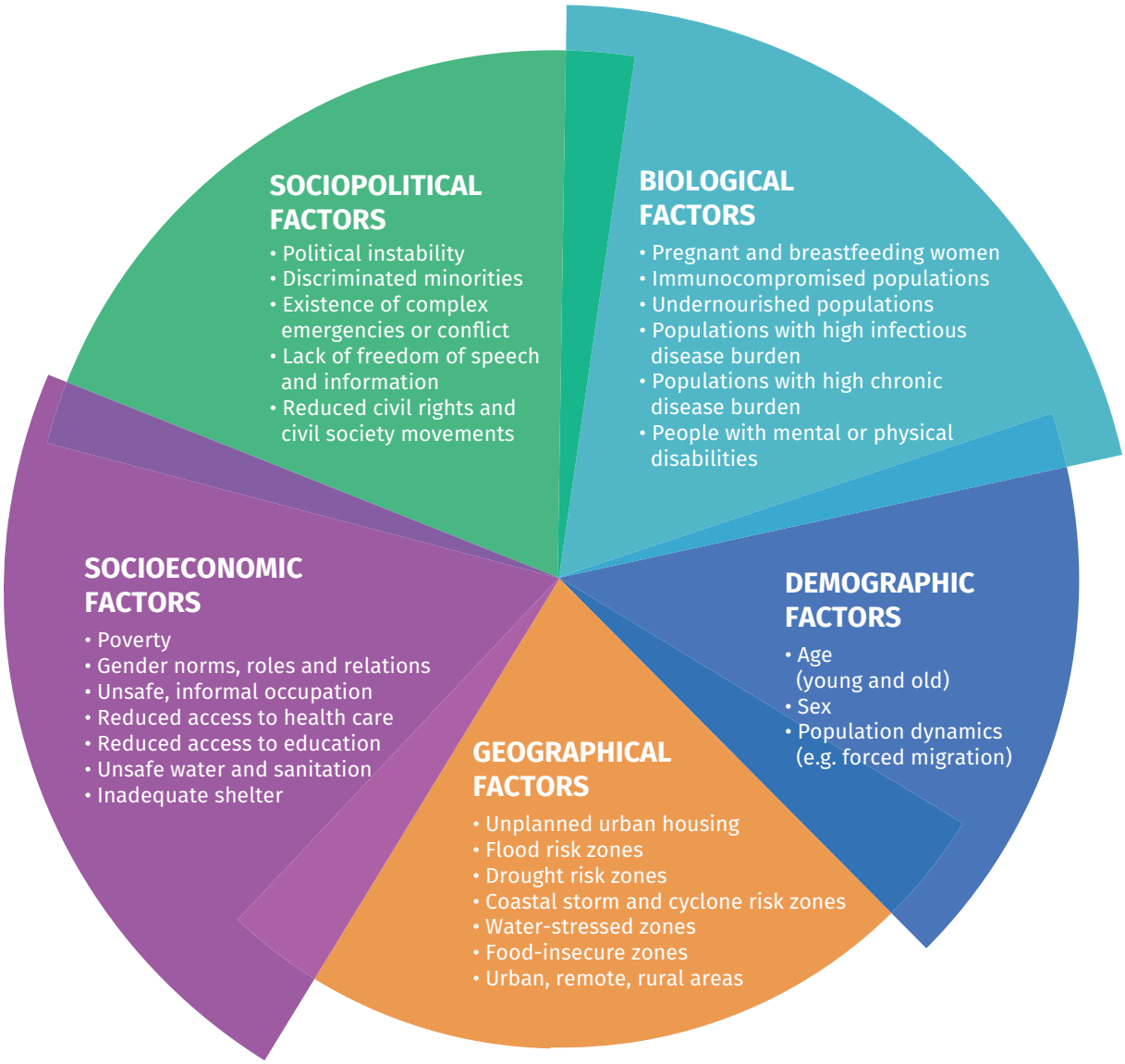
Groups with increased vulnerability	Climate-related vulnerabilities
Infants and children	Heat stress
	Ozone air pollution
	Water- and foodborne diseases
	Vector-borne diseases
	Malnutrition
Pregnant women and newborn infants	Heat stress
	Extreme weather events
	Water- and foodborne diseases
	Vector-borne diseases
	Malnutrition
	Air pollution
	Low birth weight
	Preterm birth
Older adults and people with chronic medical conditions	Heat stress
	Air pollution
	Extreme weather events
	Water- and foodborne diseases
	Vector-borne diseases
	Cardiovascular diseases
Impoverished or low socioeconomic status	Heat stress
	Extreme weather events
	Air pollution
	Water- and foodborne diseases
	Vector-borne diseases
Outdoor workers	Heat stress
	Air pollution
	Vector-borne diseases
	Ultraviolet light exposure
	Dehydration

Source: Adapted from Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med. 2009;51:33–37; and Gamble JL, Balbus J, Berger M, et al. Populations of concern. In: The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC: U.S. Global Change Research Program; 2016.

Other population groups, such as Indigenous Peoples, poor rural communities (especially those dependent on the environment or living in isolated or impoverished communities), migrants, homeless people and people with disabilities, are likely to have greater exposure, increased vulnerabilities and lower resilience to climate-related health stressors and the cumulative health effects *(40)*.

Figure 4 shows examples of multiple vulnerabilities for populations exposed to climate change.

Figure 4. Multiple vulnerability factors for health impacts of climate change



Source: Based on Gamble JL, Balbus J, Berger M, et al. Populations of concern. In: The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC: U.S. Global Change Research Program; 2016; and Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021.

Centring health equity in climate change and health vulnerability and adaptation assessments

Upstream drivers of social and health inequities (e.g. patriarchy, ableism, cis-normativity, hetero-normativity, capitalism, political and educational institutions, structural racism, historic and ongoing colonialism) result in the unequal distribution of power and resources across populations, communities and geographical regions and shape determinants of health *(41)*.

The differential status of determinants of health across populations (e.g. high versus low income, good-quality versus substandard housing) and the relative disadvantages this results in health inequities.

Climate change interacts with upstream drivers and determinants of health to exacerbate existing health inequities.

The combination and status of determinants of health, biological and genetic traits, and existing health inequities shape an individual's climate change vulnerability. It is likely that vulnerability increases as the number of poor-status determinants (e.g. low income, poor-quality housing, homelessness, water shortage, food insecurity) increases. These combinations vary for each individual, for each specific health risk, and for each geographical region. They act to increase or decrease an individual's exposure or sensitivity to climate-related health risks and can create barriers that limit adaptive capacity.

Individuals and populations that experience health inequities and poor determinants of health are not homogeneous. Much variation exists across and among populations in terms of the experience of impacts and degree of vulnerability. Strengthening determinants of health and redressing existing health inequities can help decrease vulnerability to climate-related health risks and build adaptive capacity *(42, 43)*.

Understanding and accounting for how the status of determinants of health and multiple existing health inequities can influence current and future climate change risks and health vulnerability can enhance the findings of a V&A assessment. For example, applying a health equity lens to V&A assessments can elucidate important information on conditions that contribute to climate change vulnerability specific to the geographical region being assessed, inform the design of effective adaption measures with equitable outcomes, guide the allocation of resources, and aid in prioritizing health adaptation efforts.

While the concept and promotion of health equity are not new for public health actors, challenges remain on how to effectively centre health equity in climate change and health activities, such as V&A assessments.

Practical tools, activities and frameworks exist that complement the steps of a V&A assessment and may assist public health actors in centring health equity in the V&A assessment process by:

- meaningful, inclusive and equitable community engagement, particularly of people of minority ethnicities and Indigenous Peoples, at all stages of the V&A assessment process;
- including partners from across sectors and disciplines, including those in relevant equity-focused fields, in framing the V&A assessment and informing effective adaptation actions;
- asset mapping and vulnerability mapping *(44–47)*;
- adopting guiding questions and indicators from existing health equity impact assessment frameworks *(48, 49)*;
- collecting data on the health impacts of climate change from a health equity lens to better understand how the status of determinants of health and multiple health inequities compound vulnerability;
- incorporating health equity considerations and relevant data (e.g. demographic and socioeconomic conditions) into climate change and health projections *(41, 44, 50)*;
- evaluating and monitoring adaptation measures for impacts on health equity *(51)*.

Geographical distribution of populations leads to different vulnerabilities

Some populations of concern are distributed by geographical areas that are more vulnerable to hazards from climate variability and change, which may create or exacerbate health effects. Population vulnerability differs across geographical regions (e.g. urban, rural, coastal, low-lying, mountainous) and across types of community (e.g. Indigenous, agricultural, migrant).

It can be helpful to map hotspots of vulnerability and how those hotspots could shift over time as climate-sensitive health outcomes shift their geographical range, to better communicate where impacts are most likely to occur, and to help prioritize the best practices for adaptation actions.

Mapping vulnerabilities should be done at the finest geographical scale possible, to inform policy development and regulation. Including information on weather data would facilitate understanding of the communities and individuals experiencing current challenges with climate change and how those could shift in the future.

Vulnerable urban populations

Urbanization and climate change may work synergistically to increase disease burdens. Urbanization can positively influence population health, for example by making it easier to provide safe water, improved sanitation and access to services, including health care. Rapid and unplanned urbanization are often accompanied by other challenges such as social, economic and environmental stressors; these increase risks to individuals, households and communities, leading to adverse health outcomes *(52)*.

For example, urban slums and squatter settlements are often located in areas subject to landslides, floods and other hazards expected to increase with climate change. Lack of water and sanitation in these settlements increases the difficulty of controlling disease reservoirs and vectors and facilitates the emergence and re-emergence of infectious diseases. Increasing temperatures will facilitate increases in the geographical range, incidence and seasonality of climate-sensitive infectious diseases. Populations in high-density urban areas with poor housing will be more susceptible to the effects of increasingly frequent and intense climate-related natural hazards such as heatwaves, exacerbated in part by the interaction between increasing temperatures and urban heat-island effects.

Vulnerable rural populations

Climate change and increasing climate variability and extremes have a range of adverse effects on some rural populations and subnational regions *(53)*. Rural communities often experience different vulnerabilities from those in urban areas because they are highly dependent on natural resources that are affected by climate change *(54)*. These communities also face particular obstacles in responding to climate change that increase their vulnerability to its impacts *(23)*. An example is increased food insecurity because of geographical shifts in optimum crop-growing conditions and decreases in crop yields; reduced water resources for agriculture and for human consumption; and loss of property such as crop land because of floods, droughts and a rise in sea level. Overall, the world is falling behind on achieving agreed international targets on reducing hunger, and climate change is projected to increase the number of people at risk. Undernutrition is expected to be the largest health risk of a changing climate *(54, 55)*.

Populations in coastal and low-lying areas

Climate change could affect coastal areas through an accelerated rise in sea levels, a further increase in sea-surface temperatures, intensification of tropical cyclones, changes in wave and storm-surge characteristics, altered precipitation and runoff, and ocean acidification. All these changes could affect human health through flooding and damaged infrastructure; soil erosion, salinization of soil, ground and surface water impacting food nutrients; saltwater intrusion into freshwater resources; damage to coastal ecosystems, coral reefs and coastal fisheries; population displacement; and changes in the range and prevalence of climate-sensitive health outcomes, from water-, food- and vector-borne diseases (e.g. malaria, dengue, diarrhoeal diseases) and from noncommunicable diseases (e.g. mental health conditions) *(56, 57)*.

Populations in mountain regions

Limited information is available on the possible health consequences of climate change in mountain regions. It is likely, however, that vector-borne pathogens could take advantage of new habitats in altitudes that were formerly unsuitable, and diarrhoeal diseases could become more prevalent under higher temperatures, with changes in freshwater quality and availability *(58)*. Food systems can be affected by changing precipitation patterns, reduced snow cover, water scarcity, and reduction of soil organic carbon, contributing to reduced subsistence agriculture. Infrastructure and ecosystem services co-production and regulation may be affected, with several consequence for local communities, including loss of livelihood and effects on human health and well-being *(59)*. More extreme rainfall events are likely to increase the number of floods and landslides.

Glacier-lake outburst floods are a risk unique to mountain regions; these are associated with high morbidity and mortality and are projected to increase as the rate of glacier melting increases. Changes in the depth of mountain snowpack and glaciers, and in their seasonal melting, can have significant impacts on mountain and downstream communities that rely on freshwater runoff *(60)*.

Other populations at increased risk include those living in degraded and fragile ecosystems (e.g. forests, deserts). Ecosystem services are indispensable to human health and well-being by providing food, safe water, clean air, shelter, and other life-sustaining products or services. Changes in availability of these services can affect livelihoods, income and migration, lead to political conflict, and have wide-ranging impacts on health and well-being *(61, 62)*.

Step 2E: document baseline information for monitoring changes in future vulnerability and evaluating adaptation options

The qualitative and quantitative data and analyses should be synthesized into a baseline that can be used for future analyses and assessments. For example, the numbers of cases and deaths within the regions of the country for the period 1995–2005 could be established as a baseline for future comparisons.

In general, the longer the time period, the more stable the estimate. It is important to consider whether a major weather and climate event (e.g. flood, drought, storm) could have influenced the numbers of injuries and deaths or infectious disease outbreaks. If so, then that year or time period should be excluded from the baseline.

The baseline should be based upon key metrics that describe current morbidity and mortality of the climate-sensitive health outcomes of concern, including recent trends and information on associated underlying risk factors and determinants. It should also include information on policies and programmes in place to manage those outcomes, including measures of their effectiveness.

This snapshot of current conditions can be used as a first comparison and as a reference to monitor changes and determine the success (or failure) of future adaptation policies and programmes. This step assists with the development of indicators and a monitoring plan in Step 6. The baseline should be documented as an outcome of the V&A assessment.

Box 3. Assessing vulnerabilities in health care facilities

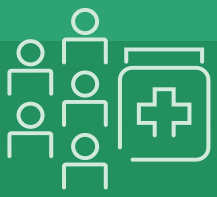
Climate variability and change are increasing risks that pose threats to health care facilities functioning. To extend its guidance for climate-resilient and environmentally sustainable health care facilities *(21)*, WHO selected the same fundamental requirements to develop a checklist to assess vulnerabilities in health care facilities for providing safe, good-quality care in the context of climate change: health workforce; water, sanitation and health care waste; energy; and infrastructure, technology, products and processes *(4)*.

This checklist supports health care facility managers and other health workers in establishing a baseline with regard to climate change resilience in health care facilities. The checklist should be used to inform the design of interventions to strengthen overall resilience of health care facilities to climate change and to address iterative vulnerability assessments in health care facilities.

To assess the measurable risk to a health care facility, the checklist proposes a three-step approach for conducting a vulnerability assessment:

1. Identify the main climate hazards facing the facility. The presence of a hazard does not imply exposure, because adaptation measures can greatly reduce or eliminate harmful exposures and impacts. For the purpose of assessing a health care facility, it can be assumed that if a hazard is threatening the facility, it is because components of the facility and its operations are exposed.
2. Identify current vulnerabilities and the geographical location of the facilities and communities they serve.
3. Examine whether the four requirements for safe, good-quality care could be impacted by the hazards. It is important to identify whether different or stronger hazards associated with climate change or other factors may increase risk to the facility now or in the future, and to identify and prioritize adaptation measures.

STEP 3



CAPACITY ASSESSMENT
assess the capacity of health and health-relevant systems

Climate-sensitive health outcomes are among the current leading causes globally of morbidity and mortality. Every year there are millions of cases of undernutrition, climate-sensitive infectious diseases (e.g. diarrhoeal diseases, malaria, dengue), cardiovascular and respiratory diseases, psychological stress, injuries, disability and deaths due to extreme weather events.

A wide range of policies and programmes exists to control these health burdens. Despite this, many countries are underprepared for the health effects of current climate variability and experience damages and health system setbacks when health burdens increase, such as during heatwaves or epidemics.

In the overall frame of health systems, it is valuable to understand the effectiveness, strengths and weaknesses of these programmes under current conditions of climate variability and recent climate change. This assessment is needed to identify possible alterations to existing programmes and actions to increase capacity and address the additional health risks due to climate change.

Step 3A: identify the policies, programmes and infrastructure to manage current and future health outcomes

This step helps to determine whether existing policies and programmes are managing climate-related health risks effectively. It may include the following:

- Generate a list of all existing policies and programmes, within and external to the health sector, that affect the climate-sensitive health outcomes of interest.
- Evaluate the interventions (e.g. vector control) or components of programmes or policies that reduce vulnerability or increase coping capacity.
- Consider the effectiveness of current programmes and systems to manage climate-related morbidity and mortality, the quality of programme management and delivery (e.g. infectious disease monitoring and surveillance capacity), and whether existing measures, systems, resources and structures are sufficient for managing current and expected future risks.
- Consult members of the disaster risk reduction community or the responsible ministry at the national level to identify existing information and to facilitate understanding of health sector vulnerability to climate hazards.
- Review preparedness and response plans for situations such as storms, floods, droughts, heatwaves, wildfires and sea-level rise.
- Identify whether early warning systems exist and are used to anticipate and notify communities and health care facilities of potentially hazardous conditions, including outbreaks of climate-sensitive diseases.
- Gather information about the state of current health sector infrastructure and service delivery that demonstrates their ability to cope in major emergencies.

Step 3B: assess the current capacity of the health system to address the risks of climate-sensitive health outcomes

When assessing the capacity of health systems to deal with climate-related shocks and stresses, it is recommended to include the required capacities related to the 10 components of the WHO Operational Framework for Building Climate-resilient Health Systems *(8)*. This assessment should be done for the specific climate change impacts (e.g. floods, increased water temperature) and the specific health outcomes of interest (e.g. cholera) or broader impacts (e.g. disruption of water and energy access in health care facilities).

In addition to the specific capacities related to climate-resilient health systems, the International Health Regulations may provide useful information, as Member States are required to develop minimum public health capacities to implement these regulations *(63)*.

The resilience of health system to address climate-related risks depends on the functioning of the health system as a whole. Few health policies and programmes are tailored to take into consideration weather conditions and seasonal trends, current climate variability or recent climate change. Most, such as surveillance and disease control programmes, were designed assuming a stable climate and rarely consider weather and climate information.

The institutions that administer health policies and programmes may have structures that enhance or restrict adaptive management, which affects their flexibility to integrate new information and respond to new conditions. As climate change accelerates, policies and programmes will need to be modified to explicitly incorporate consideration of climate change.

Core health system components such as governance, financing, workforce management, information and communication management, and health service delivery will influence the capacity of actors to reduce climate-related health risks. These aspects should be considered to ensure climate risk management measures are integrated with the health system, and are adequately protective, cost-efficient and responsive to different needs in a changing climate.

Understanding the strengths and weaknesses of the health system and specific programmes to respond to changes and shocks is of critical importance to plan modifications and transformative actions needed to increase health system capacity and resilience.

Within a health system, the Ministry of Health, nongovernmental organizations, private-sector actors and others have individual or joint responsibility for managing climate-sensitive health outcomes. For example, the Ministry of Health typically has responsibility for vector-borne disease surveillance and control programmes. Other programmes, such as disaster risk reduction and emergency management, may be joint activities across ministries (e.g. health, environment) and include nongovernmental organizations and local organizations (e.g. Red Crescent, Red Cross).

Representatives from all relevant organizations and institutions should be consulted to find out what is working well, what could be improved, and the capacity of programmes to address possible increases in the incidence or changes in seasonality or the geographical range of the health outcomes of concern.

It is important to account for planned changes to existing policies and programmes in projections, and any changes expected in levels of health-sector financing. Ministries of health generally have 5- and 10-year plans that prioritize areas of investment for health promotion and protection. These plans detail proposed changes that could affect the coverage and effectiveness of health programmes. Taking account of proposed changes is necessary when developing adaptation plans.

Most V&A assessments will focus either on specific climate-sensitive health outcomes or on impacts on health systems or facilities, and corresponding main issues to consider, including:

- health outcomes related to extreme weather events:
  - early warning systems and emergency response plans;
  - programmes to monitor adverse health outcomes during and after extreme weather events;
  - educational programmes for individuals, communities, responders and health care workers on the risks of and appropriate responses to extreme weather events;
  - cross-sectoral management of disaster risk reduction activities;
- vector-borne, rodent-borne and zoonotic diseases:
  - early warning systems;
  - surveillance and monitoring programmes for malaria and other vector-borne and zoonotic diseases;
  - maternal and child health programmes, including vaccination campaigns;
  - integrated vector management and environmental hygiene programmes;
  - educational programmes for individuals, communities and health care workers on identifying and treating diseases;
- water- and foodborne diseases:
  - regulations to control water- and foodborne diseases and contaminants;
  - programmes to increase access to and use of safe water in sufficient quantities and improved sanitation;
  - surveillance and monitoring programmes for water- and foodborne diseases;
  - educational programmes on food handling and safety;
  - water quality regulations;
  - climate-resilient water safety plans and sanitation safety plans;
- health outcomes related to air quality:
  - programmes to alert the population and health workers on days with poor air quality or fires, and appropriate personal protection measures;
  - monitoring programmes for air quality and its health consequences;
  - educational programmes for individuals, communities and health care workers on the risks of poor air quality and appropriate protection measures to adopt;
- malnutrition:
  - monitoring programmes for malnutrition in vulnerable populations;
  - programmes to support local food production and sustainable food sources;
  - emergency response plans to increase food and nutrition security;
  - nutrition education for individuals and communities;
- health care facilities:
  - health workforce;
  - reliability of water, sanitation and waste management systems;
  - reliability of energy sources;
  - safety and reliability of infrastructure, technologies, products and services.

The following questions can be used to assess the capacity and performance of health systems, current programmes and health care facilities:

- What is the management structure for the programme? This information is necessary to identify constraints and opportunities for modifying the programme.
- What human and financial resources are available? Cataloguing these assets is important when planning additional policies and programmes. Do they have enough knowledge on how to assess and address health impacts from climate change?
- How effective is the programme in controlling the current health burden? Less than optimal effectiveness may be the result of limited human and financial resources, limited laboratory and material supplies, limited coordination among partners, administrative inefficiencies, or other factors. Addressing this question should include evaluations of overall effectiveness, particularly of programmes serving vulnerable populations and subnational regions.
- How robust are core health system functions (e.g. human resource planning, disease surveillance, emergency preparedness and response) to extreme weather events? This is important for identifying existing gaps that may be exacerbated by a more variable climate.
- How might proposed changes to the programme in the next 5–10 years affect its ability to address relevant climate-sensitive health outcomes?

There are many metrics that can be used to measure the effectiveness of these programmes, including trends in reductions in the number of injuries, illnesses or deaths; coverage of geographical regions and vulnerable groups included in the V&A assessments; and the extent to which planned changes are likely to increase the ability of the programme or activity to further reduce current health burdens.

Tools and checklists can help identify programmatic strengths and weaknesses, such as those for evaluating disaster and emergency preparedness.

Countries and users interested in assessing climate change vulnerability in health care facilities should refer to the *WHO guidance for climate resilient and environmentally sustainable health care facilities (21)* and *Checklists to assess vulnerabilities in health care facilities in the context of climate change (4)*. These focus on the four fundamental requirements for providing safe and good-quality care in the context of climate change (health workforce; water, sanitation, hygiene and health care waste management; sustainable energy services; and infrastructure, technologies and products).

Step 3C: assess the current actions of other sectors that affect the risks of climate-sensitive health outcomes

Depending on the scope of the V&A assessment, it can be important to assess the extent to which policies and programmes in other sectors effectively manage the upstream drivers of health and contribute to the achievement of health co-benefits (e.g. cleaner air from reduced air pollution) or greater equity in society.

Examples include building design and infrastructure codes and standards, and laws and regulations on land use and land-use planning when evaluating preparedness for health outcomes related to extreme weather events.

Watershed protection laws are important in the control of water- and foodborne diseases but are not under the control of the Ministry of Health. Similarly, air-quality regulations to control emissions of pollutants from traffic, industry and other sources should be assessed for the extent to which they consider the impacts of future weather patterns on air quality.

Engaging a wide range of stakeholders will help to ensure all relevant policies, programmes and interventions outside the health system are assessed.

Box 4. Co-occurring epidemics of chikungunya, Zika and dengue in the Caribbean

Chikungunya is a viral disease endemic to sub-Saharan Africa and South-East Asia transmitted by the bite of the *Aedes* mosquito, which is active during the day.

Before 2013, local transmission of chikungunya was limited to the eastern hemisphere. In December 2013, local transmission of chikungunya was first reported on the Caribbean island of Saint Martin *(64)*. By the end of 2014, all 28 Caribbean small island developing States had reported autochthonous transmission of chikungunya, with 16 305 laboratory-confirmed cases and over 1 million suspected cases across the Americas by the end of 2014 *(65)*.

By mid-2016, over 2.9 million suspected and confirmed cases of chikungunya had been reported in the Americas, placing an immense burden on health systems of the region. As of 2019, 911 842 confirmed cases of chikungunya had occurred in the Americas since its emergence in 2013 *(66)*.

In addition to the burden placed on Caribbean health systems, countries experienced economic losses from reductions in worker productivity caused by the outbreaks. Trinidad and Tobago lost an estimated US$ 13.2 million from having 10% of the population infected with chikungunya; and 81% of companies in Jamaica reported having workers affected by the virus, resulting in over US$ 60 million in losses *(67)*.

Before and parallel to the chikungunya outbreak, the Americas were experiencing increasing cases of dengue, a febrile disease also transmitted by the *Aedes* mosquito. Approximately 186 050 cases of dengue were reported in the Caribbean from 2013 to 2019. In 2019 alone, the Americas reported over 3 million cases of dengue, the most ever reported *(66)*.

Dengue has caused a significant economic burden for the Caribbean. Dengue illness cost estimates for the Caribbean are around US$ 321 million annually *(68)*.

Less than a year after the emergence of chikungunya, the Zika virus emerged in the Americas. Zika is also transmitted by *Aedes* mosquitoes. By 2016, most Caribbean small island developing States were reporting cases of Zika. News of the virus caused international panic and resulted in reduced tourism rates. This significantly impacted Caribbean economies, where tourism is a staple industry. By 2019, 143 237 cases of Zika had been reported in the Caribbean *(66)*.

The quick progression of the 2014 chikungunya outbreak was associated with the expanding geographical range of *Aedes* mosquitoes, a phenomenon thought to be a consequence of climate change and globalization *(69)*. Similar patterns are suggested for dengue and Zika *(70, 71)*.

Research into the biology of *Aedes* mosquitoes and the specific climatic conditions that would support autochthonous transmission is limited. Higher temperatures, such as those experienced under future climate change conditions, are thought to shorten the extrinsic incubation period – the time it takes for the vector to be infected with the virus from biting an infected person and then transmit it to another human *(69)*.

STEP 4

FUTURE RISK ASSESSMENT
qualitatively or quantitatively project the health risks of climate change

One of the goals of the V&A assessment is to describe how the risks of climate-sensitive health outcomes, including the most vulnerable populations and geographical regions, may change over coming decades under different assumptions of climate change. This information is needed so that health systems can effectively strengthen core functions and modify current health risk management activities to prepare for and respond to changes in the numbers of injuries, illnesses and deaths from climate-sensitive health outcomes.

The magnitude and pattern of health risks that may occur in a particular location will depend on the actual climate change experienced and the vulnerability of the community and subnational region, such as how key social and environmental determinants of health (e.g. demographics, urbanization, projections of economic and employment conditions, health system, food system, social networks, physical environment) could be affected by climate change and result in increased or decreased disease burdens.

Actual impacts will also be determined by the actions taken within and outside the health system to address the projected risks and vulnerabilities and prevent negative health outcomes. For example, the effectiveness of vector-borne disease surveillance and control programmes is determined partially by choices made in other sectors that affect access to safe water, and the ability of infrastructure to withstand flooding events.

Step 4A: describe how current health risks could change under diverse scenarios of climate change and development

The future is inherently uncertain. Therefore, the climate research community uses scenarios of possible futures to explore how risks could change under different assumptions of climate change and development.

Scenarios are composed of three basic elements: pathways of greenhouse gas emissions (without considering specific policies); different development pathways; and pathways of specific mitigation policies to reduce greenhouse gas emissions.

Projections of health risks generally rely on scenarios combining one or more pathways of greenhouse gas emissions (representative concentration pathways, RCPs) with one or more development pathways (shared socioeconomic pathways).

Four basic RCPs describe the evolution of greenhouse gas emissions throughout the twenty-first century. The RCPs include all greenhouse gases (not only carbon dioxide) and are expressed in terms of radiative forcing in watts per square metre (W/m^2), where watts are a measure of power, or how much additional energy is being added to the climate system.

RCPs range from 2.6 W/m^2 (about 490 ppm carbon dioxide equivalent in 2100) to 8.5 W/m^2 (about 1370 ppm carbon dioxide equivalent in 2100).

RCPs are used as inputs in climate models to project temperate change over the twenty-first century and beyond.

Climate projections used in a country's national communication to UNFCCC or other assessments should inform the estimated change in the burden of disease. For many parts of the world, climate change will increase local temperatures by 0.5 °C within 20 years. Warmer temperatures will then increase humidity and rainfall variability by about 10%, with most of that increase at the extremes of precipitation (e.g. more droughts and more floods).

RCPs are paired with appropriate shared socioeconomic pathways to take into account demographic change, economic growth, urbanization, and changes in other factors expected to influence the magnitude and pattern of risks. This provides a more realistic assessment of the future health risks posed by climate change.

Similar approaches were used before RCPs and shared socioeconomic pathways were published, such as the WHO Quantitative Risk Assessment *(33)*. The national climate change team may have developed scenarios that could be used for the V&A assessment.

It is useful to have scenarios that describe how a range of possible futures could unfold to better understand which uncertainties are important for research and decision-making. Using common scenarios can enhance comparisons across countries and across time. Scenario combinations could be used to show the range of possible developments of climate health impacts to identify whether climate impacts are driven more by climate or socioeconomic change.

Modelling is a complex undertaking requiring highly technical expertise and specific data inputs that take time and effort to acquire and analyse. The capacity to design and run models to project health risks can be developed through training and other mechanisms. A goal of the V&A assessment could be to build research capacity and increase the availability of models to project health impacts in future studies.

A simpler method is to use expert judgement to estimate how morbidity and mortality could be altered in the future due to the interactions of climate and non-climate factors. The following actions can help to obtain relevant information to construct this estimate:

- Host an expert meeting with the goal of describing several possible climate change scenarios and development pathways over the next few decades, taking into consideration planned changes in policies and programmes. This meeting should include modelling experts to obtain quantitative projections of climate and non-climate health drivers.
- Summarize regional and national climate projections and consider using projections that cover a wider range of possible futures by creating scenarios that combine development pathways with climate change projections.
- Determine whether quantitative estimates are possible, or whether a qualitative approach will be used.
- Work with focus groups or expert interviews to estimate possible implications for health risks in the future.

Projected health risks will have several sources of uncertainty. It is necessary to describe climate scenario and development pathway uncertainties in the assessment report and the extent to which they could influence findings about projected health risks.

Step 4B: estimate the possible additional burden of adverse health outcomes due to climate change

Understanding current and future vulnerabilities provides a baseline to which can be added the additional health burden due to climate change. This additional burden can be estimated qualitatively or quantitatively, depending on the data, resources and capacity available. Quantitative methods can be used for modelling relationships and extrapolating future burdens and risks from climate variability and change. Qualitatively, expert judgement and development of qualitative scenarios can be used to estimate future impacts.

Qualitative approaches

Qualitative analysis can be used to estimate changes over shorter time periods. For example, in rural areas in tropical countries with limited access to safe water and adequate sanitation, increasing average temperatures and precipitation variability will likely increase the burden of diarrhoeal diseases. The implication of this projected increase for the control of these diseases depends on the effectiveness and geographical coverage of control programmes.

In an example that takes planned adaptations into account, assume *n* cases of malaria are currently occurring in a particular geographical region. A new control programme is planned to reduce the burden of malaria by 20%, taking into account population growth, distribution of insecticide-treated bednets, and integrated vector management programmes. The future burden of malaria would reasonably be expected to be between the current burden and 80% of the current burden over the next decade or so, without considering climate change. Higher temperatures with climate change are projected to increase the number of cases by 10%, resulting in a smaller decrease in the numbers of cases of malaria than suggested when considering the effectiveness of the control programme alone.

When possible, future health burdens should be estimated at the scale (community, city, subnational region) where policies and programmes are implemented.

Quantitative approaches

Models are generally used to quantitatively estimate how the health risks of climate change could increase or decrease over time, particularly over decades or longer. Health models can explore the range of potential impacts of a changing climate in the context of other drivers of population health to better understand where, when and in what population groups negative health outcomes could occur.

Risk managers can use the identification of vulnerable populations and subnational regions to facilitate development and implementation of adaptation policies and programmes to reduce projected negative impacts. Policy-makers can use model results to “climate-proof” decisions, to better ensure that the policies and programmes implemented will be resilient to changing weather patterns and trends. Models developed for other sectors, such as emergency management and agriculture, may be used as the basis for, or in addition to, health models to facilitate understanding of how vulnerability to health impacts might change.

Box 5. Qualitative and quantitative assessments of future health impacts of climate change

Qualitative assessments: using expert judgement

During the assessment of health risks and responses in the first Portuguese national assessment, a qualitative assessment was conducted of the possible impacts of climate change on vector-borne diseases, including malaria, West Nile virus, schistosomiasis, Mediterranean spotted fever and leishmaniasis; the latter two are endemic to Portugal. Although human cases of vector-borne diseases have generally decreased over recent decades, many competent vectors were still present in Portugal.

Disease transmission risk was categorized qualitatively based on vector distribution and abundance and pathogen prevalence. Four brief storylines of plausible future conditions were constructed based on current climate and projected climate change, and assuming either the current distribution and prevalence of vectors and parasites, or the introduction of focal populations of parasite infected vectors.

These storylines were discussed with experts to estimate transmission risk levels. For Mediterranean spotted fever, the risk of transmission was high under all storylines, suggesting that climate change is likely to have a limited impact.

For the other diseases, the risk level varied across the storylines. The risk of leishmaniasis varied from medium (current climate) to high (both climate change storylines). The risk of schistosomiasis varied from very low (current climate and current vector distributions) to medium (climate change and focal introduction).

The information provided from the qualitative assessment was sufficient for health policy-makers to begin planning for changes in the burden of climate-sensitive infectious diseases.

Quantitative risk assessment: WHO estimates of future mortality

The WHO Quantitative Risk Assessment projected cause-specific mortality in 2030 and 2050 for heat-related mortality in older adults, mortality associated with coastal flooding, mortality associated with diarrheal diseases in children aged under 15 years, malaria, dengue and undernutrition.

The projections considered a medium-high emissions scenario and three development futures (base case, high economic growth, no growth). The counterfactual was a future world with population growth and economic development, but with baseline (1961–1990) climate.

The annual mortality burden was projected for world regions. Overall, climate change was projected to have substantial adverse impacts on future mortality, with 250 000 additional deaths per year between 2030 and 2050, even considering only a subset of the expected health effects, under optimistic scenarios of future socioeconomic development and with adaptation.

These projections can be used in national V&A assessments or can be modified based on expert judgement when, for example, the national situation is expected to be better or worse than the region.

Source: based on Casimiro E, Calheiros J, Duarte Santos F, Kovats S. National assessment of human health effects of climate change in Portugal: approach and key findings. Environ Health Perspect. 2006;114:1950–1956; and Hales S, Kovats S. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization; 2014.

STEP 5

ADAPTATION ASSESSMENT
identify and prioritize policies, programmes and actions to address current and projected health risks

This step identifies and prioritizes potential modifications needed to current and planned, or proposes new, policies and programmes within the building blocks of health systems to prevent, prepare for and respond to current and emerging health risks associated with possibly more severe climate change.

It should focus on assessing which health concerns merit the greatest resource allocation, with the largest possible benefits.

The outcome should be a list of high-priority modifications to the building blocks of a climate-resilient health system that are recommended for implementation over the short, medium and longer term. The list can also distinguish which modifications are considered urgent and immediate, and which will likely be needed in the medium term.

Examples of adaptation options include:

- strengthening primary health care services, integrated with social care and environmental health services;
- strengthening early warning systems, disaster risk management and integrated disease surveillance programmes;
- mainstreaming climate change into health policies and programmes;
- improving infrastructure and including climate change and health considerations into built environment initiatives;
- strengthening dialogue with stakeholders to inform policies, programmes and proactive practices to protect health;
- conducting innovative research to integrate equity and environmental sustainability into health policies and programmes;
- building capacity and improving training of health workforce and communities on adaptation strategies;
- improving integration, planning and implementation of practices across sectors (inter- and intrasectoral).

WHO has further guidance on adaptation planning *(8, 12, 13)*.

Box 6. Climate change and health vulnerability and adaptation assessments in the WHO Eastern Mediterranean Region

In 2008 the WHO Eastern Mediterranean Regional Committee urged its Member States to take action to address climate change and its health impacts. Significant focus was placed on capacity-building of the health sector to undertake assessment of health vulnerability to climate change to proactively prepare and address the health impacts of climate change.

In 2017 the Regional Committee re-emphasized the importance of assessing health vulnerability and strengthening the preparedness of health systems to cope with the changing burden of climate-sensitive diseases as a pillar of its regional framework of action. Since then, several countries in the region have implemented V&A assessments; three examples are given here.

Jordan, represented by its Ministry of Health, has been an active member of the Regional Committee since the beginning of climate change action. In 2008 the Ministry of Health developed its National Climate Change and Health Adaptation Strategy and Plan of Action, with technical and financial assistance from WHO and the Regional Centre for Environmental Health Action. In 2012 an updated version of the Strategy and Plan of Action was issued, with a comprehensive assessment of V&A capacities on different climate-sensitive health issues over the next 25–30 years.

Morocco issued a vulnerability analysis and adaptation strategy and plan of action in 2010. This was the grounding for the 2017 adaptation of the health sector to climate change plan of action. In addition to the eight different intervention areas in the 2010 version, the 2017 version included updated areas of assessment in light of new climate data and expected effects. Future work in Morocco will include improved epidemiological surveillance and awareness-raising actions for vulnerable populations, and increased integration of risk assessment and climate change adaptation when planning and programming policies.

The Islamic Republic of Iran, a country active in climate change and health work, is aiming to finalize a V&A assessment in 2021. Ongoing efforts include initiating a national programme on climate change and health vulnerability assessment and action, and supporting a climate-based assessment of health in different fields, including communicable diseases, noncommunicable diseases, disasters, air pollution, water pollution, food safety and occupational health.

Step 5A: identify additional population health and health care policies and programmes to prevent or reduce projected health burdens

Health officials and stakeholders involved in the design and operation of current programmes are typically best placed to identify appropriate modifications because they have the detailed understanding of what works well and why, where improvements are needed, and the issues that should be addressed for effective implementation of the policies and programmes, including human and financial resources, and approaches to overcome any institutional barriers.

This information can be collected by:

- conducting a literature review (e.g. peer-reviewed publications, grey literature) to identify promising adaptation options;
- holding discussions through workshops, interviews or community meetings with health authorities, scientists, practitioners, additional stakeholders and officials outside the health sector about the adaptations they have implemented, their effectiveness and possible new actions.

The design, planning and implementation of policies and programmes in a specific geographical region take place within the context of slowly changing factors that are partial determinants of the extent of impacts experienced and that are specific to a subnational region or population. Examples include population and subnational regional vulnerabilities, social and cultural factors, and the status of the public health infrastructure and health care services. Health and other ministries and organizations will have information on these contextual factors.

Successful efforts to reduce the impacts of climate change on health will require actions to address underlying vulnerabilities within and outside the formal health sector, such as improving the resilience of health care facilities and services, reducing socioeconomic disparities, and providing equity in access to services for vulnerable populations. Addressing these underlying vulnerabilities and strengthening health systems resilience are of high priority in managing the health risks of climate change.

Many suggested interventions will likely be incremental policy changes to address weaknesses in current policies and programmes with respect to managing climate change-related risks. For example, the level of success of programmes designed to prevent foodborne diseases such as salmonella varies across high-income countries *(72, 73)*.

Incorporating climate change into these policies and programmes requires an understanding of their current effectiveness and how that could change with climate change (changes in disease burdens projected in Step 4). For example, the risk of salmonella food poisoning may increase with warmer ambient temperatures that favour the growth and spread of the bacteria; therefore, enhancing current salmonella control programmes and improving measures to encourage adherence to proper food-handling guidelines can lower current and future disease burdens, even with future changes in climate. Training of the health workforce will likely be needed to ensure effective implementation of such changes.

Modifications will likely be needed to surveillance and response activities, such as adopting different methods (e.g. syndromic surveillance) or expanding current programmes to areas where changes in weather and climate may facilitate the spread or increase the length of seasonal transmission of vector-, food- and waterborne diseases. This means considering when and where to modify surveillance programmes to monitor for the appearance of an infectious disease or its vector.

Achieving this will generally require financing, training and education of the health workforce. A challenge in many low-income countries is meeting the ongoing financial and human capital commitments needed for monitoring and surveillance programmes. Because many bilateral and international donors and organizations are using the results of V&A assessments to set priorities for additional funding, highlighting the implications of climate change for surveillance and response programmes may offer a possibility for obtaining resources.

For some climate-sensitive health outcomes, data collected from surveillance programmes can be the basis of early warning systems to reduce the magnitude or extent of a disease outbreak *(73, 74)*. Early warning systems use information on associations between a health outcome (e.g. morbidity and mortality from infectious diseases or exposure to extreme heat events) and environmental drivers (e.g. temperature and precipitation patterns) to provide warnings of when health burdens are forecast to increase.

These warnings can be days to months before an anticipated outbreak. The warnings can be used to initiate prevention programmes and public health messaging to reduce the overall health burden. If designed appropriately, early warning systems can be adjusted to incorporate projected increases in climate variability and change, thus preventing increasing burdens of adverse health outcomes.

Design, planning and implementation of early warning systems may require health and climate research, and financing for the additional service delivery.

Policies and programmes may be modified to consider situations where thresholds could be crossed (e.g. a vector-borne disease changing its geographical range), leading to large increases in negative health outcomes. Thresholds can be crossed because some aspect of disease transmission is close to its boundary conditions (e.g. removal of temperature constraints on mosquito survival with warmer temperatures).

Policies and programmes should explicitly incorporate how to prepare for the possibility that climate change will bring new risks, such as an increase in the frequency and intensity of heatwaves and other extreme weather and climate events. One approach is to conduct stress tests to determine how well the health system could manage events and disease introductions outside the current range of experience *(75)*.

Step 5B: prioritize health system adaptation policies and programmes to reduce likely future health burdens

There is no such thing as absolute safety, and policy- and decision-makers seek to understand the question of how safe is "safe enough"? The answer depends on the criteria established and the social norms in a given society. A small elevation in risk may be manageable within existing policies and programmes, and decision-makers should focus on approaches to manage larger increases in risk that are expected to occur with climate change.

The actual criteria used to set priorities will depend on the goals of the assessment (e.g. reducing vulnerability to heatwaves or increasing resilience to flooding events), the current Ministry of Health priorities, the population health impacts of recent extreme weather and climate events, and other factors. There are multiple approaches to prioritization, including basing the prioritization on:

- the number of additional cases of climate-sensitive disease, injuries, illnesses and deaths due to, for example, recent changes in temperature or precipitation;
- a comparative risk assessment to evaluate whether alternative interventions have comparable levels of risk; comparative risk refers to the notion that all risks should be approximately equal to each other following risk-reduction strategies;
- a benefit–risk assessment to evaluate the costs and benefits of risk reduction;
- a multicriteria assessment to rank how well each adaptation measure meets established criteria, such as effectiveness, feasibility or cost *(76)*; an advantage of this is that criteria do not need to be measured in common metrics, and criteria can be weighted to reflect relative importance.

Regardless of the method used, the costs of the adaptation programme should be estimated. This includes operation, maintenance, administration, staffing, equipment and other requirements.

Benefit–risk assessments compare the benefits to be gained from a particular policy or programme with the amount of risk reduction to be achieved, taking into consideration the projected risks of climate change. The benefits of the proposed programme should exceed the costs. The flexibility of the programme to be modified in a changing climate must be considered.

One assumption is that society should not invest in policies and programmes for which there will be little gain. This is particularly relevant for risks that have been reduced to a fairly low level and where climate change is not projected to materially affect the level of risk. Given that risks cannot be reduced to zero, policy-makers need to decide whether the effort required for risk reduction is an appropriate allocation of public health resources.

Benefit–risk assessments may use cost–effectiveness or benefit–cost analyses. Cost–effectiveness analyses typically involve comparing the relative costs of different policies and programmes that achieve the same or similar outcomes. Benefit–cost analyses require expression of benefits (e.g. avoided adverse

impacts from an adaptation measure) and costs in a common metric to allow benefits and costs to be compared to estimate whether the benefits exceed the costs. This is often done by expressing benefits in monetary terms. This is not straightforward for benefits that are not bought and sold in markets, such as illness and human life *(77)*.

Multicriteria analysis is a type of decision tool particularly useful in cases where a single-criterion approach such as cost–benefit analysis falls short, especially where significant environmental and social impacts cannot be assigned monetary values. Multicriteria analysis allows decision-makers to include a full range of social, environmental, technical, economic and financial criteria *(78)*. An advantage of multicriteria assessment is that criteria do not need to be measured in common metrics, and criteria can be weighted to reflect relative importance.

Multiple criteria can be used to set priorities, commonly including significance, benefits, effectiveness, costs and feasibility. There may be other criteria of importance to stakeholders, such as maintaining cultural and social institutions. The process should involve relevant stakeholders, who may identify additional criteria to apply, such as the extent to which proposed programmes reduce social inequities.

Step 5C: identify human and financial resources for implementation of identified policies and programmes and potential challenges to be addressed

For each high-priority policy and programme identified, it is helpful for policy-makers to have a brief description of the requirements that would be needed for implementation of actions over the expected timeframe. Useful elements to describe include the estimated benefits and effectiveness for reducing current and future vulnerability to the health risk, the resources required, feasibility, and constraints to implementation.

Health system resources needed for the implementation of climate-informed policy and programmes to increase resilience and reduce risks should consider the aspects given in Table 3.

Table 3. Health system resources structured around the components of the World Health Organization Operational Framework for Building Climate Resilient Health Systems

Financing	Adequate funds are needed to maintain core health system functions, including in a crisis. In addition to funds for core health and public health services (water, sanitation, environmental hygiene, disaster and health emergency preparedness), it is necessary to plan for insurance or replacement costs for health facilities and equipment lost or damaged due to extreme weather events.
Health workforce	A well-performing health workforce is needed to achieve the best health outcomes possible. This includes sufficient numbers and a mix of qualified, competent and productive staff to deliver health promotion and protection and take account of location and seasonal demands for staff (e.g. cyclone season may demand higher numbers of staff in coastal zones). It also includes capacity development to build skills, ranging from health policy and management to newer disciplines such as application of meteorological information to health policy.
Service delivery	Health service delivery should combine inputs to provide effective, safe, good-quality health interventions in an efficient and equitable manner. Health services may need to prepare for shifts or additional burdens, requiring revisions of organizational and management processes and the timing and location of service delivery.
Essential medical products and technologies	A range of medical products and technologies is needed to protect populations from climate-sensitive health conditions. These include medical equipment and supplies for emergency response, permanent and emergency health facility services, and technologies in health-supporting sectors such as water, sanitation and environmental hygiene.
Health information systems	Health information systems that ensure the production and application of reliable and timely information on health determinants, health systems performance and health status are essential for managing climate-related health risks. Resources include data collection, analysis, communication and reporting, hazard and vulnerability assessments, early warning systems, overall information infrastructure (hardware and networks), and coordination mechanisms to link relevant information (e.g. from meteorological or hydrological services) to inform health decisions.
Leadership and governance	Political will to take action to address the health risks of climate change is essential. This includes developing strategic policy frameworks, implementing adaptation plans, and ensuring effective monitoring and management. It is necessary to build coalitions between relevant sectors and partners, including national and international climate policy mechanisms. Public advocacy and risk communication are needed to ensure public understanding and support. The delivery of public health depends on individual and community use of public health services and acquisition of public health education. Partnerships across stakeholder groups and levels are necessary to engage members of society as actors in their own health protection.

Source: Operational framework for building climate resilient health systems. Geneva: World Health Organization; 2015.

Modifications of current policies and programmes to address climate change should consider approaches to ensure active and continued stakeholder engagement and financial sustainability; address changes in climate and population and health system vulnerability over time; ensure appropriate information and communication systems; and incorporate uncertainties in climate projections and development pathways into any modifications.

Typical barriers to effective risk management include lack of leadership or political will; limited human and financial resources; limited or incorrect information and communication; lack of authority or jurisdiction to act; lack of coordination and partnerships; and social, political and cultural factors. There may also be barriers internal to decision-makers, such as attitudes and beliefs. Options for overcoming barriers should be identified, evaluated and incorporated into adaptive management processes.

It is helpful to have a summary of the costs and benefits of each programme that will be modified to incorporate climate change, including how the programme is planned to reduce the burden of climate-sensitive health outcomes, the possible consequences for population health if the programme is not implemented, and estimates of the costs over time for implementation and continued support of the programme.

In deciding which policies and programmes are possible to implement now or in the future, based on existing resource constraints (technological, human, financial), it is useful to have a prioritized list of options from which policy-makers can choose. Key considerations when prioritizing options are the current morbidity and mortality from the health outcome of concern, projections of future health impacts, and how well risks are managed with current policies and programmes.

The criteria used to identify the priorities should be explicitly described, such as with the following questions:

- Is the option technically feasible?
- Is the option effective in reducing health risks?
- Is the option socially acceptable?
- What are the expected positive or negative consequences of this option? (If negative consequences are likely, consider how best to monitor them and pre-design corrective actions. The best options reduce negative health outcomes and improve the natural and built environment.)
- What are the costs versus benefits now and in the future?
- What are the required human and financial resources and financing options?
- Are adequate financial resources available for implementing and sustaining the option?
- Are adequate human and technological resources available for implementing and sustaining the option?
- Does the option have positive effects on health systems and health infrastructure resilience?
- Does the option respond to expected changes under a specific emission scenario or covering several potential scenarios?
- When is the option expected to show a positive impact? Is the timing sufficient to prevent the expected adverse health impacts of the climate hazards?
- Does the option contribute to the reduction of greenhouse gases?

For each adaptation option, list possible constraints or barriers to implementation by considering technological, human and financial resources required; the expected timeframe for implementation; and other possible implementation requirements.

Differentiate constraints (i.e. those that can be overcome) from limits (i.e. no adaptation option is possible, or the available options are too difficult or expensive to implement). Working with officials from other sectors can help overcome adaptation barriers. These officials should be included in discussions about adaptation constraints to identify non-health sector opportunities to move forward with the adaptation options and reduce risks from climate change.

Step 5D: estimate the costs of action and inaction

Decision-makers are interested in the economic costs of impacts of climate change on health, and the costs to modify and maintain policies and programmes to adapt to or avert these impacts.

Estimates of the costs of current impacts and projected risks without adding additional transformative policies and programmes (e.g. cost of inaction) and of the costs of policies and programmes to address these risks (e.g. cost of action) can inform resource decisions.

The costs of inaction ("damage costs") include costs of treating additional health burdens resulting from climate change, costs associated with premature mortality, and other non-health care costs associated with illness, such as time and costs of informal caregivers and lost productivity time.

The costs of action to modify policies and programmes include all health promotion, preventive and curative interventions, including surveillance, monitoring, early warning systems and emergency response plans. Obtaining cost figures may be challenging, so estimates can be used to understand the rough order of magnitude of costs. When it is not possible to do these estimates directly, estimates can be obtained from the scientific literature or existing government economic analyses on related or similar policies and programmes.

Once decision-makers are convinced they have to act, they need to know the costs of alternative courses of action and their relative merits (e.g. effectiveness and efficiency) to decide on a course of action. Many health actions are "low regret" measures that are relevant even in the absence of climate change hazards or under high uncertainty about the magnitude and pattern of climate change because they aim to strengthen health system resilience overall.

Given that health policies and programmes are rarely 100% effective, there are likely to be excess disease burdens, or residual health damages, from non-avoided impacts. This may be because some health impacts are very difficult to mitigate (e.g. from natural disasters) or, more often, the marginal costs of avoiding some impacts are higher than households or governments are willing to pay. These residual health damages can be estimated and valued.

There is high uncertainty when estimating future costs in a changing environment. A simple approach to estimating the costs of adaptation is to estimate current or future cases of a health outcome attributable to climate change (with or without adaptation programmes) and to multiply that by the cost of prevention or, for non-avoided cases, the cost of treatment.

It should be noted that because of the adaptation deficit (i.e. countries are underprepared for current climate conditions and even less for future climate change hazards), in many communities, subnational regions and nations, climate change-motivated investments in improving health-sector policies have the potential to address the burden of disease not attributed to climate change – that is, under certain conditions, using adaptation funds to strengthen policies and response capacity can lead to net health gains.

The cost–effectiveness of individual or combined programmes can be assessed, providing estimates of the cost per case or death averted, or as the cost–benefit ratio, when health and other benefits are valued in monetary terms. Cost–effectiveness guidance is available *(79, 80)*.

Tools are available for costing specific diseases such as malaria *(81)* and water and sanitation *(82)*. The Carbon Reduction Benefits on Health (CaRBonH) calculation tool allows quantification of the physical and economic consequences for human health achieved through improvements in country-level air quality from domestic carbon reductions *(83)*.

Step 5E: identify actions to reduce the potential health risks and maximize health co-benefits of adaptation and of greenhouse gas emission mitigation policies and programmes implemented in other sectors

Climate change adaptation and greenhouse gas mitigation decisions taken in other sectors can have important implications for population health. Health officials must engage with these sectors to identify possible health consequences from adaptation and mitigation plans, and to identify and recommend actions for minimizing health risks and maximizing any potential health gains.

For example, changes in water conservation practices can potentially cause resurgence of diseases or create vector-breeding sites. Changes to industrial processes to reduce carbon dioxide emissions have the potential to impact human exposure to potentially hazardous materials, depending on the technology, the chemicals or other agents involved, and how they are implemented.

It is imperative that other sectors take into consideration potential health impacts. Public health officials must engage with other sectors to identify intentional and unintentional health consequences and work together to minimize risks and maximize possible health gains and co-benefits.

Most countries have climate change teams, often within the Ministry of the Environment, that coordinate climate change activities, including developing national communications and applications to international and bilateral donors for climate change funds. Health sector engagement with these programmes can facilitate the prioritization of adaptation and greenhouse gas mitigation choices that promote health.

Assessment of the possible health harms of actions taken in other sectors can be accomplished by an expert review of the policies proposed to determine the nature and magnitude of possible health impacts. These auxiliary health effects are generally unintended and can range from none to highly significant.

Assessment of possible health harms can be done within the framework of a health impacts assessment to identify where impacts are unlikely, minor or more significant. Such an evaluation would facilitate the design, planning and implementation of necessary additional programmes, including monitoring, to maximize benefits and to reduce potential likely and significant adverse effects.

Assessment of the health implications of decisions across multiple sectors can be supported by integrated settings-based approaches, such as the Healthy Cities process based on establishing priorities and strategic plans, soliciting political support, taking local action, and evaluating progress to meet community needs *(84)*.

The results of studies conducted by the health sector can provide valuable input into decisions on possible policies and programmes to reduce the risks of climate change.

For example, water shortages due to population growth, climate change and other factors are projected to affect 2.7–3.2 billion people by the 2050s *(85)*. Until the 2050s, population projections have a greater impact than differences in emission scenarios on the estimated number of people at risk. General programmes for increasing reliable access to safe water include increasing supply and decreasing demand. Some programmes are relatively simple, such as promoting Indigenous practices for sustainable water use, but others are expensive and complex, such as desalination.

A Cochrane Review of interventions to improve water quality from source to use to prevent diarrhoea concluded that household interventions are more effective than interventions at the water source *(86)*. This is because water users in many developing countries rely on self-provision, informal exchanges to obtain water, and local community institutions. Overall, diarrhoeal disease episodes can be reduced by 25% by improving water supply, 32% by improving sanitation, 45% by handwashing, and 39% by household water treatment and safe storage *(87)*.

Box 7. Adaptation and mitigation actions to enhance health equity: promising practices

Public health actors can leverage adaptation actions meant to protect health and the health co-benefits of mitigation efforts to strengthen determinants of health and promote health equity (45).

In Los Angeles in the United States of America, the BlueLA carshare programme combines efforts to reduce air pollution and mitigate greenhouse emissions associated with vehicle use with health equity objectives. BlueLA provides members with access to a fleet of electric vehicles, prioritizing service to disadvantaged communities, accounting for low-income residents in areas with high air pollution exposure. Memberships are provided to low-income residents at a discounted cost.

In the first year, 80 electric vehicles were introduced to the community, nearly 2000 residents registered for the programme, and 260 tonnes of carbon dioxide were avoided (88, 89).

In Nain in Canada, a collaborative adaptation initiative, *InosiKatigeKagiamik Illumi* (Healthy Homes in Nunatsiavut), involved the development of climate-resilient housing infrastructure designs that were culturally relevant, affordable and energy-efficient, and reduced the health impacts from overcrowded dwellings and mould.

The initiative included a community-driven housing design process where residents could share existing housing challenges (e.g. damage from permafrost melt, difficulties with heat retention, overcrowding, homelessness) and design preferences informed by important cultural values (e.g. large open living spaces for gathering, space to store hunting equipment, steel sink for cleaning fish and preparing sealskins) (90, 91).

STEP 6

SYNTHESIZE THE ASSESSMENT
as input into relevant climate change and health policies, plans and reporting mechanisms

The information generated in the previous steps should be synthesized and used as input to develop a climate change and health adaptation plan that supports the integration of climate change adaptation into existing health-related planning processes.

The plan should consider shorter and longer timescales and facilitate coordination and collaboration with other sectors to promote resilience and reduce risks to health.

The health adaptation plan does not have to be extensive but should provide sufficient information so that those not involved in its development can understand it and use it to implement the recommended actions.

In addition, the final step of conducting a V&A should develop the process by which the health risks of climate change and the climate resilience of health systems can be monitored and managed.

Step 6A: synthesize the knowledge and understanding gained as input into a health adaptation plan

As part of the V&A technical report, an executive summary and synthesis of key messages should be prepared to allow for more effective communication of the results to decision-makers who oversee the implementation of recommendations and to stakeholders.

Health authorities have disseminated the results of V&A assessments in many ways (e.g. social media, presentations to community groups, health sector planning and evaluation workshops) and using a variety of mechanisms (e.g. policy briefs, infographics, interactive web-based vulnerability maps, resilience case studies, videos, podcasts).

It is useful to ensure the results of the V&A assessment are included in relevant national climate change policy processes and reporting mechanisms, such as nationally determined contributions (NDCs), national communications and NAPs. The V&A assessment provides the key content to inform the development of HNAPs.

WHO has published guidance on developing HNAPs *(12, 13)* and recommendations for inputting into NDCs that recognize the importance of health and contribute to the achievement of positive health outcomes *(92)*.

Box 8. Role of vulnerability and adaptation assessments in the global climate change agenda

V&A assessments are essential for the implementation of the global climate change agenda and processes that include NAPs, nationally appropriate mitigation actions (NAMAs), NDCs and national communications.

National adaptation plan

The NAP process enables UNFCCC parties to formulate and implement NAPs as a means to identify and address medium- and long-term adaptation needs. Normally, NAPs integrate high-priority climate-sensitive sectors to provide an integral vision of the actions that will be taken by each sector.

In most cases, in addition to developing an overarching NAP, countries also develop sectoral plans. The section or chapter of a NAP dedicated to health, or the sectoral plan developed as part of the NAP process and led by the Ministry of Health, is known as the HNAP *(13)*.

Conducting a comprehensive health V&A assessment is essential for the NAP process, as the V&A assessment will identify the vulnerabilities (gaps, barriers, opportunities) and inform the high-priority actions included in the NAP, ensuring they are evidence-based.

The implementation of NAPs is time- and resource-intensive. Having an evidence-based NAP ensures resources are spent wisely on the areas most in need. The NAP process was created by UNFCCC to build on the existing national adaptation programmes of action process. As such, countries are requested to submit NAPs to UNFCCC as soon as possible.

Nationally appropriate mitigation actions

NAMAs are "any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative". They are diverse in scope. They may consist of a single action or a group of actions to help countries meet their mitigation goals. "They can be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus" *(93)*.

Accordingly, NAMAs can be focused on mitigation efforts within the health sector. Unfortunately, the majority of submitted NAMAs do not involve the health sector.

The evidence included in health V&A assessments can inform the submission of health-related NAMAs by identifying components in national health systems with high mitigation potential. In many instances, implementing NAMAs in the health sector may yield significant health co-benefits, helping countries to contribute to mitigation and adaptation goals with a single activity (e.g. increased adoption of renewable energy in health facilities reduces emissions while fostering climate resilience). Without the baseline data collected during a comprehensive health V&A assessment, many of these opportunities may be overlooked.

Nationally determined contributions

NDCs embody countries' commitments to reduce greenhouse gas emissions and adapt to the impacts of climate change. Countries are mandated to submit updated NDCs every five years to UNFCCC as part of the 2015 Paris Agreement.

Given their status as official government commitments, NDCs are frequently cited to large funding institutions such as the Green Climate Fund and the Global Environment Facility as evidence that countries are serious about responding to climate change. This is especially true when seeking funds for specific projects. As such, countries with ambitious NDCs, including evidence-based health adaptation commitments (informed by V&A assessments), are more likely to receive approval for funding in climate change and health activities.

In addition, the inclusion of health V&A assessment findings within an NDC demonstrates cohesiveness and communication between sectors in a given country, an absolute necessity for addressing the cross-cutting nature of climate change.

National communications

National communications are open-ended reporting documents submitted by countries to UNFCCC to show updated greenhouse gas inventories in addition to other topics. Countries frequently use national communications as an opportunity to highlight progress made on various mitigation and adaptation initiatives, such as the development of V&A assessments, NAPs, NDCs and NAMAs.

Similar to NDCs, commitments and actions mentioned in national communications are viewed by funding institutions as supporting evidence that a country is a strong candidate to receive funding. National communications that include health V&A assessment findings have a competitive edge in strengthening the health argument for climate action.

Step 6B: establish an iterative process for managing and monitoring the health risks of climate change and climate resilience of health systems

As the climate continues to change, it is important to proactively manage and monitor changes in health risks and the climate resilience of health systems. V&A assessments form an important part of creating a baseline that can be measured over time to detect changing conditions and emerging risks.

An iterative process for managing and monitoring health risks at population and health system levels from climate change is recommended and involves the following:

- Identify a lead agency to coordinate monitoring and reporting of changes in health risks.
- Recommend when the V&A assessment should be reviewed or repeated to examine how risks are changing or to identify new risks.
- Monitor changes in population vulnerability, the geographical range and temporal occurrence of health outcomes, and health system capacity.
- Consult with multidisciplinary national and regional partners and stakeholders.
- Communicate information about changing risks to communities, health professionals and decision-makers (noting that many communities have already observed these changes and the effect they have had in their lives).

A more comprehensive process is a climate change adaptation monitoring and evaluation (M&E) and learning system, which would help to determine:

- how the burden of climate-sensitive health outcomes and related vulnerabilities are changing over time;
- whether adaptation actions have achieved their desired results to increase resilience;
- whether resources were used effectively and efficiently, including through coordination and collaboration.

A well-designed M&E system and its corresponding indicators can track and report on progress towards improving the ability of communities and nations to prepare for and respond effectively to the health risks of a changing climate over time. It is expected that the Ministry of Health at the national or subnational level will have lead responsibility for the system.

The results of the V&A assessment will provide important input, including baseline information, to the design of the M&E system, particularly through the provision of indicators that can be used to:

- evaluate progress in reducing the burden of climate-sensitive health outcomes by tracking changes in the geographical range, seasonality and incidence;
- evaluate the effectiveness of adaptation measures or programmes by determining the extent they:
  - reduce the burden of a climate-sensitive health outcome;
  - reduce the risks associated with exposure to a climate-related hazard;
  - increase resilience to climate variability and change;
- monitor the capacity of individuals, communities and health systems at all levels to manage changing burdens of climate-sensitive health outcomes and increases in the frequency and intensity of extreme weather and climate events;
- facilitate the design of policies and decisions that provide the additional interventions needed to manage the risks of climate change in the coming decades;
- identify increases in the resilience of individuals, communities and health systems to manage future risks;
- identify important information gaps and knowledge needs to support adaptation efforts and the completion of the next V&A assessment.

There is no "one size fits all" set of indicators for climate change and health impacts, adaptation and health system resilience. Indicators should be developed based on the national and subnational needs, and the level of capacity to measure them regularly, including the available human and financial resources.

Individual steps of the V&A assessment, as described in the sections above, will use a number of indicators to help with gathering and analysing information – for example, about important demographic shifts that may increase vulnerability, changes in disease incidence and effectiveness of adaptation measures. An important starting point for developing the M&E system will be to draw upon these indicators and the existing information associated with them.

Based on the needs of decision-makers, the M&E approach may be supplemented with the example indicators shown in Tables 4–6. As much as possible, these data should be disaggregated by key variables (e.g. sex, age, ethnicity). Data sources include the Ministry of Health, the Ministry of the Environment, and other ministries or institutions.

Table 4. Examples of burden of disease and vulnerability indicators[a]

Indicator	Definition
Proportion of households exposed to extreme weather events	Proportion of households affected by floods, drought and storms per month
Proportion of communities vulnerable to extreme weather events	Proportion of communities classified as "highly vulnerable" to floods, drought and storms per year
Disaster mortality rate	Number of deaths due to disaster (flood, drought, storms) versus total number of disaster-affected people per year

[a] Data sources include th e Ministry of Health, the Ministry of the Environment, and other ministries or institutions.

Health adaptation and resilience

Programming that systematically considers climate change in public health activities, including efforts to prepare health systems, will make new demands on technical knowledge and capacities, require enhanced and novel surveillance, and necessitate engagement across all sectors where climate change-related impacts may affect human health (e.g. power generation and transmission). This mainstreaming of climate change into policies and programmes is supported by regular monitoring and surveillance activities and the translation of results into meaningful and timely information products for decision-makers.The need for specific types of information is likely to change over time. There should be a process for reviewing and modifying indicators as needs change because of development or because of changing risks in response to the magnitude and pattern of climate change. The process of undertaking regular V&A assessments provides the opportunity to update the indicators, but health authorities may wish to do this even between conducting these studies.

Measuring climate resilience in health systems is part of this process, and guidance is available to support countries in their efforts to assess progress towards measuring climate resilience in health systems *(94)*.

Table 5. Examples of health adaptation and resilience indicators[a]

Indicator	Definition
Existence of climate-resilient infrastructure in the health system	Number of health facilities that are “flood-proof” (out of total number of health facilities) per year
Extent of public awareness of and actions to address health risks of climate change	Number of climate change and health public awareness campaigns
Status of climate change integrated into financial planning for Ministry of Health	Climate change adaptation included in Ministry of Health budget
Status of development of technical guidelines for diagnosis, detection, control, prevention and treatment of vector-borne diseases associated with climate change	Number of updated guidelines and practices introduced into health care system
Access to safe water	Increase in percentage of population with access to protected water source per year
Effectiveness of enhancing early warning systems	Proportion of health care facilities reporting climate-sensitive health risk data on weekly basis

Leadership and governance

Indicators for leadership and governance are central to the health adaptation process. They need to consider that institutions, actors, governance and geographical units of analysis and action are not uniform, with some communities and ecosystems better able to cope with changing climate, vulnerabilities and capacities. A range of actors from national to local organizations and institutions is responsible for preparing for, responding to, coping with and recovering from impacts associated with climate variability and change.

[a] Data sources include th e Ministry of Health, the Ministry of the Environment, and other ministries or institutions.

Examples of indicators include:

- existence and effectiveness of collaborative mechanisms with other sectors, such as meteorological services, agriculture and water, to measure the extent to which departments and ministries are sharing data and coordinating efforts to manage risks that span sectors;
- extent of local, subnational and national government commitments to climate change adaptation, such as by incorporating adaptation strategies into development plans and budgets. Climate change adaptation is not only local. Most climate change impacts are indeed experienced locally, such as floods, reductions in crop yields, or spread of disease, but these localized impacts can have national and international ramifications that require action beyond the local level.

The growing risks from climate variability and change, and increasing interest from development partners, mean that many local actors are implementing adaption options designed by and for local human and natural systems, such as mangrove restoration to reduce the vulnerability of coastal communities to storm surges. Ideally, these should be embedded within national adaptation and development plans, to ensure the adaptation options implemented promote achieving national development objectives.

To facilitate climate resilience and sustainable development, systems-based approaches are needed that incorporate the interplay of local to national vulnerabilities and capacities, and local to national actors and institutions, as well as active engagement of the health sector with other sectors. Indicators measuring the effectiveness of health adaptation policies and programmes should include measures of the extent of coordination and collaboration across local to national, and sometimes international, organizations and institutions.

Table 6. Examples of indicators on leadership and governance[a]

Indicator	Definition
Development of climate change and health strategies and action plans	Number of climate change and health strategies and action plans completed
Effectiveness of cross-sector collaboration regarding climate change and health actions	Number and frequency of climate change and health working groups
Incorporation of climate and health into national adaptation plans, water safety plans, and infectious disease control programmes	Frequency of updates to national adaptation plans, water safety plans, and infectious disease control programmes to include sections on climate change and health risks

Information from the M&E system will help to build climate resilience and protect human health only if it is communicated to decision-makers, stakeholders and the public. A variety of mechanisms may be used to share and use the results, including:

- development of dedicated reports or briefings;
- inclusion in annual subnational and national state of health reports;
- disseminating the results of regular V&A assessments;
- inclusion in international and regional reports.

[a] Data sources include th e Ministry of Health, the Ministry of the Environment, and other ministries or institutions.

Conclusions

Conducting a V&A assessment is a similar process for all nations and regions. The goal remains to better understand how climate variability and climate change can affect health and increase risks today and in the future to better inform policies and programmes that can protect public health.

The context, structure and content of the assessment will vary, depending on local circumstances, socioeconomic conditions, legal and regulatory frameworks, and other factors that reflect local decision needs.

All policies and programmes identified to protect health through the V&A assessment process need to take into account the evolving social, economic, environmental and political contexts within which they will be implemented. Differences among communities and among nations will influence the structure and implementation of policies and programmes.

Local policy-making processes, institutions and available resources will influence the choices of which policies and programmes to implement to address the current and likely future health risks from climate change. For example, some communities and nations have vector-borne disease surveillance systems that legally require individuals to clean up vector breeding sites within their living areas, but most nations do not have this option for improving vector control.

The ability of a nation or community to identify and implement effective adaptation policies and programmes depends on a range of factors. Policy-makers and the public must have sufficient knowledge of the health risks from climate change and the range of responses needed to reduce current and projected adverse health impacts.

Once there is motivation for action, policy-makers need to know the magnitude of potential risks and identify a range of adaptation options (including their feasibility, benefits, acceptability, effectiveness and costs); the availability of resources and their distribution across the population; and the structure of critical institutions, including the allocation of decision-making authority. A carefully conducted assessment can be a major contribution to protecting health from climate change.

Managing the health risks of climate change involves an iterative management process that starts with assessing the current and likely future vulnerability of the target community or geographical region; qualitatively or quantitatively estimating the extent of future health burdens due to climate change; designing and implementing policies and programmes to reduce current and future health risks due to climate change; and then monitoring and evaluating these policies and programmes to identify necessary modifications.

Stakeholder engagement is integral to the process. At each step, there are opportunities to communicate findings to, and learn from, stakeholders, policy-makers, researchers and the public to enhance understanding of the health risks and impacts of climate change, and adaptation policies and programmes to address them.

The risks of climate change provide an opportunity and a challenge to the health sector to demonstrate leadership within and outside the sector on adaptation and mitigation strategies. Maximizing opportunities to engage with other sectors in designing climate resilient pathways would bring benefits to all.

References

1. Smith KR, Woodward A, Campbell-Lendrum D, et al. Human health: impacts, adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, et al., editors. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press; 2014 (https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf).
2. Haines A, Ebi K. The imperative for climate action to protect health. New Engl J Med. 2019;380:263–273.
3. Watts N, Amann M, Arnell N, et al. The 2020 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. Lancet. 2021;397(10 269):129–170.
4. Checklists to assess vulnerabilities in health care facilities in the context of climate change. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/checklists-vulnerabilities-health-care-facilities-climate-change).
5. Critical infrastructure including schools, health facilities, and roads threatened by the climate crisis. Geneva: United Nations Office for Disaster Risk Reduction; 2019 (https://www.undrr.org/news/critical-infrastructure-including-schools-health-facilities-and-roads-threatened-climate).
6. Hoegh-Guldberg O, Jacob D, Taylor M, et al. The human imperative of stabilizing global climate change at 1.5°C. Science. 2019;365:eaaw6974.
7. Ebi K, Hasegawa T, Hayes K, et al. Health risks of warming of 1.5 °C, 2 °C, and higher, above pre-industrial temperatures. Environ Res Lett. 2018;13:063007.
8. Operational framework for building climate resilient health systems. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/bitstream/handle/10665/189951/9789241565073_eng.pdf).
9. Matthews JBR. Annex I: glossary. In: Masson-Delmotte V, Zhai P, Pörtner H-O, et al., editors. Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above preindustrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: Intergovernmental Panel on Climate Change; 2018 (https://www.ipcc.ch/sr15/chapter/glossary/).
10. Haines A, McMichael AJ, Smith KR, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. Lancet. 2009;374:2104–2114.
11. Protecting health from climate change: connecting science, policy and people. Geneva: World Health Organization; 2009 (http://whqlibdoc.who.int/publications/2009/9789241598187_eng.pdf).
12. WHO guidance to protect health from climate change through health adaptation planning. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/bitstream/handle/10665/137383/9789241508001_eng.pdf?sequence=1).
13. Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/quality-criteria-health-national-adaptation-plans).
14. Ebi KL, Berry P, Campbell-Lendrum D, et al. Health system adaptation to climate variability and change. Rotterdam and Washington, DC: Global Center on Adaptation; 2019 (https://gca.org/wp-content/uploads/2020/12/HealthSystemAdaptationToClimateVariabilityandChange_0.pdf).

15. Ebi KL, Ogden NH, Semenza JC, Woodward A. Detecting and attributing health burdens to climate change. Environ Health Perspect. 2017;125(8):085004.

16. Zhu C, Kobayashi K, Loladze I, et al. Carbon dioxide (CO_2) levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries. Sci Adv. 2018;4(5):eaaq1012.

17. Springmann M, Mason-D'Croz D, Robinson S, et al. Global and regional health effects of future food production under climate change: a modelling study. Lancet. 2016;387(10 031):1937–1946.

18. Gasparrini A, Guo Y, Sera F, et al. Projections of temperature-related excess mortality under climate change scenarios. Lancet Planet Health. 2017;1(9):e360–e367.

19. Hallegatte S, Bangalore M, Bonzanigo L, et al. Shock waves: managing the impacts of climate change on poverty. Washington, DC: World Bank; 2016 (https://www.worldbank.org/en/topic/climatechange/brief/shock-waves-managing-the-impacts-of-climate-change-on-poverty-background-papers).

20. Berry P, Enright PM, Shumake-Guillemot J, et al. Assessing health vulnerabilities and adaptation to climate change: a review of international progress. Int J Environ Res Public Health. 2018;15(12):2626.

21. WHO guidance for climate resilient and environmentally sustainable health care facilities. Geneva: World Health Organization; 2020 (https://www.who.int/publications/i/item/climate-resilient-and-environmentally-sustainable-health-care-facilities).

22. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med. 2009;51:33–37.

23. Crimmins A, Balbus J, Gamble JL, et al., editors. The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC: U.S. Global Change Research Program; 2016 (https://health2016.globalchange.gov/).

24. Data distribution centre. Geneva: Intergovernmental Panel on Climate Change (http://www.ipcc-data.org/).

25. World population prospect 2019. New York: United Nations Department of Economic and Social Affairs; 2019 (https://population.un.org/wpp/).

26. Global health estimates. Geneva: World Health Organization; (https://www.who.int/data/global-health-estimates).

27. Lessons learned on health adaptation to climate variability and change: experiences across low- and middle-income countries. Geneva: World Health Organization; 2015. (https://apps.who.int/iris/bitstream/handle/10665/176009/9789241564953_eng.pdf?sequence=1).

28. Paris Committee on Capacity-Building. Strategic plan for stakeholder engagement, communications and resource mobilization. Bonn: United Nations Framework Convention on Climate Change; 2019 (https://unfccc.int/sites/default/files/resource/20190715-Strategic%20plan%20FINAL%20Version.pdf).

29. Abram N, Gattuso J-P, Prakash A, et al. Framing and context of the report. In: Pörtner H-O, Roberts DC, Masson-Delmotte V, et al., editors. Special report on the ocean and cryosphere in a changing climate. Geneva: Intergovernmental Panel on Climate Change; 2019 (https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/05_SROCC_Ch01_FINAL.pdf).

30. Guidelines for considering traditional knowledges in climate change initiatives. Climate and Traditional Knowledges Workgroup; 2014 (http://climatetkw.wordpress.com/).

31. The global health observatory. Geneva: World Health Organization (https://www.who.int/data/gho).

32. Campbell-Lendrum D, Woodruff R. Climate change: quantifying the health impact at national and local levels. Geneva: World Health Organization; 2007 (https://apps.who.int/iris/handle/10665/43708).

33. Hales S, Kovats S, Lloyd S, Campbell-Lendrum D. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/134014).

34. World weather information services. Hong Kong, China: Hong Kong Observatory on behalf of World Meteorological Organization (https://worldweather.wmo.int/en/home.html).

35. Climate data library. Palisades, NY: International Research Institute for Climate and Society and Lamont-Doherty Earth Observatory (http://iridl.ldeo.columbia.edu/).

36. The R project for statistical computing. Vienna: R Foundation (https://www.r-project.org/).

37. QGIS (https://qgis.org/en/site)/.

38. Maps: visual representation of data by location. Atlanta, GA: Centers for Disease Control and Prevention (https://www.cdc.gov/epiinfo/user-guide/maps/mapsintro.html).

39. ArcGIS online. Aylesbury: Esri (https://www.arcgis.com/index.html).

40. Gamble JL, Balbus J, Berger M, et al. Populations of concern. In: The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC: U.S. Global Change Research Program; 2016 (https://cmerwebmap.cr.usgs.gov/catalog/item/5a60fc65e4b06e28e9c23e0e).

41. Just societies: health equity and dignified lives. Report of the Commission of the Pan American Health Organization on Equity and Health Inequalities in the Americas. Washington, DC: Pan American Health Organization; 2019 (https://iris.paho.org/handle/10665.2/51571).

42. Friel S, Krieger N. Climate change and the people's health. Oxford: Oxford University Press; 2019.

43. Ebi KL, Hess JJ. Health risks due to climate change: inequity in causes and consequences. Health Aff. 2020;39(1)2:2056–2062.

44. Guide to equitable, community-driven climate preparedness planning. San Francisco, CA: Urban Sustainability Directors Network; 2017 (https://www.usdn.org/products-climate.html).

45. Rudolph L, Harrison C, Buckley L, North S. Climate change, health, and equity: a guide for local health departments. Oakland, CA and Washington, DC: Public Health Institute and American Public Health Association; 2018 (https://www.apha.org/-/media/files/pdf/topics/climate/climate_health_equity.ashx?la=en&hash=14D2F64530F1505EAE7AB16A9F9827250EAD6C79).

46. Raval A, Chen T, Shah P. Mapping resilience: a blueprint for thriving in the face of climate disasters. Oakland, CA: Asian Pacific Environmental Network; 2019 (https://apen4ej.org/wp-content/uploads/2019/07/APEN-Mapping_Resilience-Executive_Summary.pdf).

47. Yu J, Castellani K, Yao A, et al. Mapping spatial patterns in vulnerability to climate change-related health hazards. Vancouver: University of British Columbia; 2020 (http://hdl.handle.net/2429/71647).

48. Health equity impact assessment (HEIA) workbook. Toronto: Ministry of Health and Long-term Care; 2012 (http://www.health.gov.on.ca/en/pro/programs/heia/docs/workbook.pdf).

49. Race forward equity assessment tool. New York: Race Forward; 2018. (https://www.usdn.org/uploads/cms/documents/equity_assessment_tool_-zero_cities_project_-_race_forward_2019.pdf).

50. Ebi KL, Anderson V, Berry P, et al. Ontario climate change and health vulnerability and adaptation assessment guidelines. Toronto: Ministry of Health and Long-term Care; 2016 (http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_toolkit.pdf).

51. Boeckmann M, Zeeb H. Justice and equity implications of climate change adaptation: a theoretical evaluation framework; Healthcare. 2016;4(3):65.

52. Revi A, Satterthwaite DE, Aragón-Durand F, et al. Urban areas. In: Field CB, Barros VR, Dokken DJ, et al., editors. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press; 2014 (https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap8_FINAL.pdf).

53. Hoegh-Guldberg O, Jacob D, Taylor M, et al. Impacts of 1.5ºC global warming on natural and human systems. In: Masson-Delmotte V, Zhai P, Pörtner H-O, et al., editors. Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: Intergovernmental Panel on Climate Change; 2018 (https://www.ipcc.ch/sr15/chapter/chapter-3/).

54. Food and Agriculture Organization, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme and World Health Organization. The state of food security and nutrition in the world: safeguarding against economic slowdowns and downturns. Rome: Food and Agriculture Organization; 2019 (https://www.who.int/nutrition/publications/foodsecurity/state-food-security-nutrition-2019-en.pdf?ua=1).

55. Mbow C, Rosenzweig C, Barioni LG, et al. Food security. In: Shukla PR, Skea J, Calvo Buendia E, et al., editors. Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Geneva: Intergovernmental Panel on Climate Change; 2019 (https://www.ipcc.ch/srccl/).

56. Climate change and its impact on health on small island developing states. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/feature-stories/detail/climate-change-and-its-impact-on-health-on-small-island-developing-states).

57. Oppenheimer M, Glavovic BC, Hinkel J, et al. Sea level rise and implications for low-lying islands, coasts and communities. In: Pörtner H-O, Roberts DC, Masson-Delmotte V, et al., editors. IPCC special report on the ocean and cryosphere in a changing climate. Geneva: Intergovernmental Panel on Climate Change; 2019 (https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/08_SROCC_Ch04_FINAL.pdf).

58. Ebi K, Woodruff R, von Hildebrand A, Corvalan C. Climate change-related health impacts in the Hindu Kush-Himalayas. Ecohealth. 2007;4:264–270.

59. Palomo I. Climate change impacts on ecosystem services in high mountain areas: a literature review. Mountain Res Dev. 2017;37(2):179–187.

60. Hock R, Rasul G, Adler C, et al. High mountain areas. In: Pörtner H-O, Roberts DC, Masson-Delmotte V, et al., editors. IPCC special report on the ocean and cryosphere in a changing climate. Geneva: Intergovernmental Panel on Climate Change; 2019 (https://www.ipcc.ch/srocc/chapter/chapter-2/).

61. Millennium ecosystem assessment: ecosystems and human well-being – health synthesis. Geneva: World Health Organization; 2005 (https://www.who.int/globalchange/publications/ecosystems05/en/).

62. Sena A, Ebi K. When land is under pressure health is under stress. Int J Environ Res Public Health. 2021;18(1):136.

63. International Health Regulations (2005) monitoring framework. Geneva: World Health Organization (https://www.who.int/data/gho/data/themes/international-health-regulations-(2005)-monitoring-framework).

64. Chikungunya in the French part of the Caribbean isle of Saint Martin. Geneva: World Health Organization; 2013 (https://www.who.int/emergencies/disease-outbreak-news/item/2013_12_10a-en).

65. Número de casos reportados de chikungunya en países o territorios de las Américas 2013–2014. Washington, DC: Pan American Health Organization; 2015 (http://www.paho.org/hq/index.php?option=com_docman&task=doc_download&Itemid=270&gid=30199&lang=es).

66. Health information platform for the Americas. Washington, DC: Pan American Health Organization (http://www.paho.org/data/).

67. Ramrattan L. Measuring the economic impact of chikungunya in the Caribbean. Port of Spain: Caribbean Public Health Agency; 2015 (http://carpha.org/Portals/0/docs/MEETINGS/CHIKV/S6P4-Ramrattan.pdf).

68. Lowe R, Gasparrini A, Van Meerbeeck CJ, et al. Nonlinear and delayed impacts of climate on dengue risk in Barbados: a modelling study. PLoS Med. 2018;15(7).

69. Khan K, Bogoch I, Brownstein JS, et al. Assessing the origin of and potential for international spread of chikungunya virus from the Caribbean. PLOS Curr. 2014;6.

70. Kilpatrick AM, Randolph SE. Drivers, dynamics, and control of emerging vector-borne zoonotic diseases. Lancet. 2012;380(9857):1946–1955.

71. Paixão ES, Teixeira MG, Rodrigues LC. Zika, chikungunya and dengue: the causes and threats of new and re-emerging arboviral diseases. BMJ Glob Health. 2018;3(suppl. 1):e000530.

72. Kovats R, Edwards SJ, Hajat S, et al. The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries. Epidemiol Infect. 2004;132(3):443–453.

73. Lake IR, Barker GC. Climate change, foodborne pathogens and illness in higher-income countries. Curr Environ Health Rep. 2018;5(1):187–196.

74. Ebi KL, Lindgren E, Suk JE, Semenza JC. Adaptation to the infectious disease impacts of climate change. Climat Change. 2013;118:355–365.

75. Ebi K, Berry P, Hayes K, et al. Stress testing the capacity of health systems to manage climate change-related shocks and stresses. Int J Environ Res Public Health. 2018;15(11):2370.

76. Whyte A, Burton I. Environmental risk assessment: SCOPE 15. Chichester: Wiley; 1980.

77. Guidelines for preparing economic analyses. Washington, DC: United States Environmental Protection Agency; 2010 (https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses).

78. Multi-criteria analysis. In: Assessing the costs and benefits of adaptation options: an overview of approaches. Bonn: United Nations Framework Convention on Climate Change; 2010 (https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf).

79. New cost-effectiveness updates from WHO-CHOICE. Geneva: World Health Organization; 2021 (https://www.who.int/news-room/feature-stories/detail/new-cost-effectiveness-updates-from-who-choice).

80. Tan-Torres Edejer T, Baltussen R, Adam T, et al. Making choices in health: WHO guide to cost–effectiveness analysis. Geneva: World Health Organization; 2003 (https://apps.who.int/iris/handle/10665/42699).

81. User guide for the Malaria Strategic and Operational Plan Costing Tool. Geneva: World Health Organization (https://www.afro.who.int/publications/user-guide-malaria-strategic-and-operational-plan-costing-tool).

82. Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage. Geneva: World Health Organization; 2012 (https://www.who.int/water_sanitation_health/publications/2012/globalcosts.pdf).

83. Achieving health benefits from carbon reductions: manual for CaRBonH calculation tool. Copenhagen: World Health Organization Regional Office for Europe; 2018 (https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/2018/achieving-health-benefits-from-carbon-reductions-manual-for-carbonh-calculation-tool-2018).

84. Flynn BC. Healthy Cities: toward worldwide health promotion. Annu Rev Public Health. 1996;17:299–309.

85. Water and climate change. Geneva: UN-Water; 2020 (https://www.unwater.org/water-facts/climate-change/).

86. Clasen T, Alexander KT, Sinclair D, et al. Interventions to improve water quality for preventing diarrhoea. Cochrane Database Syst Rev. 2015;(10):CD004794.

87. Fewtrell L, Kaufmann RB, Kay D, et al. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. Lancet Infect Dis. 2005;5(1):42–52.

88. Electric and equitable. learning from the BlueLA Carsharing Pilot. Los Angeles, CA: Shared-Use Mobility Center; 2019 (https://learn.sharedusemobilitycenter.org/wp-content/uploads/NewFile_SUMC_04.15.19.pdf).

89. BlueLA Electric Vehicle Carshare Pilot a success after one year – awarded $3 million to expand to three additional disadvantaged communities in Los Angeles. Los Angeles, CA: Shared-Use Mobility Centre; 2019 (https://sharedusemobilitycenter.org/bluela-electric-vehicle-carshare-pilot-a-success-after-one-year-awarded-3-million-to-expand-to-three-additional-disadvantaged-communities-in-los-angeles/).

90. Bennett J. Housing innovations in Nunatsiavut. Canadian Geographic, 19 June 2015 (https://www.canadiangeographic.ca/article/housing-innovations-nunatsiavut).

91. Matthews D. Community voices on climate change and health adaptation in northern Canada: research and action and the stories behind them 2012–2016. Gatineau, QC: Department of Indigenous Services; 2019 (http://www.climatetelling.info/uploads/2/5/6/1/25611440/19-012-climate-change-c2-ang.pdf).

92. WHO review: health in the nationally determined contributions. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/who-review-health-in-the-ndcs).

93. Nationally Appropriate Mitigation Actions (NAMAs). Bonn: United Nations Framework Convention on Climate Change; 2021 (https://unfccc.int/topics/mitigation/workstreams/nationally-appropriate-mitigation-actions).

94. Monitoring science and evidence on climate change and health. Geneva: World Health Organization (https://www.who.int/activities/monitoring-science-and-evidence-on-climate-change-and-health).

Department of Environment, Climate Change and Health
World Health Organization (WHO)
Avenue Appia 20 – CH-1211 Geneva 27 – Switzerland
www.who.int/phe/en/