CGE Training Materials for Vulnerability and Adaptation Assessment

Chapter 8
Human Health

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8.1. Introduction

It is likely that climate change will adversely affect some of the fundamental prerequisites for good health: clean air and water, sufficient food, adequate shelter and freedom from disease. The most severe risks are likely to be experienced in low-income countries, most of which are Parties not included in Annex I to the Convention (non-Annex I Parties). The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) concluded that until the mid-century, climate change will mainly exacerbate existing health problems (Smith et al., 2014). New conditions may emerge under climate change (low confidence level) and existing diseases (e.g. foodborne infections) may extend their geographic range. But the largest risks will apply in populations that are currently most affected by climate-related diseases. Impacts on health will be reduced, but not eliminated, in populations that benefit from rapid social and economic development, particularly among the poorest and least-healthy groups. Climate change is an impediment to continued health improvements in many parts of the world. If economic growth does not benefit the poor, the health effects of climate change will be exacerbated.

There are three basic pathways by which climate change affects health:

1. Direct impacts that relate primarily to changes in the frequency and intensity of extreme weather, including heat, drought and heavy rain;
2. Effects that are mediated through natural systems such as changes in the geographic range and incidence of infectious diseases (e.g. water-, food- and vector-borne diseases) and health outcomes associated with poor air quality (e.g. high concentrations of ozone and air-borne allergens);
3. Effects that are heavily mediated by human systems (e.g. occupational impacts, undernutrition, mental stress).

This chapter provides an overview of the methods that are commonly used in the health sector for vulnerability and adaptation (V&A) assessment. Background information on the vulnerability of health to climate change and on adaptation options is provided in the appendices to this chapter.

- Appendix 8-1 discusses climate and non-climate drivers of change in the health sector;
- Appendix 8-2 summarizes literature on potential impacts of climate change on human health;
- Appendix 8-3 briefly presents options for adaptation in health.

Other chapters in the training materials contain important information for conducting assessments of climate change V&A in health. In particular:

- Chapter 2 discusses V&A frameworks;
- Chapter 3 addresses baseline socioeconomic scenarios.
- Chapter 4 is on climate change scenarios;

- Chapters 5, 6 and 7 discuss coastal resources, water resources and agriculture, respectively. There will be important interactions between human health and all of these sectors;
- Chapter 9 discusses integration across sectors as well as adaptation, mainstreaming, monitoring and evaluation;
- Chapter 10 is on communication of V&A assessment in national communications.

8.2. Key resources

Key resource documents provide a review of human health issues within the context of climate change, and guidance for conducting V&A assessments. The *Human Health: Impacts, Adaptation, and Co-Benefits* chapter in the IPCC Working Group II contribution to tAR5 (Smith et al., 2014) comprehensively reviews the health risks of and responses to climate change. Resources produced by the World Health Organization (WHO) and other United Nations agencies are shown in table 8.1.

This chapter summarizes these resources and emerging literature, and provides additional technical support where required.

Table 8-1
Key resources

Resource	**Year**	**Description**	**Link**
World Health Organization (WHO): *Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s*	2014	Assessment takes into account a subset of the possible health impacts and assumes continued economic growth and health progress. Even under these conditions, it concludes that climate change is expected to cause approximately 250,000 additional deaths per year between 2030 and 2050.	<http://www.who.int/globalchange/publications/Quantitative-risk-assessment/en/>
WHO: *Guidance to Protect Health from Climate Change through Health Adaptation Planning*	2014	Guidance document offers a systematic process to (1) engage in the overall national adaptation planning process at the national level; (2) identify national strategic goals for building health resilience to climate change; and (3) develop a national plan with prioritized activities to achieve these goals, within a specific time period and given available resources.	<http://www.who.int/globalchange/publications/guidance-health-adaptation-planning/en/>
WHO Europe: Climate Change and Health: A Tool to Estimate Health and Adaptation Costs	2013	Tool provides step-by-step guidance on estimating the costs associated with climate-related damage to health, the costs for adaptation in various sectors to protect health from climate change and the efficiency of adaptation measures.	<http://www.euro.who.int/__data/assets/pdf_file/0018/190404/WHO_Content_Climate_change_health_DruckIII.pdf>

Resource	Year	Description	Link
WHO: *Atlas of Climate and Health*	2012	This document, the product of a unique collaboration between the meteorological and public health communities, provides scientific information on the connections between weather and climate and major health challenges. These range from diseases of poverty to emergencies arising from extreme weather events and disease outbreaks. Challenges also include environmental degradation, the increasing prevalence of noncommunicable diseases and the universal trend of demographic ageing.	<http://www.who.int/globalchange/publications/atlas/report/en/>
WHO: *Protecting Health from Climate Change: Vulnerability and Adaptation Assessment*	2012	Technical guidance describes the basics and key concepts of vulnerability and adaptation (V&A) assessment and provides detailed guidance for conducting an assessment on national or sub-national scales. The assessment outcome will provide information for decision makers on the extent and magnitude of likely health risks associated with climate change and priority policies and programs that can prevent or reduce the severity of future risks.	<http://www.who.int/globalchange/publications/Final_Climate_Change.pdf>
WHO: *Mainstreaming Gender in Health Adaptation to Climate Change Programs*	2012	Technical guidance to climate change and health programme managers on integrating gender as a key element in all phases of an adaptation project cycle, including V&A assessment.	<http://www.who.int/globalchange/publications/Mainstreaming_Gender_Climate.pdf>
WHO: Training Course for Health Professionals on Protecting Our Health from Climate Change	2011	Training course dedicates several chapters to discussing the health risks of climate change; reviewing increases in the frequency and intensity of extreme weather events; alterations in the transmission dynamics of food-, water-, and vector-borne diseases; and changes in the concentration of air pollutants.	<http://www.who.int/globalchange/training/health_professionals/en/>
WHO: Heat Waves, Floods and the Health Impacts of Climate Change: A Prototype Training Workshop for City Officials	2010	Training manual designed to accompany a workshop for health officials on the health risks of climate change.	<http://www.who.int/kobe_centre/publications/climate_media/2010_climate_change_manual.pdf>
WHO: Global Climate Change and Child Health: A Review of Pathways, Impacts and Measures to Improve the Evidence Base	2009	Paper summarizes what is known about climate change and its link to child health, identifies evidence at varying levels of risks and documents the disproportionate vulnerability of children to environmental factors.	<http://www.earthchildinstitute.org/wp-content/uploads/2012/06/Climatechange_Childhealth.pdf>
WHO: Global Climate Change: Implications for International Public Health Policy	2009	The second part of this article describes measures to build the capacity of the health sector to respond to risks posed by climate change.	<http://www.who.int/bulletin/volumes/85/3/06-039503/en/>

Resource	Year	Description	Link
WHO: *Protecting Health from Climate Change: Connecting Science, Policy and People*	2009	Report provides an overview of the science of climate change and human health. It describes the most recent evidence on health risks associated with climate change and the most vulnerable populations.	<http://www.who.int/globalchange/publications/reports/9789241598880/en/index.html>
WHO: *Protecting Health from Climate Change: Top 10 Actions for National and Local Policy-Makers*	2008	One-page document outlining 10 key actions for national and local policymakers for protecting health from climate change.	<http://www.who.int/globalchange/publications/key_messages/local_authorities/en/index.html>
WHO: Climate Change: Quantifying the Health Impact at National and Local Levels	2007	Environmental Burden of Disease series report outlines methods that can be used to quantify health impacts for both regional and local levels dependent upon data availability.	<http://www.who.int/quantifying_ehimpacts/publications/ebd14/en/index.html>
WHO: *Using Climate to Predict Infectious Disease Epidemics*	2005	Report on the potential of early warning systems based on climate variations to enhance global surveillance and response to epidemic-prone diseases.	<http://www.who.int/globalchange/publications/infectdiseases/en/index.html>

8.3. Methods, tools and data requirements

To assess the potential health risks of climate variability and long-term climate change it is necessary to have an understanding of the hazards associated with a changing climate, the individuals and communities exposed to those changes and the vulnerability of a population and its capacity to respond to new conditions. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Populations, subgroups and systems that cannot, or will not, adapt are more vulnerable, as are those that are more susceptible to weather, climate extremes and climate change. Understanding a population's capacity to adapt to new climate conditions is crucial to realistically assessing the potential health effects of climate change. In general, the vulnerability of a population to a health risk depends on factors such as population density, level of economic development, food availability, income level and distribution, local environmental conditions, health status and the quality and availability of health care. These factors are not uniformly distributed across a region or country or across time, and differ based on geography, demography and socioeconomic factors, including age and gender. Effectively targeting prevention or adaptation strategies requires understanding which demographic or geographical subpopulations may be most at risk and when that risk is likely to increase. Thus, individual, community and geographical factors determine vulnerability.

8.3.1. General considerations

The report *Operational Framework for Building Climate Resilient Health Systems*, (WHO, 2015b) addresses how WHO member states and partners can effectively address the challenges increasingly presented by climate variability and change. The objective is to strengthen health systems to maintain their basic structure and functioning in the face of climate-related stresses and shocks to protect population health. The framework identifies 10 components for building climate resilience, grouped into six main categories, as shown in figure 8-1.

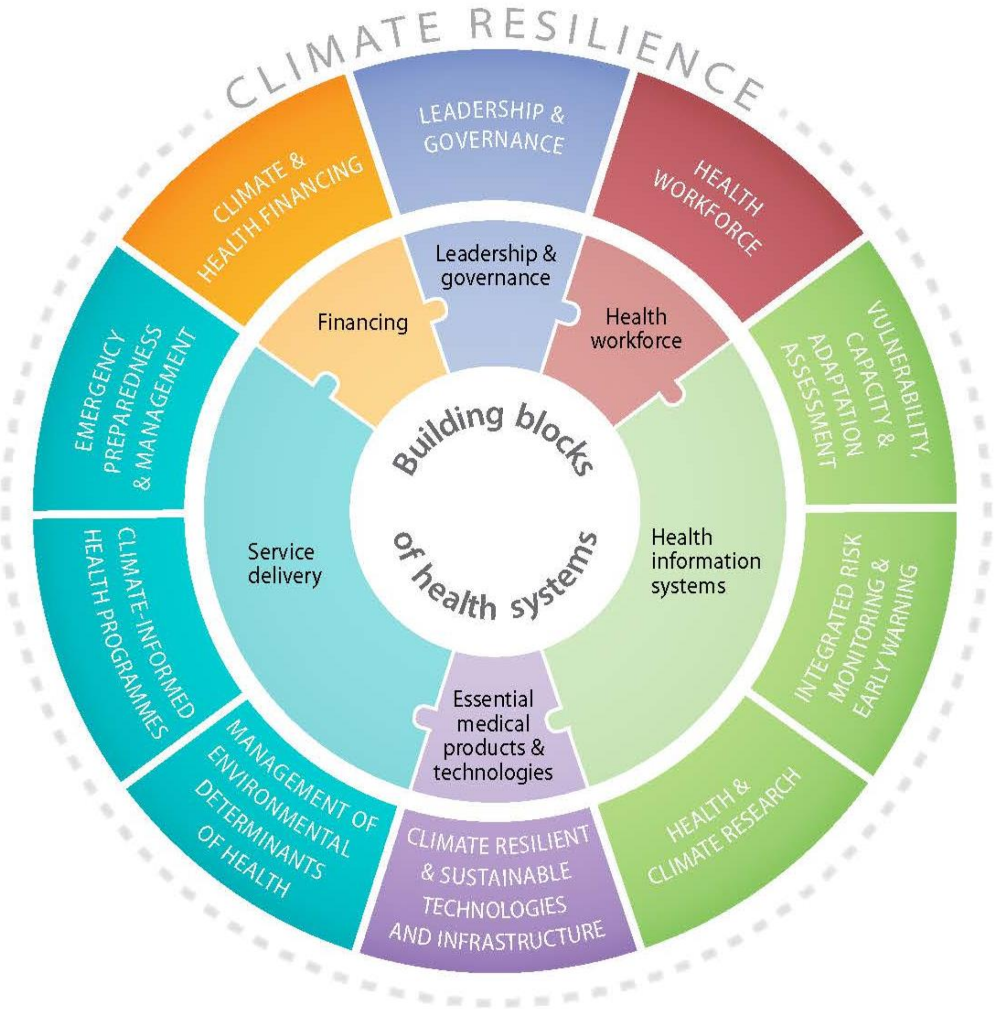
One key component of the WHO operational framework is to conduct the health component of a national adaptation plan (“H-NAP”) to ensure that the health and environment sectors follows a systematic process to:

1. Engage in the overall national adaptation plan (NAP) process at the national level;
2. Identify national strategic goals for building health resilience to climate change (if countries have not yet done so through, for example, a national health adaptation strategy);
3. Develop a national plan with prioritized activities to achieve these goals, within a specific time period and given available resources.

There are four basic steps in conducting an H-NAP:

- Step 1 is to lay the groundwork and address gaps in undertaking the H-NAP process;
- Step 2 is to prepare the H-NAP, including conducting a health V&A assessment;
- Step 3 is to develop a strategy for implementation;
- Step 4 is to report on, monitor and review the H-NAP.

Figure 8-1
World Health Organization operational framework for building climate resilient health systems

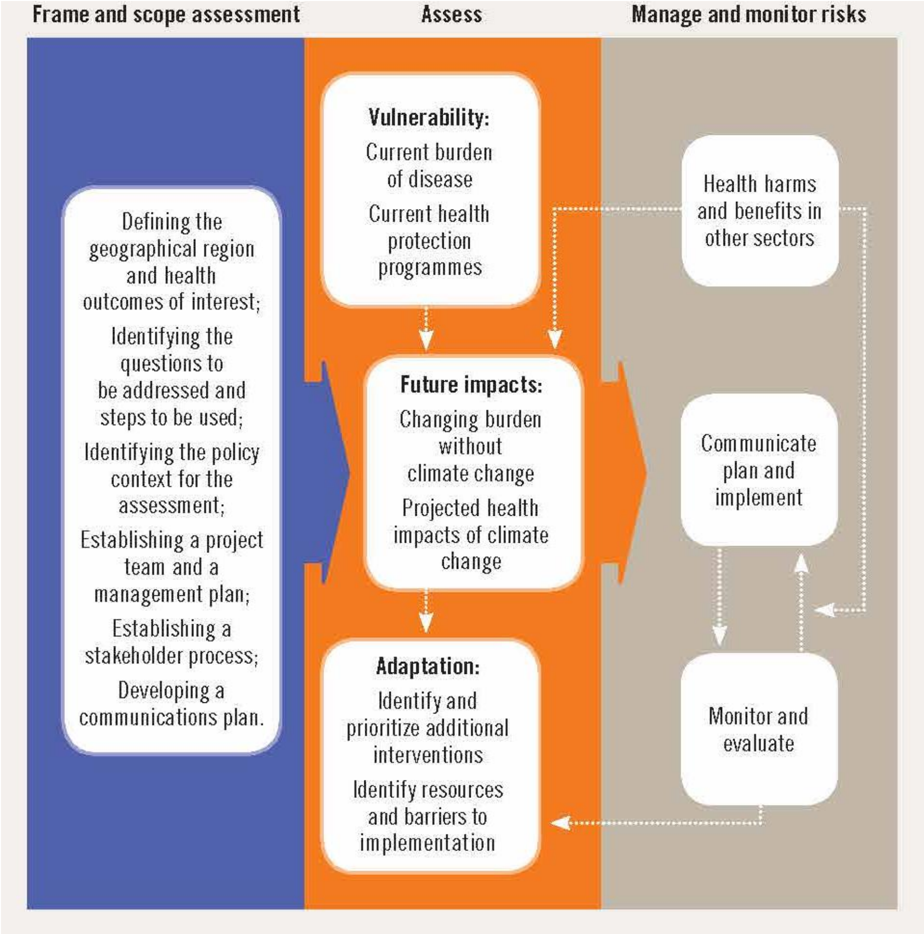


Source: WHO, 2015b.

The main approach to assessing climate change vulnerability in the health sector is in the guidance document from WHO and the Pan American Health Organization (PAHO) on conducting V&A assessments (WHO, 2012). Figure 8-2 shows the basic steps in conducting a V&A assessment. The three categories of activities are:

1. Framing and scoping the assessment;
2. Conducting the assessment;
3. Managing and monitoring risks.

Figure 8-2
Steps in conducting a health vulnerability and adaptation assessment



Source: WHO, 2012.

The outcome provides information for policymakers on likely health risks associated with climate change, as well as priority adaptation options to build resilience of the health system and reduce the severity of future impacts.

National assessments of the health risks of climate change have used quantitative and qualitative approaches. The three key issues to be addressed are:

1. Estimating the current distribution and burden of climate-sensitive diseases;
2. Estimating the future potential health impacts attributable to climate change;
3. Identifying current and future adaptation options to reduce the burden of disease.

Guidance and direction for the first two issues are discussed briefly below and adaptation is discussed in Section 8.4.

8.3.2 Estimating current distribution and burden of climate-sensitive diseases

Estimating possible future health risks of climate change must be based on an understanding of the current burden and recent trends in the incidence and prevalence of climate-sensitive diseases, and of the associations between weather and climate and the health outcomes of concern. In most countries, the ministry of health, hospitals and similar sources can provide data on disease incidence and prevalence at the required scale for an appropriate analysis. These sources can also provide information on whether health systems are satisfying the demand. The current associations between climate and disease need to be described in ways that can be linked with projections of changes in temperature, precipitation and other weather variables. The associations can be based on routine statistics collected by national agencies or on published literature. Table 8-2 lists some sources for health data.

Table 8-2
Sources for health data

Description	Source	URL
National health statistics, including disease and injury statistics	World Health Organization (WHO) Global Health Observatory	<http://www.who.int/gho/en/>
National health statistics	WHO/Regional Office Western Pacific Region:	<http://www.wpro.who.int/en/>
	WHO/Regional Office South East Asia	<http://www.searo.who.int>
	WHO/Regional Office/PAHO	http://new.paho.org/index.php>
	WHO/Regional Office for Africa	<www.afro.who.int/en/rdo.html>
Projected burden of specific cause of death in the 2030s and 2050s	WHO (regional level)	<http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/>
Database of impacts of natural disasters	[Centre for Research on the Epidemiology of Disasters Emergency Disasters Database	<http://www.emdat.be/>
National profiles of the burden of disease	Institute for Health Metrics and Evaluation, University of Washington	<http://www.healthdata.org/results/country-profiles>

8.3.3. Estimating future potential health impacts attributable to climate change

Once the current burdens of climate-sensitive health outcomes are described, including recent trends, future risks need to be described based on modelling of how projected changes in temperature and precipitation could affect the magnitude and pattern of health burdens, or based on qualitative expert judgements on how changes in temperature and precipitation over a particular time period could alter the distribution and incidence of health outcomes. Health models can be complex spatial models or can be based on a simple relationship between exposure and response. Models should include projections of how other relevant factors could change in the future, such as population growth, income, fuel consumption and other relevant factors. Projections from models developed for other sectors can be incorporated, such as projections for flood risk, changes in food supply and land use changes.

The practice of attributing a portion of a disease burden to climate change is in its infancy. Analysis should consider both the limits of epidemiologic evidence and the ability of the model to incorporate the non-climatic factors that also determine a health outcome. For vector-borne diseases, other factors, such as population growth and land use, may be more important drivers of disease incidence than climate change.

Three sets of approaches are described: (1) quantitative risk assessment; (2) disease-specific models; and (3) qualitative assessment.

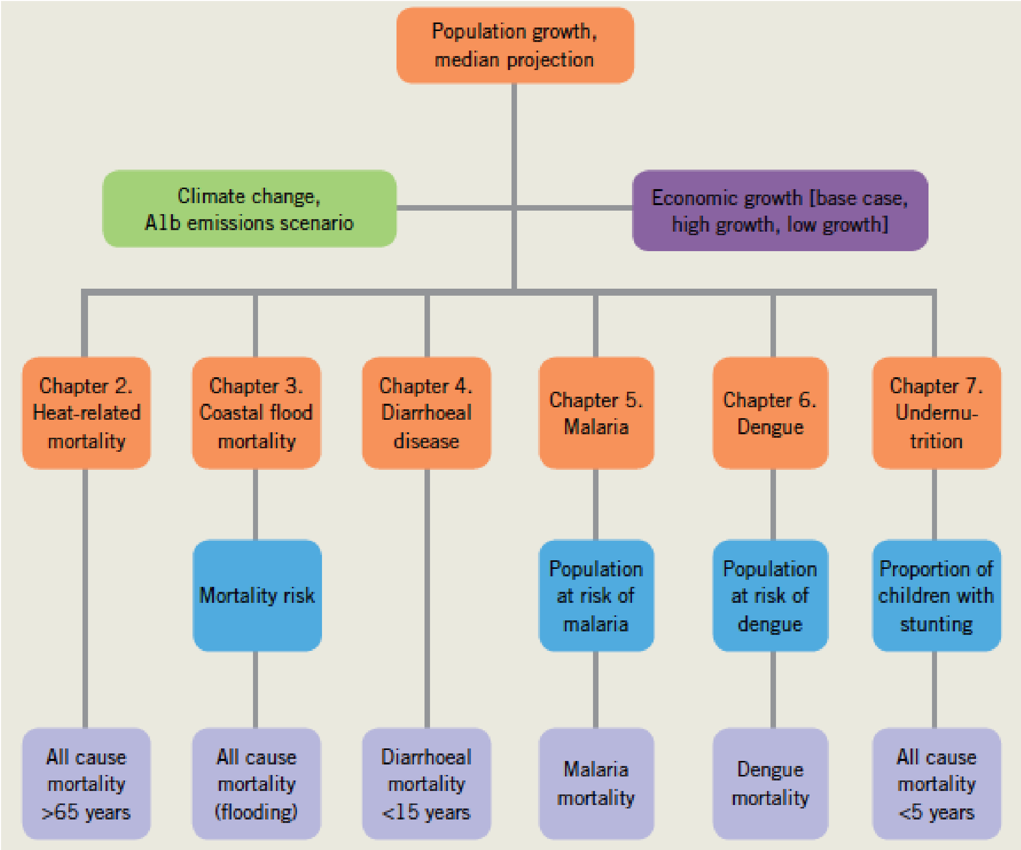
Quantitative risk assessment

WHO supported a quantitative risk assessment of the projected effects of climate change on selected causes of death in the 2030s and 2050s (WHO, 2014). The climate change attributable impacts were defined as the additional mortality in future years (2030s and 2050s) under climate change scenarios compared with the mortality in the same time periods under the 1961–1990 climate.

Mortality projections were based on observed mortality trends in relation to major drivers of health status, such as socioeconomic development, education and technology, together with projections of these drivers on a national scale. Cause-specific mortality in the absence of climate change was estimated using regression methods for three development futures: base case, high-growth, and no-growth scenarios. Outcome-specific global climate-health models were developed for: heat-related mortality in older people; mortality associated with coastal flooding; mortality associated with diarrhoeal disease in children aged under 15 years; malaria (population at risk and mortality); dengue (population at risk and mortality); and undernutrition (stunting) and associated mortality. Future climate change was characterized by a medium–high emissions scenario (A1-B) run through three climate models (see chapter 3 for discussion of emissions scenarios).

The counterfactual was a future world with modelled population growth and economic development but with the baseline (1961–1990) climate. The annual burden of mortality due to climate change was estimated for world regions. Figure 8-3 describes the models and output metrics used, and table 8-3 describes the adaptation assumptions used in this quantitative risk assessment.

Figure 8-3
Models and output metrics used in the World Health Organization quantitative risk assessment



Source: WHO, 2014.

For most pathways considered, the results reflect positive and negative impacts on health in different regions.

Compared with a future without climate change (in 2030), the following additional deaths were projected: 38,000 due to heat exposure in older people; 48,000 due to diarrhoea; 60,000 due to malaria; and 95,000 due to childhood undernutrition. The projected dramatic decline in the burden of child mortality is reflected in declining climate change impacts from child malnutrition and diarrhoeal disease between 2030 and 2050.

By the 2050s, deaths related to heat exposure (over 100,000 per year) are projected to increase. Impacts are greatest under a low economic growth scenario because of higher rates of mortality projected in low- and middle-income countries. By 2050, impacts of climate change on mortality are projected to be greatest in South Asia. These results indicate that climate change will have a significant impact on child health by the 2030s. Under a base case socioeconomic scenario, approximately 250,000 additional deaths per year would be attributed to climate change per year between 2030 and 2050. These numbers do not represent a full picture of the overall impacts of climate change on health because many causal pathways, such as water scarcity or economic damage, are not sufficiently characterized to include in the projections. Figure 8-4 shows the projected future annual mortality attributable to climate change for the base case socioeconomic scenario in 2030 and 2050 by world region, for undernutrition, malaria, diarrhoeal disease, dengue and heat.

Table 8-3
Adaptation assumptions used in the World Health Organization quantitative risk assessment

	Underlying trends	Adaptation assumptions included in model	Potential options not included in model	Foreseeable limits to adaptation
Heat-related mortality in elderly people	Population growth and ageing; improved health in elderly people due to economic development	Three levels of autonomous adaptation assumed – none, partial and full – based on shifts to optimum temperature	Improved heat health protection measures; early warning systems	Cost and feasibility of active and passive cooling measures in dwellings
Coastal flooding	Coastal population increase; increased vulnerability due to rapid urban development, which then declines	Evolving coastal protection measures	Population relocation	Technical and cost barriers to coastal defences, particularly in atoll countries, deltas and low-lying areas in poor countries
Diarrhoeal disease	Improved mortality outcomes due to technology and economic development	None	Improved water, sanitation and hygiene	Cost of installation and maintenance of water and sanitation facilities. Potential future decreases in water availability
Malaria and dengue	Assumed reductions in mortality rates resulting from socioeconomic development	Assumed reductions in mortality rates resulting from socioeconomic development	Specific novel interventions, e.g. vector control, vaccination, early warning systems	Insecticide or drug resistance
Undernutrition	Population growth; improved population health due to technology and economic development	Crop yield models include adaptation measures	Non-agricultural interventions, e.g. water and sanitation provision; reduced meat consumption in countries with currently high consumption	Limits of maximum productivity of agricultural systems

Source: WHO, 2014, Table 1.1.

Figure 8-4

Projected future annual mortality attributable to climate change for the base case socioeconomic scenario in 2030 (blue bars) and 2050 (orange bars) by world region for undernutrition, malaria, diarrheal disease, dengue and heat

Source: WHO, 2014, Figure 1.2.

Disease-specific models

Predictive models of the health risks of climate change use different approaches to project how the magnitude and pattern of climate-sensitive health outcomes could shift under different pathways of climate and development. For malaria, results from models are commonly presented as maps of potential shifts in distribution attributed to climate change. The models are typically based on climatic constraints on the development of the vector and parasite, and produce maps that identify potential geographic areas of risk, but do not provide information on the number of people who may be at risk within these areas. Few models incorporate adequate assumptions about other determinants of the range and incidence of disease, such as land-use change or prevalence of drug resistance of malaria, or about adaptive capacity.

Qualitative assessment

Potential future health risks of climate change can be estimated from knowledge of the current burden of climate-sensitive diseases, the effectiveness of current policies and measures to control those diseases and how temperature and precipitation can affect the geographic range and incidence of disease. For example, is highland malaria a current problem? What is the extent of that problem? How well is the disease controlled during epidemics? How could the burden of disease be affected if the temperature increased so that the vector moved into highland areas? This approach allows local-level knowledge of disease trends to be incorporated into projections of future risks, to add weight to the qualitative assessment.

8.4. Adaptation assessment

8.4.1. Planning

Planning health-related adaptive responses for specific risks builds on the assessment of potential impacts through:

- Ensuring an up-to-date review of peer-reviewed literature on health-related aspects of climate change;
- A review of available information from international and regional agencies (WHO, PAHO and others) and national health and social welfare authorities (ministries of health);
- Consultations with in-country agencies and experts that deal with the impacts of the health outcome of concern.

Targeted analyses can determine the feasibility of and priorities among adaptation options. When identifying specific measures to implement, it is often informative to list all potential measures, without regard to technical feasibility, cost or other limiting criteria, known as the theoretical range of adaptive choice (White, 1961; Ebi and Burton, 2008). The theoretical range of adaptive choice is a comprehensive listing of all the measures that have been used anywhere in the world, new or untried measures plus measures under development. The list can be compiled from a careful review of practice and experience, from a search for measures used in other jurisdictions and in other societies and from a brainstorming session with scientists, practitioners and affected stakeholders on measures that might be options in the future. Listing the full range of potential measures provides policymakers with a picture of measures that could be implemented to reduce a climate-related risk and which choices are constrained because of a lack of information or research, as a consequence of other policy choices (Ebi and Burton, 2008).

Using malaria as an example (table 8-4), the theoretical range of choice would include measures to improve vector control by eliminating mosquito breeding sites, measures to improve disease surveillance, development of an early warning system based on weather and environmental variables, development of a malaria vaccine and genetic engineering of mosquitoes to prevent replication of the malaria pathogen (Ebi and Burton, 2008). Genetic engineering has not yet been achieved, but could be possible with additional research funding and so remains a theoretical possibility.

Table 8-4
Screening the theoretical range of response options – malaria at local and regional levels

Theoretical range of choice	**Technically feasible?**	**Effectiveness in addressing health outcome?**	**Environmentally acceptable?**	**Financially feasible?**	**Socially and legally acceptable?**	**Closed/open (practical range of choice)**
Improve public health infrastructure, monitoring and evaluation programmes	Yes	Low	Yes	Sometimes	Yes	Open
Forecasting and early warning based on El Niño Southern Oscillation (ENSO) and weather conditions	Yes	Medium	Yes	Often	Yes	Open
Public information and education/awareness campaigns	Yes	Low	Yes	Yes	Yes	Open
Control of vector breeding sites	Yes	Yes	Spraying – no	Yes	Sometimes	Open
Impregnated bed nets	Yes	Yes	Yes	Yes	Yes	Open
Malaria prophylaxis	Yes	Yes	Yes	Only affordable for a few people	Yes	Closed for many people
Vaccination	No					Closed

Source: Ebi and Burton, 2008.

The next step is to screen the theoretical range of choice to determine which measures are achievable for a particular community or country over a particular time period (Ebi and Burton, 2008). Five criteria can be used to determine which theoretical choices are practical:

1. Technical feasibility;
2. Effectiveness;
3. Environmental acceptability;
4. Economic viability;
5. Social and legal acceptability.

After this screening process, some measures will remain available and others will be eliminated or blocked in the immediate term. This does not mean that they will be unavailable in the future. The fact that a theoretical choice is blocked may be an incentive to find ways of removing the constraint by carrying out research to create a new vaccine, changing laws or educating the public about the benefits of a practice that is considered culturally unacceptable. Those that are available constitute the currently available practical range of choice.

Once the measures have been narrowed to practical choices, additional data collection and analysis are required to provide policymakers with a basis for prioritizing which measures to implement. This information will then be used by the responsible authorities and by civil society, particularly those authorities and participants in civil society likely to be affected by the policy choice, to make the final determinations. Five additional criteria are suggested to facilitate the selection of priorities and to aid in the formulation of public health policies, measures and settings (Ebi and Burton, 2008):

- Magnitude of the event or intensity of the experience;
- Technical viability;
- Financial capacity;
- Human skills and institutional capacity;
- Compatibility with current policy.

This list of criteria is not comprehensive, as there may be others that policymakers may wish to take into account. Nevertheless, these criteria provide a useful framework for considering optimal adaptive responses, as shown in the case of malaria (table 8-5).

Completion of the adaptation choice policy analysis should result in recommendations of policies and measures that could be abandoned, modified or implemented immediately.

Table 8-5
Analysis of practical range of response options – malaria at local and regional levels

Practical range of choice	Technically viable?	Financial capability?	Human skills and institutional capacity?	Compatible with current policies?	Target of opportunity?
Improve public health infrastructure, monitoring and evaluation programmes	Yes	Low	Low	Yes	Yes
Forecasting and early warning based on El Niño Southern Oscillation (ENSO) and weather conditions	Yes	Yes	Yes	Yes	Yes
Public information and education/ awareness campaigns	Yes	Yes	Sometimes	Yes	Yes
Control of vector breeding sites	Yes	Sometimes	Sometimes	Yes	Yes
Impregnated bed nets	Yes	Sometimes	Yes	Yes	Yes
Malaria prophylaxis	Yes	Sometimes	Yes	Yes	Yes

Source: Ebi and Burton, 2008.

8.5. Implementation

WHO (2015a) conducted a qualitative review and synthesis of documents covering the first 5 years of implementation (2008–2013) of 3 multinational health adaptation projects covering 14 countries (Albania, Barbados, Bhutan, China, Fiji, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Macedonia, the Philippines, Russia, Tajikistan and Uzbekistan). In addition, qualitative data were collected through a focus group consultation and interviews with 19 key informants specifically selected for their expertise and role in health adaptation to climate change. The results indicate that the national projects increased resilience for particular weather-sensitive health outcomes by focusing on incremental improvements in policies and programmes to address the current adaptation deficit associated with climate variability, and by beginning to establish enabling environments for additional adaptation. However, the activities undertaken may not be sufficient to address significant increases in climate variability and change.

National health plans and budget processes need to move beyond focusing on shorter-term activities to address climate variability to prepare for climate change through better understanding of potential risks, strengthening health systems, ensuring adequate policies and legislation, facilitating institutional support, and public education and awareness programmes, including disaster preparedness measures.

Key aspects to be considered in implementation include:

- Mainstreaming and embedding adaptive actions in existing health systems;
- Ensuring a multi-stakeholder approach across national governments, related health providers and development partners;
- Ensuring effective public engagement and communication;
- Taking an adaptive management approach.

8.6. Example health vulnerability and adaptation assessment

The WHO guidance on conducting V&A assessments (WHO, 2012) contains many examples to illustrate choices made by countries as they conducted their assessments. Figure 8-5 shows an example from Cambodia.

Figure 8-4
Health vulnerability and adaptation assessment for Cambodia: Prioritizing adaptation options using problem trees

Box 20 Prioritizing adaptation options in Cambodia
By Piseth Raingsey Prak, Ministry of Health of Cambodia

The Cambodian Vulnerability and Adaptation Assessment focused on addressing risks of vector-borne diseases (malaria, dengue fever), food security, waterborne and foodborne diseases, and the health consequences of extreme weather events. Once a list of potential actions had been identified, priority adaptation options were narrowed down using problem trees (see Figure 7) based on answers to the following questions:

Is, or does, the adaptation option:

- effectively address a current and future climate change-related public health issue?
- technically feasible given current resources and expertise?
- satisfy local community (and cultural) needs and preferences?
- integrate with, or complement, other programmes and national priorities?
- sustainable over time? Can it be scaled up?
- contribute to capacity building of the community, health sector or research capability?
- able to be monitored and evaluated?
- cost-effective? In the short-, medium- and long-term?
- have any potentially adverse public health outcome?

Figure 7 Cambodia assessment: Problem trees identifying different causal linkages and opportunities for health protection

Source: WHO, 2012, Box 20.

8.7. References

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Appendix 8-1: Drivers of change in the health sector

Climatic drivers

The climate drivers affecting human health have been well-summarized in national and international assessments. Figure 8-6 below, from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) summarizes the associations between climate drivers and the global prevalence and geographic distribution of selected vector-borne diseases. Box 8-1 summarizes the current situation and future risks for many climate-sensitive health outcomes.

Figure 8-5
Associations between climate drivers and the global prevalence and geographic distribution of selected vector-borne diseases

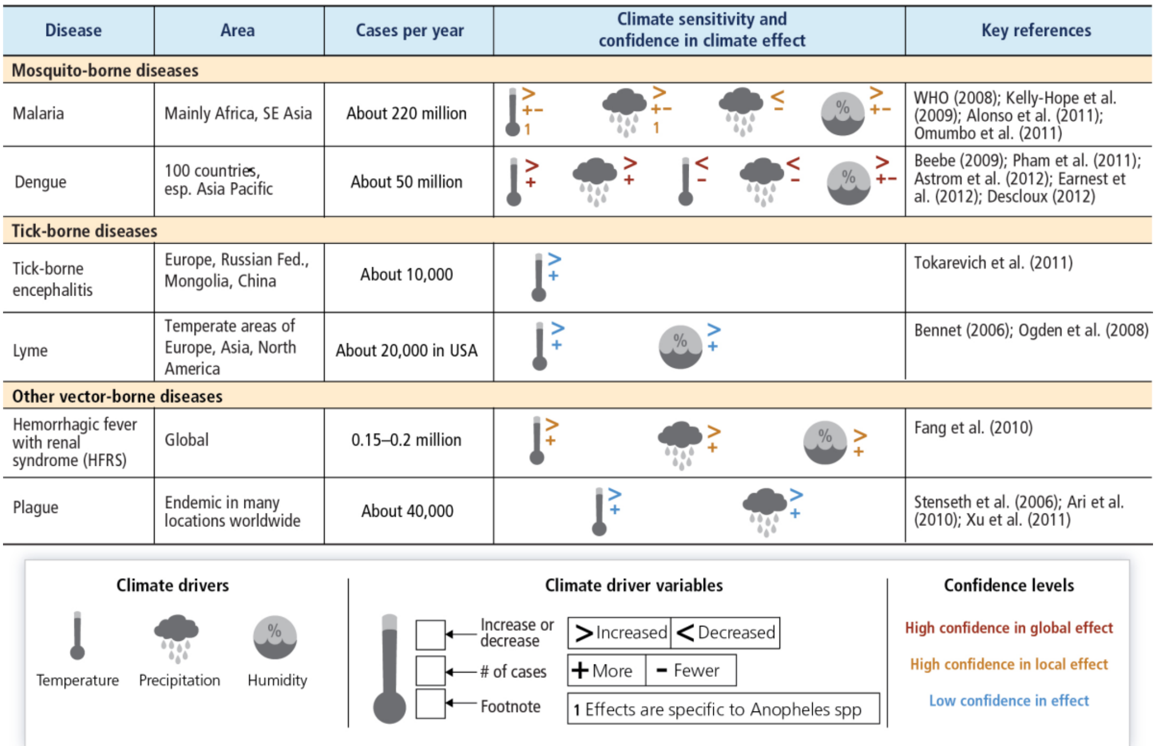


Table 11-1 | The association between different climatic drivers and the global prevalence and geographic distribution of selected vector-borne diseases observed over the period 2008-2012. Among the vector-borne diseases shown here, only dengue fever was associated with climate variables at both the global and local levels (*high confidence*), while malaria and hemorrhagic fever with renal syndrome showed a positive association at the local level (*high confidence*).

Disease	Area	Cases per year	Climate sensitivity and confidence in climate effect	Key references
Mosquito-borne diseases				
Malaria	Mainly Africa, SE Asia	About 220 million		WHO (2008); Kelly-Hope et al. (2009); Alonso et al. (2011); Omumbo et al. (2011)
Dengue	100 countries, esp. Asia Pacific	About 50 million		Beebe (2009); Pham et al. (2011); Astrom et al. (2012); Earnest et al. (2012); Descloux (2012)
Tick-borne diseases				
Tick-borne encephalitis	Europe, Russian Fed., Mongolia, China	About 10,000		Tokarevich et al. (2011)
Lyme	Temperate areas of Europe, Asia, North America	About 20,000 in USA		Bennet (2006); Ogden et al. (2008)
Other vector-borne diseases				
Hemorrhagic fever with renal syndrome (HFRS)	Global	0.15–0.2 million		Fang et al. (2010)
Plague	Endemic in many locations worldwide	About 40,000		Stenseth et al. (2006); Ari et al. (2010); Xu et al. (2011)

Source: Smith et al., 2014.

Box 8-1

Climate-sensitive health outcomes: Current situation and future risks

Air. Extreme high air temperatures can kill directly; it has been estimated that more than 70,000 excess deaths occurred during the extreme heat in summer 2003 in Europe. By the second half of the twenty-first century, such extreme temperatures will be the norm. In addition, rising air temperatures will increase levels of important air pollutants such as ground-level ozone, particularly in areas that are already polluted. Indoor and outdoor air pollution is linked with 7 million premature deaths each year, mainly by increasing mortality from cardiovascular and respiratory diseases.

Water. Shifting rainfall patterns, increased rates of evaporation and melting of glaciers, combined with population and economic growth, are projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions, intensifying competition for water among sectors. For each degree increase in the global mean surface temperature, approximately 7% of the global population is projected to be exposed to a decrease of renewable water resources of at least 20%. Almost 90% of the burden of diarrhoeal disease is attributable to the lack of access to safe water and sanitation. Climate change is projected to reduce raw water quality, posing risks to drinking water quality even with conventional treatment. The sources of the risks are increased temperature, increases in sediment, nutrient and pollutant loadings due to heavy rainfall, reduced dilution of pollutants during droughts and disruption of treatment facilities during floods.

Food. All aspects of food security are potentially affected by climate change, including food access, utilization and price stability. For the major crops (wheat, rice and maize) in tropical and temperate regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late twentieth century levels, although individual locations may benefit. Projected impacts vary across crops and regions and adaptation scenarios, with about 10% of projections for the period 2030–2049 showing yield gains of more than 10%, and about 10% of projections showing yield losses of more than 25%, compared to the late twentieth century. After 2050, the risk of more severe yield impacts increases and depends on the level of warming. Global temperature increases of around 4°C or more above late twentieth century levels, combined with increasing food demand, would pose large risks to food security globally and regionally. These changes are likely to aggravate the burden of malnutrition in developing countries, which currently causes more than 3 million deaths each year, both directly through nutritional deficiencies and indirectly by intensifying vulnerability to diseases such as malaria and diarrhoeal and respiratory infections. Malnutrition accounts for more than 50% of childhood mortality.

Box 8-1 (cont.)
Climate-sensitive health outcomes: Current situation and future risks

Shelter. By the second half of the twenty-first century, climate change is projected to cause an increase in the frequency of extreme storms, heavy rainfall and heat waves. From 1970 to 2012, 8,835 disasters, 1.94 million deaths, and US$2.4 trillion of economic losses were reported globally from hazards such as droughts, extreme temperatures, floods, tropical cyclones and related health epidemics. Repeated floods and droughts may force population displacement, which, in turn, is associated with heightened risks of a range of health effects, from mental disorders such as depression to communicable diseases and, potentially, civil conflict. Key risks related to shelter include (Smith et al., 2014):

- Risk of death, injury, ill health or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, coastal flooding and sea level rise;
- Risk of severe ill health and disrupted livelihoods for large urban populations due to inland flooding in some regions;
- Systemic risks due to extreme weather events, leading to the breakdown of infrastructure networks and critical services such as electricity, water supply and health and emergency services;
- Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas.

Disease. Rising temperatures, shifting rainfall patterns and increasing humidity could affect the transmission of diseases by vectors and through water and food. Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 1 million deaths annually. More than 2.5 billion people in over 100 countries are at risk of contracting dengue. Malaria causes more than 600,000 deaths annually, most of them in children under five years of age. Taking into account economic growth, studies suggest that climate change could increase the population at risk of malaria by 200 million in 2050. For dengue, assuming high economic growth that benefits all populations, the number exposed to dengue in 2050 falls to 4.46 billion (i.e. adverse effects of climate change on the geographic spread and incidence of dengue are balanced by the beneficial outcomes of development).

Table 8-6 summarizes climate-related risks and the health outcomes that potentially could be affected.

Table 8-6
Mechanisms by which climate change could affect health outcomes

Climate-related health risks	Potential health impacts
Extreme heat and thermal stress Increased number of warm days and nights Increased frequency and intensity of heat waves Increased fire risk with low rainfall conditions	Greater risk of injury, disease and death due to more heat waves and fires, including: Excess heat-related mortality Increased incidence of heat exhaustion and heat stroke Exacerbated circulatory, cardiovascular, respiratory and kidney disease
Storms and floods Increased intensity of tropical storms and more intense rainfall events Related damage to critical infrastructure, housing and contamination of water	Morbidity and mortality associated with: Exposure to and recovery from storms and floods Population displacement and disruption of lives, including access to health services
Waterborne and foodborne diseases Higher temperatures accelerate microbial growth, survival, persistence, transmission and virulence of pathogens Heavy rainfall events increase enteric pathogens in drinking and recreational waters Increased occurrence and duration of harmful algal blooms	Foodborne diseases may extend their range Increased transmission of enteric pathogens and shifting seasonal trends Outbreaks of cholera and other vibrios Increased exposure to harmful algal blooms from longer, at-risk periods of exposure
Zoonotic and vector-borne diseases Higher temperatures accelerate pathogen replication and alter biting rates Altered humidity and precipitation patterns affect local ecology and vector proliferation and survival	Increased geographic range of current diseases Re-emergence of formerly prevalent diseases Prolonged transmission cycles
Allergic diseases and cardiopulmonary health	Increased premature mortality related to ozone and air pollution from wildfires Earlier onset and longer duration of allergy seasons Asthma triggered by increased ozone and grass pollen
Nutrition Higher temperatures and changes in precipitation can decrease food quality and quantity Combined effects of increased food prices, enteric diseases and reduced food availability/quality	Increased risk of undernutrition, particularly in poor regions, including: Reduced per calorie availability Increased childhood undernutrition and proportion of stunted children Increased undernutrition-related childhood deaths
Mental health and disability Extreme weather-associated stress, particularly on those with mental illnesses Extreme events increase risk of injury and death Higher temperatures increase heat stress for patients using psychotropic medications	Increased incidence of severe anxiety reactions and longer-term impacts in populations experiencing disasters Increased injury and death for physically and mentally disabled Increased heat stress in those using psychotropic medications

Non-climate drivers

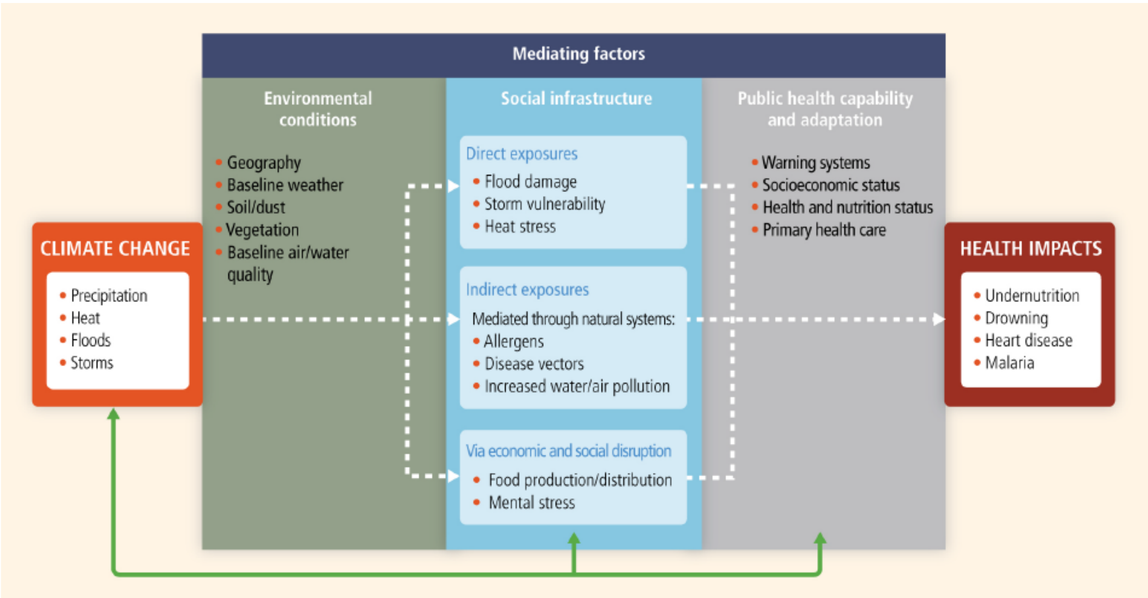
The chain of associations from climate change to changing disease patterns can be extremely complex and include many non-climatic factors. Therefore, the severity of impacts actually experienced will be determined not only by changes in climate, but also by concurrent changes in non-climatic factors and by the adaptation measures implemented to reduce negative impacts.

Non-climate factors that should be considered when assessing the health risks of climate change can be broadly categorized into the following:

- Overall economic development affecting human well-being (e.g. wealth and distribution of income; efforts to reduce poverty and tackle gender equity; issues around industrial development, pollution, urbanization and population growth; access to adequate nutrition, clean water and sanitation; deforestation);
- Non-climatic disasters (e.g. volcanic activity, earthquakes and tsunamis);
- Future improvements in health interventions;
- Mass migration, conflicts and war.

Figure 8-7 is a conceptual diagram showing the primary exposure pathways by which climate change could affect human health and interactions with climate and non-climatic drivers.

Figure 8-6
Conceptual diagram of pathways by which climate and non-climate drivers could affect health



Source: Smith et al., 2014.

Table 8-7 lists some sources of information on non-climate drivers of climate-sensitive health outcomes.

Table 8-7
Summary of key information sources on non-climate drivers of climate-sensitive health outcomes

Data/tool	**Source**	**URL**
Demographic and health data		
Gridded maps of human population and of socioeconomic data	Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Network (CIESIN)	<http://sedac.ciesin.columbia.edu/data/collection/gpw-v3>
	Population Reference Bureau	<http://www.prb.org/>
	United Nations population statistics for every country	<http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf>
Projections of national populations to 2300	United Nations Population Division	<http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf>
Core national demographic and health statistics	National census and health statistics offices	
World Health Organization (WHO) global database on child growth and malnutrition	WHO	<http://www.who.int/nutgrowthdb/en/>
WHO water, sanitation and health databases and statistics	WHO	<http://www.who.int/entity/water_sanitation_health/database/en>

A useful approach for considering non-climate drivers of climate-sensitive health outcomes when developing national adaptation plans (NAPs) is to develop specific baseline socioeconomic scenarios that integrate these factors. Importantly, this approach could help minimize the potential to ‘silo’ health as an adaptation sector that stands alone by considering the multiple causal links between climate change and non-climatic factors on human health. Such consideration is particularly important to assist in the monitoring and evaluation of health-related adaptive actions, outlined in section 8.3. Further information on the development of socioeconomic scenarios is provided in chapter 3.

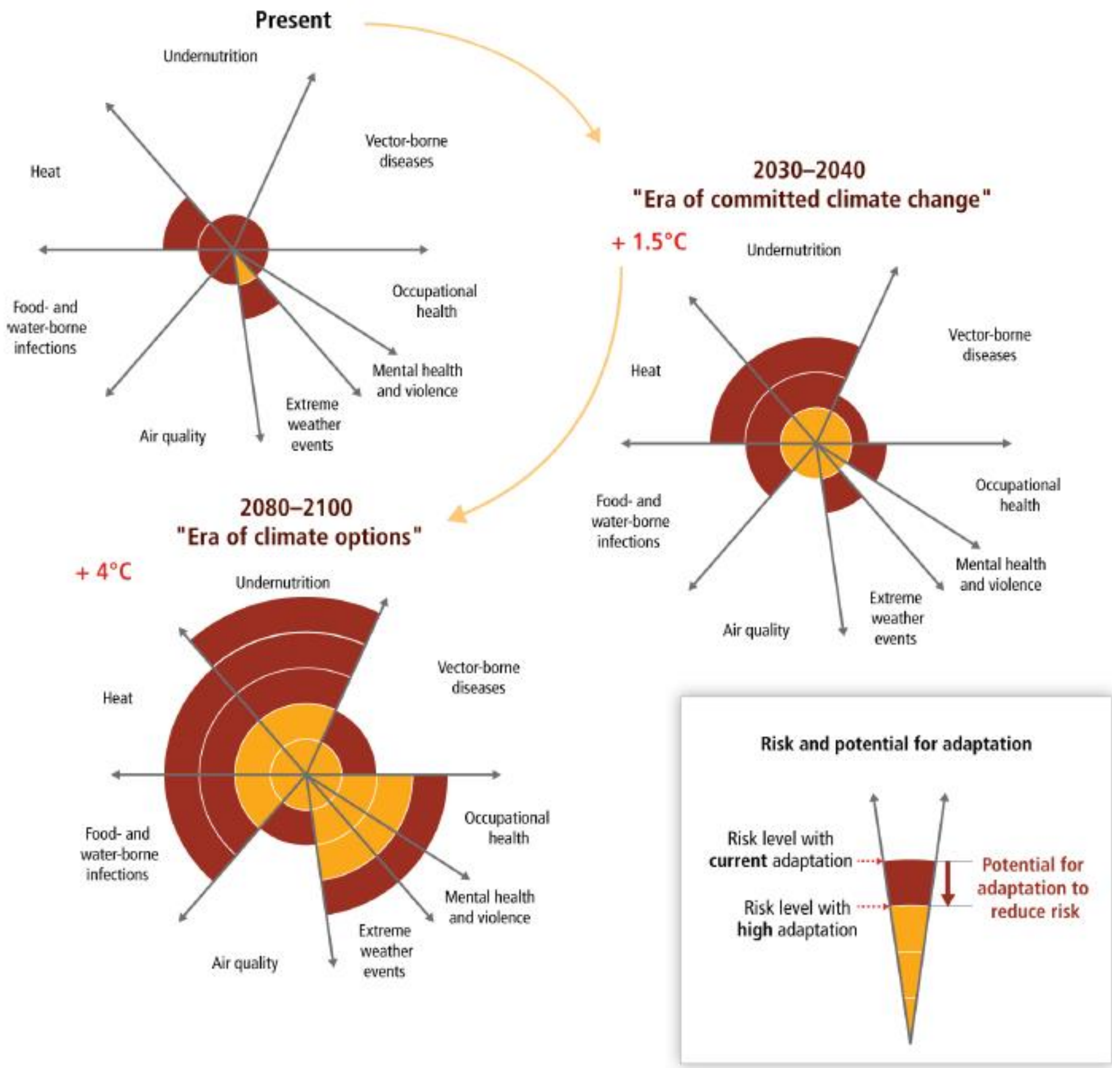
Appendix 8-2: Potential climate change impacts on the health sector

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) concludes that if climate change continues as projected, the major changes in ill health compared with no climate change would occur through (with confidence levels bracketed):

- Greater risk of injury, disease and death due to more intense heat waves and fires (very high confidence);
- Increased risk of undernutrition resulting from diminished food production in poor regions (high confidence);
- Consequences for health of lost work capacity and reduced labour productivity in vulnerable populations (high confidence);
- Increased risks of food- and water-borne diseases (very high confidence) and vector-borne diseases (medium confidence);
- Modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence); geographical shifts in food production and reduced capacity of disease-carrying vectors due to exceedence of thermal thresholds (medium confidence). These positive effects will be increasingly outweighed, worldwide, by the magnitude and severity of the negative effects of climate change (high confidence).

Figure 8-8 (below) is a conceptual presentation of health impacts from climate change and the potential for impact reduction through adaptation. Impacts are identified in eight health-related outcomes based on assessment of the literature and expert judgements by the IPCC authors. The width of the slices indicates in a qualitative way the relative importance in terms of burden of ill health globally at present and should not be considered completely independent. Impact levels are presented for the near-term ‘era of committed climate change’ (2030–2040), in which projected levels of global mean temperature increases do not diverge substantially across emissions scenarios. For some sectors (e.g. vector-borne diseases, heat/cold stress, agricultural production and undernutrition), there may be benefits to health in some areas, but the net impact is expected to be negative. Estimated impacts are also presented for the longer-term ‘era of climate options’ (2080–2100) for a global mean temperature increase of 4°C above preindustrial levels, which could potentially be avoided by vigorous mitigation efforts For each timeframe, impact levels are estimated for the current state of adaptation and for a hypothetical highly adapted state, indicated by different colours.

Figure 8-7
Conceptual presentation of the health impacts from climate change and the potential for impact reduction through adaptation



Source: Smith et al., 2014.

Appendix 8-3: Health adaptation

The WHO (2015b) operational framework identifies six categories where adaptation actions are needed to promote climate resilience:

1. ***Governance and policy*. **Advance the resilience of health governance, policies and cross-sectoral collaboration; and promote cross-sectoral collaboration to develop a shared vision and design coherent policies;
2. ***Capacity development.*** Strengthen the technical and professional capacity of health personnel and of the organizational capacity required for the health system to effectively identify, prevent and manage the health risks posed by climate variability and change. Raise the awareness of different audiences on the links between climate change and health, including policymakers, senior staff, the media and communities;
3. ***Information and early warning systems.*** Develop evidence and information to understand, cope with and communicate the health risks posed by climate change. Conduct assessments to understand context-specific, climate-sensitive health risks, the main vulnerable populations and areas; and to identify adaptation options. Integrated disease surveillance and early warning systems are key tools for managing health risks;
4. ***Essential products and technologies.*** Promote sustainability of health operations through revising current policies and measures to effectively respond to the risks of climate change. Innovative technologies and processes may facilitate better delivery of interventions;
5. ***Financing.*** Integrate climate change considerations in traditional funding mechanisms for health and increase health funding opportunities under specific climate change funding streams;
6. ***Service delivery*.** Improve management and operations of policies and measures for managing climate-sensitive health outcomes (e.g. vector-borne diseases), environmental determinants of health and disaster risk reduction.

Public health has a long history of designing, implementing, monitoring and evaluating strategies, policies and programmes to manage the risks of climate-relevant health outcomes. The degree to which programmes will need to be augmented will depend on factors such as:

- The current burden of climate-relevant health outcomes. The focus of V&A assessments is often on outcomes that cause the largest health burdens now. Adaptation will help populations to prepare for changes that could increase the incidence, seasonality or geographic range of climate-relevant health outcomes or that make their control more difficult;
- The effectiveness of current interventions to manage health risks of climate variability and change. Few current programmes and measures are as effective as desired. Understanding the extent to which current public health and health care policies and programmes are effective and the reasons for limits to effectiveness are first steps in understanding what modifications are needed to address the risks of a changing climate;

- Projections of where, when and how health burdens could change with changes in the mean and variability of climate.

Health adaptation highlights the need for efforts to reduce current vulnerability to weather and climate in conjunction with efforts to address the health risks projected to occur over coming decades (Smith et al., 2014). Health-specific adaptive options range from incremental changes in current activities and interventions (e.g. the translation of interventions from other countries/regions to address changes in the geographic range of diseases) to the development of new interventions to address new disease threats. The degree of response will depend on factors such as: who is expected to take action; the current burden of climate-sensitive diseases; the effectiveness of current interventions to protect the population from weather- and climate-related hazards; projections of where, when and how the burden of disease could change as the climate changes (including changes in climate variability); the feasibility of implementing additional cost-effective interventions; other stressors that could increase or decrease resilience to impacts; and the social, economic and political context within which interventions are implemented (Ebi and Burton, 2008).

It is useful to consider health-related adaptive strategies as ***autonomous*** or ***planned*** adaptation. ***Autonomous adaptation*** actions are responses that will be implemented by individuals, health professionals and communities based on perceived or real climate change in the coming decades, without intervention and/or coordination by regional and national governments and international agreements. ***Planned adaptation*** includes changes in policies, institutions and infrastructure that will be required to facilitate and maximize long-term benefits of adaptation responses to climate change.

An adaptive risk management approach should be considered when designing, implementing and evaluating health-related adaptive actions. This is because of the magnitude and distribution of potential health risks of climate change and the long timeframes of these impacts; adaptation to these changes will be required on an ongoing basis. Consequently, active management of the risks and benefits of climate change needs to be incorporated into disease control policies and measures across the institutions and agencies responsible for maintaining and improving population health.

In addition, understanding the possible impacts of climate change in other sectors could help decision makers to identify situations where impacts in another sector, such as water, agriculture or coastal zones, could adversely affect the health of a population (see chapters 5–7).

Many of the possible measures for adapting to climate change lie primarily outside the direct control of the health sector. They are embedded in areas such as sanitation and water supply, education, agriculture, trade, tourism, transport, development, urban planning, housing and so on. Intersectoral and cross-sectoral adaptation strategies are needed to reduce the potential health impacts of climate change and to optimize adaptive responses. Ebi (2009) presents health adaptation options for the United States. Further information on developing integrated responses is provid