TECHNICAL DOCUMENT

Climate change and communicable diseases in the EU Member States

Handbook for national vulnerability, impact and adaptation assessments

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This report is the result of the European Centre for Disease Prevention and Control (ECDC)'s service contract A 'Decision instrument for assessing European vulnerabilities to communicable diseases exacerbated by climate change' and contract B 'Developing European adaptation strategies to communicable diseases exacerbated by climate change'.

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Acronyms and abbreviations

DHF	Dengue haemorrhagic fever
ECDC	European Centre for Disease Prevention and Control
EU	European Union
EC	European Commission
Eurostat	Statistical Office of the European Communities
GHG	Greenhouse gas
IHR	International Health Regulations
IPCC	Intergovernmental Panel on Climate Change
LB	Lyme borreliosis
NGO	Non-governmental organisation
SIAM	Scenarios, Impacts and Adaptation Measures
SRES	Standardized Reference Emission Scenarios (Intergovernmental Panel on Climate Change)
TBE	Tick-borne encephalitis
UNFCCC	United Nations Framework Convention on Climate Change
VL	Visceral leishmaniasis
WHO	World Health Organization

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Executive summary

Climate change has already had measurable effects on the varied climates of Europe. Further changes, such as overall warmer temperatures, increased rainfall in Northern Europe, increased water scarcity in Southern Europe and even more extreme weather events, such as flooding and acute precipitation events across much of Northern and Central Europe, are anticipated. The transmission patterns of communicable diseases are influenced by many factors, including climatic and ecological elements. It is widely anticipated that climate change will impact the spread of communicable diseases in Europe. In some instances these impacts will be favourable, but in many cases they will pose new threats to public health. Food- and waterborne disease incidence, for example, have been correlated to warmer temperatures. Disease vectors (e.g., mosquitoes, sandflies and ticks) are highly sensitive to climatic conditions, including temperature and humidity. The distribution of these vectors is expected to shift in Europe, particularly at their latitudinal and altitudinal limits, meaning that certain vector-borne diseases may be introduced to regions that have not previously encountered them.

This handbook is intended to be a resource to encourage planning activities that anticipate and address the possible impact of climate change on communicable disease spread. Informed by current climate change science, particularly as it relates to communicable disease spread, this handbook suggests various processes and important points for consideration when conducting vulnerability assessments and developing adaptation strategies for climate change. Numerous appendices point to additional information sources that can facilitate this process.

Many countries have already developed climate change vulnerability assessments and/or adaptation strategies. This handbook is based on best practices and experiences from not only in Europe, but also from assessments undertaken in Australia, Canada, New Zealand and the USA. Although the content and context of vulnerability and adaptation assessments will necessarily vary from country to country and region to region, the process is fundamentally similar. This handbook stresses a methodology that involves as many different stakeholders as is feasible, is iterative in nature, and is carefully managed throughout all phases. Identifying potential vulnerabilities first requires describing the current situation, including demographic and socio-economic factors, health systems, epidemiologic factors, and information from non-health sectors. With careful analysis, priority diseases and vulnerable groups can be identified. These findings can then inform public health adaptation programs that strategically leverage existing strengths and mitigate the future weaknesses of health systems.

Introduction

This handbook was developed as an aid for European Union (EU) Member States to assess and manage changes in the risk of infectious disease transmission posed by climate change. The handbook draws on current scientific knowledge as well as experiences and best practices from previous national risk, vulnerability and adaptation assessments (see definitions in Textbox 5, Chapter 4). The primary aim of this handbook is to provide suggestions, tools, and hands-on approaches on how to access data, organise and manage assessments. Additionally, the handbook will help authorities choose analysis methods for national assessments based on local conditions, competence and aims. The approach is designed to be flexible with multiple entry points depending on whether the assessment will focus primarily on vulnerability, adaptation or both.

For the most part climate change adversely affects human health, with the extent and magnitude of effects expected to increase with further climate change. Changes in the mean and variance of climate variables (such as temperature and precipitation) can alter the incidence and geographic range of many climate-sensitive infectious diseases, with impacts varying across geographic and temporal scales. While populations in most countries will be exposed to the hazards of climate change, the risks will be greater in lower income countries because the current burden of climate-sensitive diseases is higher and, relatively speaking, their public health systems are weaker.

Climate change rarely acts in isolation. Changes in the incidence and/or geographic range of infectious diseases arise from the interaction of changes in temperature, precipitation and other climate variables with underlying vulnerabilities. These vulnerabilities include the effectiveness of infectious disease surveillance and control programs, access to healthcare, educational levels, economic resources, equity, and social cohesion. Climate change acts to multiply these and other stressors that affect population health.

The ability of a nation or community to identify and implement response options to address the additional health risks of climate change depends on a range of factors. Of primary importance are concerns that policy-makers and the public have sufficient knowledge of the health risks that climate change pose and the range of responses needed to reduce current and projected adverse health impacts. Once there is motivation for action, policy-makers need to evaluate practical options (including the feasibility, benefits, effectiveness and costs of those options), and understand the availability of resources and their distribution across the population as well as the structure of critical institutions, including the allocation of decision-making authority. Thus local policy making processes, institutions and resources influence the choices about which programs and activities to implement in order to address the current and likely future health risks of climate change.

The primary health concerns associated with climate change are often already problems today. Therefore vulnerability and adaptation assessments should identify modifications to current and planned programs designed to reduce burdens of climate-sensitive infectious diseases to ensure that current vulnerabilities to climate variability are effectively addressed (i.e. focusing on shorter-term decisions, such as development of early warning systems). Determining where populations are affected by climate variability facilitates identifying the additional interventions that are needed now.

At the same time, implementing interventions that only address current vulnerabilities is not sufficient to protect against health risks from ongoing and possibly more severe climate change. Because of the inherent inertia in the climate system and the length of time required for carbon dioxide to reach equilibrium in the atmosphere, the world is committed to three to five decades of climate change no matter how quickly greenhouse gas (GHG) emissions are reduced [1]. The future health impact of climate change will vary over spatial and temporal scales and will depend on changing socioeconomic and environmental conditions, with possibilities for diseases to increase in incidence and/or change their geographic range, resulting in significant outbreaks. Therefore capacities need to be built within public health and healthcare organisations and institutions to assess how climate change might alter the effectiveness of proposed programs or might affect future population health with regards to options implemented outside the health sector (e.g. whether changes in proposed land use to address climate change could alter vector breeding sites). These evaluations should consider short-term rapid climate change as well as longer-term changes in means of meteorological variables. Programs and activities addressing the health risks of climate change should also explicitly consider how to avoid cumulative or catastrophic events with large health impacts.

Reducing current and projected health risks attributable to climate change is simultaneously a risk assessment and risk management issue. As the context varies with changing climatic conditions, along with changes in demographics, technology, and socioeconomic development, an iterative approach is likely to be most effective. Because climate change is one of many public health issues that need to be addressed, policies and measures need to ensure that actions taken to reduce climate-related health risks support current programs to address health burdens and explicitly consider key uncertainties.

The process of estimating the potential effects on health by projected climate change differs in important ways from more traditional quantitative risk assessment methodologies. One critical distinction is the inapplicability of the primary assumptions underlying risk assessment; that a defined exposure to a specific agent causes an adverse health outcome to identifiable exposed populations, including specific people at particular risk. The health outcomes of concern with climate change are associated with many, often interrelated, factors.

Conducting a national vulnerability, impact and adaptation assessment will focus on the following issues: the current state of climate-sensitive infectious diseases and groups, and regions that are particularly vulnerable; how the 'burden of disease' could change with climate change; the effectiveness of current programs and activities in addressing climate-sensitive health outcomes; how planned programs and activities could address any additional burden of climate-sensitive health outcomes; which additional public health interventions may be needed; and the estimated costs and benefits of action versus inaction.

Although the process of conducting an assessment is similar across nations and regions, the context and content will vary depending on local circumstances, socioeconomic conditions, legal and regulatory frameworks and other factors.

This handbook is based on best practices and experiences not only from European assessments but also from countries such as Australia, Canada, New Zealand and the USA.

How to use this handbook

This handbook is designed to assist national level projects aimed at assessing and adapting to the potential impact that climate change will have on communicable disease transmission. It can be used by itself, as part of a more extensive assessment of health consequences of climate change in an area, or as one of many tools in a comprehensive national assessment that covers multiple sectors of society.

Within the handbook, Chapters 1–5 provide a theoretical background on relevant subjects and Chapters 6–8 provide illustrative questions and methods on how to conduct an assessment. An assessment can include both a vulnerability and adaptation assessment or can assess just vulnerability or adaptation. Because climate change will continue to affect the geographic range and incidence of infectious diseases for decades to come, assessments will be an ongoing process, with the results of one assessment providing the baseline for the next.

Chapter 1 describes how the climate in different parts of Europe will change, and the communicable diseases in the region that may be affected by changes in climate are described in Chapter 2. The ways in which climate change can affect infectious diseases and what this means for Europe are also described in Chapter 2 and Appendix 1. Chapter 3 highlights key uncertainties and how to address these issues in the assessment. Chapter 4 and Appendix 2 provide definitions and the theory behind the assessment process. Chapter 5 and Appendices 3 and 4 provide information on previous national assessments and focus on best practices and lessons learned.

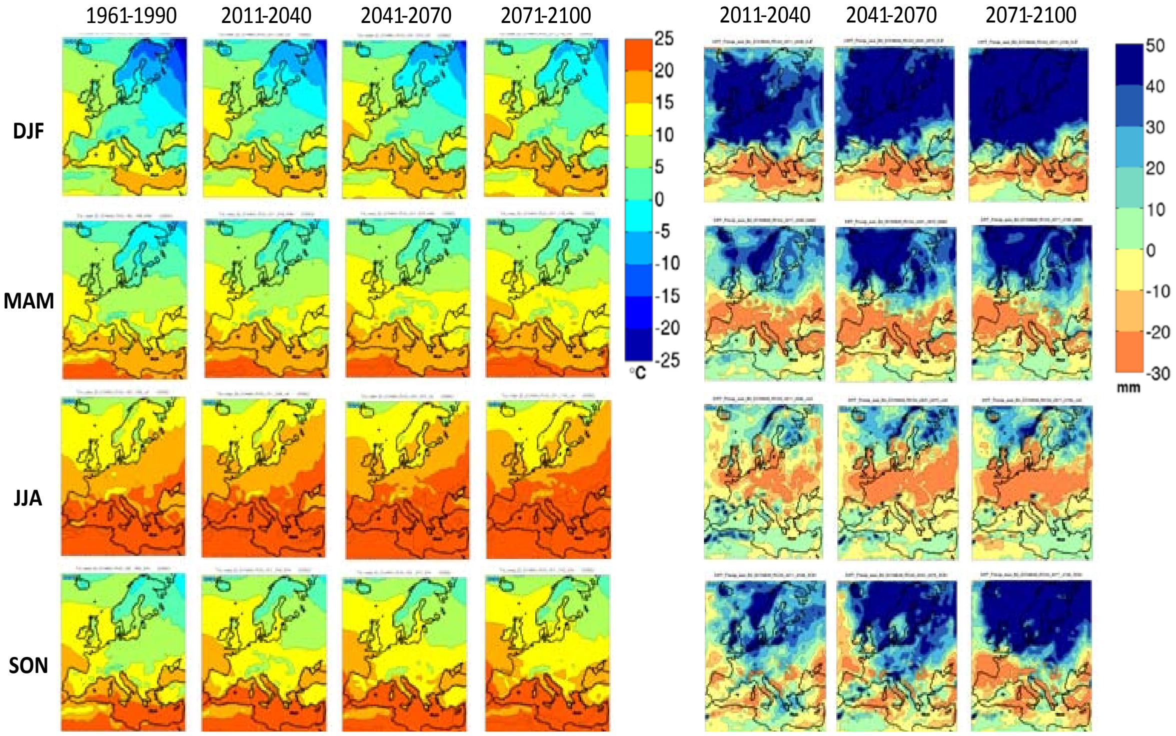
Chapter 6 provides guidance on how to organise, structure and manage a national vulnerability, impact and adaptation assessment. Chapters 7 and 8 provide guidance on what to include in the assessment, the pros and cons of different methods, and step-by-step approaches for conducting the analysis. Appendix 5 provides a list of where to access data for baseline descriptions and the assessment analysis.

1 Climate change in Europe

The latest report from the Intergovernmental Panel on Climate Change (IPCC) estimates that mean annual temperatures may increase between 2 and 7°C by 2100 in Europe [1]. In Northern Europe, the warming is likely to be highest in winter, with a 5–7°C increase in the Baltic Region, and marked increases in the length of the vegetation period. Similar temperature increases are likely to be seen in the Mediterranean region during the summer periods (Figure 1, left map). The number of extreme cold days will decrease markedly at high latitudes, whereas the frequency and intensity of heat waves are expected to increase in the whole region.

Annual mean precipitation is projected to increase in the northern parts of Europe and decrease in the south [1]. Precipitation amounts and patterns will differ between seasons (Figure 1, right map). In Northern and Central Europe, the winter periods are expected to experience the highest precipitation increases, whereas at high latitudes precipitation is projected to increase throughout all seasons. Extreme precipitation events are likely to become more frequent and intense in Northern and Central Europe. In the Mediterranean region, summer precipitation will probably decrease substantially. The frequency and intensity of summer droughts are likely to increase in both Southern and Central Europe. However, several scenarios suggest that even if mean summer precipitation amounts decrease, torrential rain events may still occur. Projections are inconsistent with regard to changes in wind speed and storm frequency in Europe.

Figure 1: Mean seasonal temperature projections and comparison



Mean seasonal temperatures in 2011–2040, 2041–2070, and 2071–2100 (left map section) and differences in mm precipitation compared to 1961-1990 during the same seasons and same time periods (right map section). Mean temperatures for the period 1961-1990 are shown for comparison. DJF=Dec-Feb, MAM=March-May, JJA=June-Aug, SON=Sep-NOV. The scenarios are based on the B2 emission scenario and scaled down from the ECHAM4/HADAM3H models.

Source: The Rossby Centre, Sweden, see web link in Appendix 5.

Box 1. Standardized Reference Emission Scenarios

Standardized reference emission scenarios (SRES) were developed by the IPCC as alternative images of how the future might unfold [2]. Four different narrative storylines (labelled A1, A2. B1 and B2) were developed to describe the relationship between GHG emission's driving forces and their evolution. Probabilities or likelihoods were not assigned to the individual scenarios. There is no single 'most likely' or 'best guess' scenario. None of the scenarios represent an estimate of a central tendency for all driving forces or emissions.

Each SRES storyline assumes a distinctly different direction for future development, such that the four storylines differ in increasingly irreversible ways. The storylines were created along two dimensions—global versus regional development patterns and whether economic or environmental concerns would be primary. It is important to note that the scenarios do not cover all possible future worlds. For example, there is no SRES world in which absolute incomes are constant or falling. The A2 and B2 storylines are frequently used in modelling for health impacts.

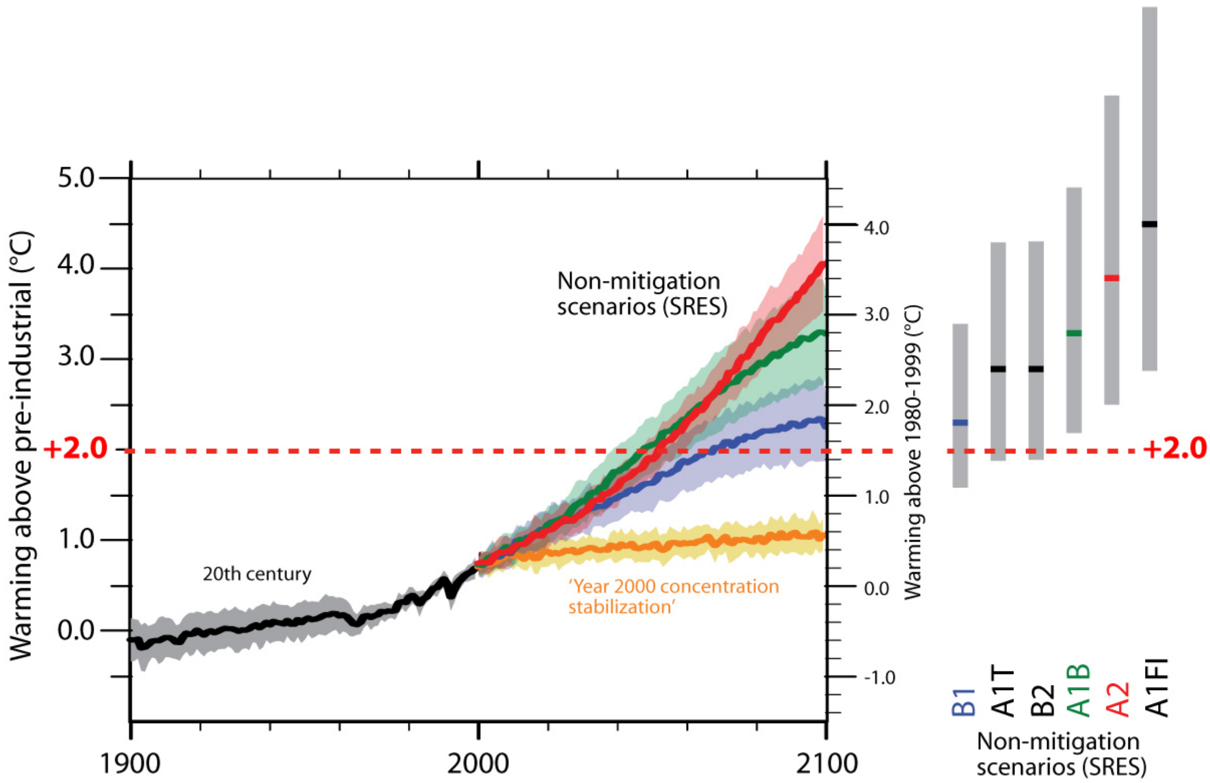
The A2 storyline describes a very heterogeneous world with an underlying theme of self-reliance and preservation of local identities. Fertility patterns across regions vary slowly, resulting in a continuously increasing global population. Economic development is primarily regional and per capita economic growth and technological change are fragmented and slower compared with the other scenarios.

The B2 storyline describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population (at a rate slower than A2), intermediate levels of economic development, and less rapid yet more diverse technological change.

Total cumulative carbon dioxide emissions are categorised as very high in the A2 scenario (more than 1800 gigatons of carbon (GtC)) and medium-low in the B2 scenario (1100–1450 GtC) in 2100.

In 1996, the European Council adopted the climate target that 'global average temperature should not exceed 2 degrees C above pre-industrial levels' [3], which the EU continues to reaffirm [4,5]. The IPCC [6] indicates that to achieve the 2°C target, GHG concentrations will need to stabilise in the atmosphere at about 445–490ppm CO_2-equivalents (this includes a number of GHGs and corresponds to about 400ppm CO_2 alone). However, there are uncertainties regarding whether 2°C is sufficient to prevent dangerous and unacceptable climate change [7].

Figure 2: Projections of global mean surface temperatures for the B1, A1B and A2 scenarios and the 'Year 2000 constant concentration'. Source: IPCC2007a [1]

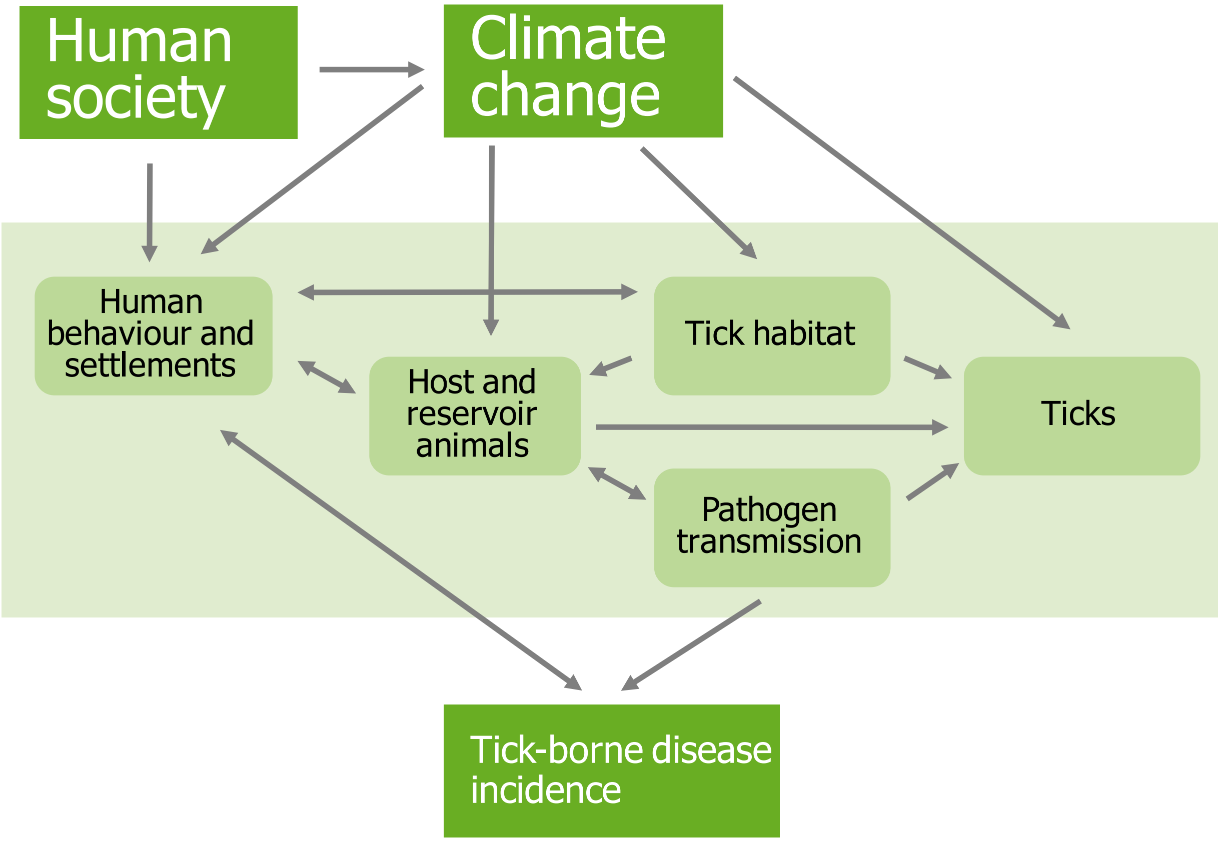


The current global annual mean temperature increase is 1.3°C compared with pre-industrial levels, which is above the IPCC's high emission scenarios for 2010 (A1B) and 2100 (A2) [8,9]. If global GHG emissions had been 'frozen' at the year 2000 level, global mean temperature would still rise by an additional 0.4°C in 2100 (or a total increase of 1.7°C), as illustrated by the yellow-orange line in Figure 2; this is called climate change commitment. Without the mitigation of emissions, the 2°C target will be exceeded towards the middle of the century, shown by the red dashed line in Figure 2.

2 Infectious disease and climate change

Climate change will influence the prevalence of infectious diseases through a variety of mechanisms [10]. The magnitude of climate change impacts depends on local conditions and the specific ecology and epidemiology of the different diseases, as explained in Appendix 1. Improved understanding of climate-related determinants of health requires a socio-ecological system perspective rather than the traditional epidemiological focus on proximate, individual-level risk factors.

Figure 3: Examples of the links between climate change and tick-borne disease incidence. Reproduced from Lindgren [11]



Changes in temperature will affect the risk of foodborne disease outbreaks if food is stored, transported or handled in an inadequate way under hotter ambient conditions. Outbreaks of waterborne diseases may be related to higher temperatures, decreased or increased water flows (causing, for example, increased leakages of pathogens from the soil and the animal sector), or by infrastructure damages due to extreme climate events.

Box 2. Climate influences the latitude and altitude limits of most vector-borne diseases

Insects and ticks do not have temperature regulations of their own and are thus sensitive to changes in ambient temperatures. This is particularly relevant close to their latitudinal and altitudinal distribution limits, where climate plays a major role in vector ecology and survival.

The geographical distribution of disease-transmitting ticks in Europe has changed since the early 1980s. Ticks are now found at higher latitudes and altitudes where the seasons were previously too short or too cold for ticks to survive and establish new populations. Studies from north-central Sweden have shown northward expansion of ticks along the Baltic Sea coastline and new establishments around larger bodies of water in the north. These changes are statistically correlated in time and space with recent changes in climate: the observed number of days with temperatures representing milder winters and increases in the length of the tick activity season [12].

Tick distribution in the mountainous region of the Czech Republic has been studied in the same locations since 1950s. Tick collection from the early 1950s and 1981 show that ticks were not found higher than 700 meters above sea level. When the same locations were studied in 2001, 2002 and 2003, ticks were prevalent as high as 1250 meters above sea level [13].

Changes in temperature and precipitation patterns and in the length and climate of the different seasons will affect the geographical distribution, seasonality and incidence of vector- and rodent-borne diseases in the EU (see Appendix 1 for details about the different diseases). Extreme events such as floods, droughts and wildfires may also influence the risk of disease through affecting habitats along with vector and host animal occurrence.

Climate change may facilitate the emergence of new diseases in Europe.

Box 3. The changing risk panorama of visceral leishmaniasis in Europe

Visceral leishmaniasis (VL) is caused by a parasite that is present mainly in dogs and that is transmitted to humans by sandflies. The sandflies, currently endemic to Southern Europe, are very temperature sensitive and do not require standing water for breeding. Visceral leishmaniasis infection rarely causes symptoms in healthy individuals. It has lately emerged as a health problem because co-infection of the Leishmania parasite with HIV results in a mean survival of only 13 months. However, encouraging results have been shown with highly active antiviral therapy (HAART) treatments, which decrease the incidence of new cases but do not reduce relapses of visceral leishmaniasis in HIV-infected persons. With the more uncontrolled movements of pet dogs within the EU, the pathogen is now present in many countries. With increasing temperatures, the geographical range of sandflies will change [14].

Increasing travel and trade facilitate a rapid spread of pathogens, vectors and reservoir animals around the globe. If climate change leads to changes in local environmental conditions, these can lead to the emergence of new diseases by facilitating establishment of vectors and pathogens in the area. Surprises are possible with new species combinations. The number of people travelling to and from Europe is increasing, as is inter-European travel, which increases the risk of spread of diseases including the introduction of new pathogens, vectors and reservoirs. Immigrants and European ex-pats returning from other continents may also contribute to the introduction of new diseases to the EU Member States.

Another trend of importance is population growth in the EU Member States, mainly due to high net immigration and low death rates (EpiStat, see Appendix 5). An overall ageing population has implications for general immunity.

Box 4. New diseases pose threats to the European region

The chikungunya epidemic in Italy in 2007 [15]

The first European epidemic of chikungunya fever occurred in the late summer of 2007. The joint epidemiological investigation by ECDC/WHO that followed showed that the outbreak was due to several conditions being present simultaneously. Favourable climate conditions enabled high population densities of the mosquito vector *Aedes albopictus* , which had been previously introduced in Italy through global trade in used tyres. Meanwhile, an Italian who had become infected with the virus in India returned to Italy while still viraemic, thus introducing the virus into Italian vector populations. Favourable climate conditions for virus replication prevailed long enough to result in about 200 cases.

The potential risk of chikungunya and dengue fevers in Europe [16]

Asian tiger mosquitoes (*Ae. albopictus*) are now established in Southern Europe and are better adapted to lower temperatures than the primary vector (*Aedes aegypti*) of the chikungunya and dengue viruses. ECDC's Tiger Map project (2009) suggests that *Ae. albopictus* is likely to spread further in Europe with climate change. However, the potential areas for future transmission of chikungunya and dengue viruses are more restricted than areas with possible vector occurrence (see web links to scenario maps in Appendix 5). Potential introduction and establishment of *Ae. aegypti* is restricted to the southernmost parts of Europe.

The transmission of some diseases, like dengue fever and airborne infections, are favoured by crowded conditions. The risk of others, like zoonotic waterborne and vector-borne diseases, depends more on environmental conditions and human behaviour. Socioeconomic conditions and the capacity of health systems and the healthcare sector differ between the Member States. Because of national differences in diagnostic criteria and reporting, it can be difficult to compare data between countries. Communicable diseases that are notifiable on a national level also differ between countries. In the summer of 2009, 49 infectious diseases, some of which are climate-sensitive, were reported by the Member States to the ECDC (see Appendix 1).

3 Uncertainties

With regards to the distant future, sizeable uncertainties are invariably present when considering possible or even likely changes in risks associated with human health and the environment. In addition, there are many unresolved empirical questions about the sensitivity of particular health outcomes to weather, climate and climate-induced changes in environmental conditions critical to health. Assessments of the possible impact of climate change on infectious diseases are based on relationships that are often indirect or non-linear and interlinked with other factors. For many diseases, there is a lack of information about the current association with climate. There is uncertainty about the magnitude, timing and nature of changes in the climate system, and there are critical uncertainties in projections of the future health status of potentially affected populations. These uncertainties need to be identified, described and managed.

3.1 Describe uncertainties

A vulnerability, impact and adaptation assessment should describe the important uncertainties. Stakeholders, particularly decision-makers, need to understand the size and type of the uncertainties, the likelihood that they could be reduced in the near-term through additional research, and the implications of these uncertainties based on the results presented. Some of the IPCC recommendations [17] related to describing uncertainties include the following:

- Make expert judgements, including a traceable account of the steps used, to arrive at estimates of uncertainties or degrees of confidence for key findings.
- Develop clear statements for key quantitative findings, giving as explicit a timeframe as is possible.
- Define variables and outcomes, their context and any conditional assumptions.
- Consider the most appropriate way to describe the relevant uncertainties, or levels of confidence, through a hierarchy of expressed uncertainties using expressions like 'less to more confidence' and 'less to more probabilistic approaches'.
- Avoid value-laden statements and be aware that how the findings are presented will affect how it is interpreted. For example, a 10% risk of dying is interpreted more negatively than a 90% chance of surviving.
- Consider the use of tabular, diagrammatic or graphical approaches to illustrate uncertainties.

3.2 Manage uncertainties

Four approaches to managing uncertainties include:

- Reducing uncertainties in key areas by using complementary data, more detailed analyses and different analysis methods and tools. (See Chapters 6 and 7 for methods and Appendix 5 for a list of usable data sources.)
- Using scenarios and projections to illustrate how some key factors may change and what that could imply. It is important not to focus only on the most probable outcome; decision makers need to know about low probability/high consequence events, including worst-case scenarios. It is useful to explore the vulnerabilities of different scenarios and the measures needed to address these risks. (For a discussion on scenario types and techniques, see Börjeson et al. 2006.)
- Performing sensitivity and uncertainty analyses to evaluate the robustness of the results. Sensitivity analysis can be used to explore how impacts of the options could change in response to variation in key parameters and how they could interact (e.g. EPA 2009, European Commission 2009).
- Peer reviews provide the main mechanism for the evaluation of scientific papers. Therefore experts, agencies, organisations and stakeholders should review the draft assessment. Another approach is to use a reference group with relevant knowledge, skills and experiences for the evaluation. Consultation and public participation are other approaches that may be useful for increasing the quality and transparency of the assessment (see Chapter 6). These methods could also be used within the process when scenarios, assessment methods, etc. are chosen.

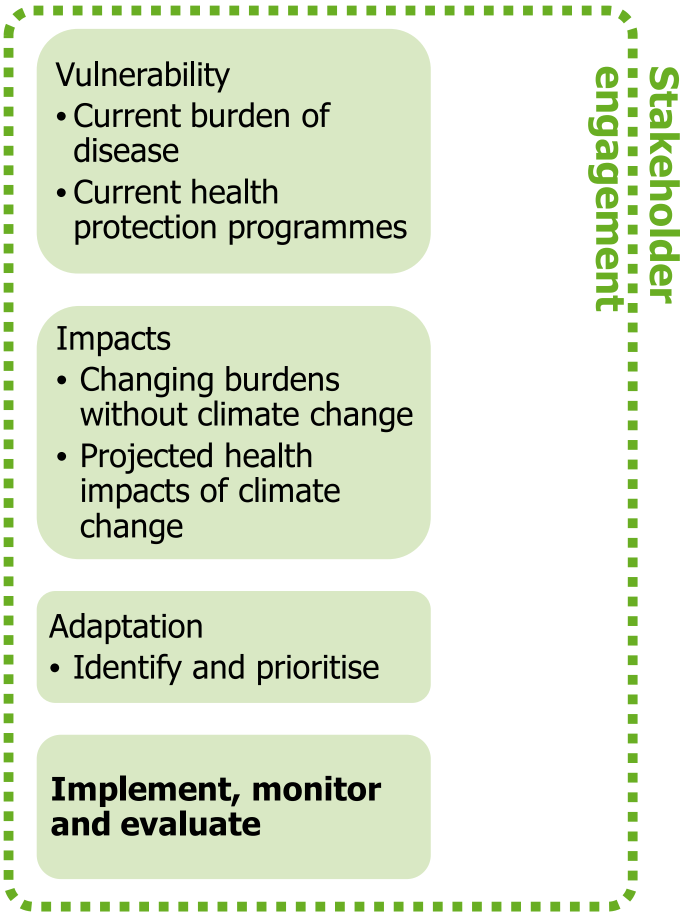
4 National vulnerability, impact and adaptation assessments

All countries that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC) are required to produce regular national communications that include a summary of the national vulnerability to the potential effects of climate change. In addition to national communications, least developed countries (LDCs) have developed National Adaptation Programmes of Action (NAPA). Agreements under the UNFCCC resulted in the establishment of several adaptation funds to implement strategies, policies and measures to increase resilience to climate change. These funds are administered by the Global Environment Facility.

The purpose of conducting a vulnerability, impact and adaptation assessment is to identify current vulnerabilities, possible risks and the interventions needed to reduce exposure to climate-related hazards and/or to decrease vulnerability. The assessment can arise as part of a country's national communication to the UNFCCC or because of national or regional concerns of the potential health impact of climate change.

Stakeholders should be engaged throughout the assessment. This process is shown in Figure 4 and practical guidance described in Chapters 6–8.

Figure 4: National vulnerability, impact and adaptation process



Appendix 2 describes the key management deliverables of a national assessment; see also the Chapters 6–8. Appendix 2 also lists the 10 main public functions as they relate to climate change and infectious diseases.

Box 5. Definitions

Vulnerability is the susceptibility to harm, defined in terms of a population or a location. The IPCC defines vulnerability to climate change as the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate variability and change [1].

Adaptation is the term used by the climate change community to describe the process by which strategies and measures to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, implemented and monitored [18]. In public health, prevention is the term analogous to adaptation.

Adaptive capacity describes the general ability of individuals, communities and institutions to effectively prepare for and cope with the consequences of climate variability and change.

5 Previous national assessments

The European Commission (EC) published a White Paper in April 2009 on adaptation measures and policies to reduce the European Union's vulnerability to the impact of climate change. This policy paper was accompanied by a staff working document entitled *Human, Animal and Plant Health Impacts of Climate Change*. It describes possible key problems, the means that are currently in place, and essential steps that the community and the Member States will have to take in order to tackle this problem in the most effective way possible, with available tools and financing plans.

European countries have generally been active with respect to climate change adaptation policy initiatives. At least 10 of the EU Member States have performed some kind of national vulnerability, impact and adaptation assessment that includes impacts on communicable diseases (for access to these assessments, see Appendix 3; Appendix 4 gives an international example).

National assessments have differed in several aspects. In the past, the initiative for the assessment has come from the government/parliament (Denmark, Finland, the Netherlands and Sweden), the Ministry of Environment (Germany and Spain), and the Department of Health (UK). In other cases, such as in Italy, an international organisation (WHO) was involved, and in Portugal the initiative came from the research community. The aims differ as well; Italy, Switzerland and the UK focused solely on the health sector, whereas other countries covered several sectors (some of which were area specific, such as the low-lying coastal regions of the Netherlands. Others considered the impacts on minority groups, like the Sami people and their reindeer husbandry in and close to the polar regions of Finland and Sweden).

Box 6. The Swedish assessment

In the summer of 2005, Sweden was hit by a severe hurricane leaving some rural households without electricity for up to 45 days, and causing huge economic losses for the forestry sector. Estimations of the direct costs neared 2.2 billion euros. In response, the Swedish government funded a 2½ year national assessment that covered all sectors of society. The national meteorological institute developed over 10 000 maps of projected climate change for different climate variables and parameters on demand (see section 7.2). The working group responsible for the health component included experts and stakeholders from the human and animal health sectors, animal keeping, and water resources and water management sectors.

The structure, content and work plans of the different assessments varied depending on their individual aims (see Chapter 6). The Portuguese assessment involved mostly scientists, developed national climate scenarios, and modelled certain infectious diseases (see Textbox 7). The German assessment used local expertise from several sectors in different federations to evaluate possible local impact and adaptation needs. The Italian assessment used input from expert meetings at the start and the end of the assessment in addition to the small team responsible for the report. The Spanish assessment focused on climate change impacts on ecosystems and components of natural systems (soils, water, flora, and fauna) and, consequently, on associated human activities and sectors. The first UK assessment gave a comprehensive scientific picture of possible health implications from climate change. The 2008 UK update included tailor-made modelling studies on several vector-borne diseases, along with analogue studies and high-level expert judgments (see Appendix 3). The Netherlands assessment used the same structure as Finland and Sweden; with cross-sectoral interactions between ministries, governmental agencies and local stakeholders including policy- and decision-makers, the national meteorological institute and scientists from different disciplines.

In France, a national observatory monitoring the impact of climate change was created in 2001. It reports directly to the prime minister and Parliament each year, and its mandate includes:

- collecting and disseminating information, studies and research results on climate change risks and extreme climate events; and
- making recommendations on preventive and adaptation measures to limit climate change risks.

The majority of the national assessments used expert's judgements, often in combination with literature reviews, to assess possible health effects from climate change. The national assessments that included case studies on local climate variability and specific health effects focused mostly on heat and mortality (with or without confounding for air quality) with statistical studies of specific events. A few of the assessments, like Portugal's, included case studies on infectious diseases, and used historical meteorological data and disease outbreaks/incidence or compared regions.

A couple of countries have already updated their first assessments, including the UK (originally performed in 2001/2002 and updated in 2008) and USA. The WHO's Regional office for Europe maintains an updated website on national assessments and their results (see Appendix 5).

Box 7. Climate change in Portugal: Scenarios, Impacts and Adaptation Measures (SIAM)

Qualitative storylines were used during the assessment of health risks and responses in the first Portuguese national assessment (SIAM). Included was an assessment of the possible impacts of climate change on some of the vector-borne diseases currently endemic to Portugal and some with the hypothetical potential of becoming introduced with climate change. Disease transmission risk was categorised qualitatively based on vector distribution and abundance, and pathogen prevalence. Four brief storylines were constructed based on current 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. The results were discussed with experts to estimate transmission risk levels.

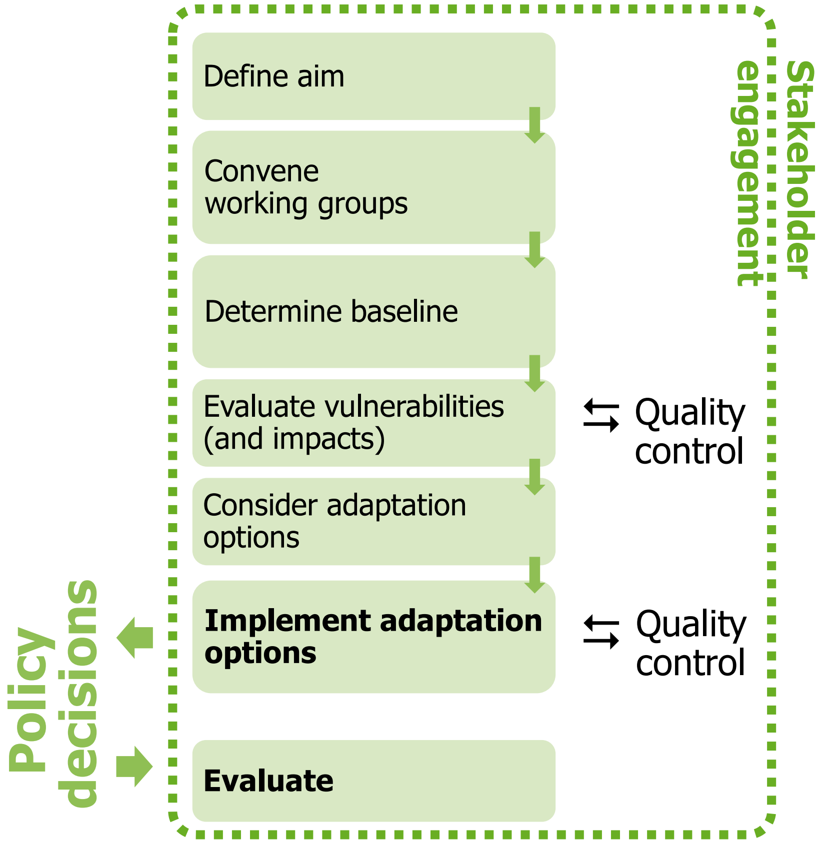
The following three chapters provide guidance on how to set up and perform a national assessment. The aim and structure of the assessment are addressed in Chapter 6. Guidance on what to include in baseline descriptions is found in section 7.1. Explanations of different methods available for the vulnerability and risk assessment analysis, with step-by-step instructions, can be found in sections 7.2 and 7.3. Chapter 8 covers adaptation in more detail.

6 The assessment process: Organising and managing the assessment

The assessment process should begin by defining the aim; depending on the aim, the scope and demarcations of the assessment should be further defined. Emphasis should be placed on the goals of the assessment and not specific details.

Various parts of the process are shown in Figure 5; however, the work is iterative and several of the steps will, in reality, be performed at the same time (see Chapter 6, and the best practices from previous assessments in Chapter 7 along with Appendices 3 and 4). Also, note that stakeholders should be involved from the beginning and participate in all the steps shown in Figure 5.

Figure 5: The assessment process



Examples of questions and suggestions that can be useful at the beginning of the assessment process are listed in Guidance checklist 1. List 1 details issues to consider for good quality performance.

Guidance checklist 1: Aim and demarcation

Identify and describe the aim of the assessment.

- Is the assessment covering several sectors of society, only the health sector, or restricted to infectious diseases?
- What will be the output (i.e. modelled projections of impacts)?
- How will decision-makers use the results (to develop an adaptation action plan, etc.)?
- Will cost analyses be included?

Decide on what will be included in the assessment.

- What sectors will be included?
- Which potential health impacts will be included?
- How detailed shall the assessment be?
- Which geographical areas (counties, etc) will be included?

What time period(s) will the assessment cover?

List 1: Key issues to address for a good assessment

- Well defined mission and aim
- Well defined work plan
- Stakeholders and decision-makers engaged from the beginning
- Iterative process
- Transparency and reference
- Quality control

Guidance checklist 2: Structure and work plan

- Determine the overall process and the management structure. An effective assessment requires at least one working and one steering group.
- Establish the organisation, including project leaders, working group/s, reference group/s, and stakeholders (including decision makers). Depending on the scope of the project, experience and expertise are needed from different sectors and regions.
- A project plan needs to be designed at the start-up phase and should include:
  - Activities during the process and the person/s responsible for each activity, including meetings of working and reference groups, the writing of the reports, etc.
  - Timetable

Working groups need to include a wide range of expertise and still be a manageable size. Additional expertise and skills can be obtained from ad hoc specialist groups, public consultations and peer reviews during the process. Even if the assessment is limited to infectious disease, skills and expertise are needed from veterinary medicine, water management, the food sector and other sectors of society. A secretariat is needed if several working groups are included.

When identifying possible stakeholders, consideration should be given to the stakeholders who will be involved with the effective design, implementation and monitoring of public health and healthcare interventions. These stakeholders may differ from those involved in a vulnerability assessment.

Reference groups generally include experts and/or persons in authority. The needs depend on the size and expertise of the working groups. Quality control could be done by consultation and/or through expert reviewing. Comments regarding the assessment should be sought from reference groups and others throughout the process. It is advisable to request reviews, for instance, when the work with the baseline description is completed and when it has been decided what to include and how to perform the assessment. The first draft should be sent out for expert comments before finalising the project. The involvement of local stakeholders, NGOs, private citizens and others is important for the quality and relevance of the work.

Additionally, proper documentation enhances transparency and accountability, aids in decision-making processes and provides a reference for future assessments.

Box 8. Example of skills and experience needed

- Policy- and decision-makers at different levels.
- International, governmental and regional agencies and ministries (e.g. health, environment, physical planning and infrastructure, agriculture, food industry, veterinary medicine, water resources and management, etc).
- Regional and local teams (e.g. regarding water sources etc).
- Non-governmental organisation (NGO).
- Scientific and technical experts.

7 The assessment analysis

The following sections will assess how climate change could affect the transmission of communicable diseases in the EU Member States, identifying the required adaptive and preventive policies and measures to address these risks.

It is important not only to look at the direct impact of climate change but also the secondary and tertiary health consequences caused by the effect of a changing climate on ecosystems, water flows and sources, and how this effects the vital infrastructure of any country (Chapter 2 and Appendix 1).

7.1 Baseline description

The nature and magnitude of the impact that climate change has on infectious disease risks depends on local vulnerability, which in turn depends on local conditions, their resilience to change and capacity to adapt.

In assessing what may happen in the future in different parts of any country, a baseline description of the current situation needs to be performed first. Factors to include depend on the diseases or the location being studied. In general, the following factors are of interest (in addition to current climatic conditions):

- demographic and socio-economic factors;
- the health system (including the healthcare sector, public health infrastructure and programs);
- epidemiologic factors;
- land cover and land use; and
- sectors other than the health sector.

7.1.1 Demographic and socio-economic factors

Demographic and socio-economic data can be collected from national registries or the Statistical Office of the European Communities (Eurostat), (see Appendix 5).

The following factors will give policy makers an indication of their population's vulnerability to climate change and the changing risk of communicable diseases:

- age and gender distribution;
- life-expectancy at birth;
- household incomes;
- the general health status and immunity;
- current prevalence of climate-sensitive infectious diseases (see section 7.1.3);
- vulnerable groups (see List 2);
- disease-specific risk groups (see sections 7.3.1–7.3.3);
- the structure and function of the health system (see section 7.1.2)
- the density and geographical distribution of the population; and
- the magnitude of travel and trade, which is an indicator for the risk of introducing and establishing new diseases.

List 2: Vulnerable groups in general

- The elderly
- Low income households
- Populations in remote areas with limited access to medical care
- Mentally and physically disabled individuals who are living alone, which increases the risk of not seeking medical attention when needed
- Children
- Pregnant women

Guidance checklist 3: Demographic and socioeconomic baseline data

- State the population's age, gender distribution and life expectancy at birth.
- What is the country's general health status? Current main causes of mortality and morbidity?
- Which groups are most vulnerable? How large are these groups? Where are they located?
- State current population density and geographical distribution of people within the country.
- What proportion of the population has ready/easy access to affordable healthcare?
- How many citizens return from visiting/working in countries outside of Europe? Which countries?
- How many citizens visit other European countries? Which countries?
- How many tourists and immigrants are there per year? From which countries did they originate?

7.1.2 Health systems

By following the recommendations in Guidance checklist 4, policy makers can get an overview of the vulnerabilities and adaptive capacities linked to their country's health system (including the healthcare sector and public health infrastructure and programs).

National and occasionally county data are available at the WHO's country profile website and at the EuroStat (see Appendix 5).

Guidance checklist 4: Health systems

- What is the number of physicians per inhabitant?
- What is the number of hospital beds per inhabitant?
- Does access to healthcare services differ markedly across regions? Which areas are considered most vulnerable in this regard?
- Who pays for healthcare services? The government? Insurance companies? The patient?
- What are the relevant preventive programs, including risk information campaigns?
- What are the vaccination recommendations? For travellers?
- If tick-borne encephalitis (TBE) is endemic in your country, is vaccination subsidised?

7.1.3 Epidemiological data

The current, climate-sensitive, infectious disease situation will need to be described as the baseline for further assessments, including:

- the frequency of water- and foodborne disease outbreaks, including their locations and causes if known; and
- the current burden and geographical distribution, seasonality and incidence of vector-borne diseases, as well as climate-sensitive rodent-borne diseases in different areas. Note if the current distribution of vectors differs from current risk areas of disease.

In section 7.3, more detailed, disease-specific data is described along with approaches for baseline description and assessment analysis of water-related outbreaks, foodborne diseases, vector- and rodent-borne diseases.

Appendix 1 gives an overview of climate-sensitive diseases of interest in the EU region.

Guidance checklist 5: Epidmioloical situation—climate-sensitive diseases

- Which diseases are currently notifiable?
- Which diseases are voluntarily reported?
- What national standardised diagnostic criteria (including laboratory methods) and reporting exist?

Guidance checklist 6: Status of current health protection programs for climate-sensitive infectious diseases

- What surveillance and control programs exist and for which infectious diseases?
- How long have these programs been operational?
- What data are collected and evaluated? For how many years have the data existed?
- What is the size (staff and budget) and geographic coverage of these programs?
- Have there been recent changes in the programs? If yes, please describe.
- What would be needed to increase the effectiveness of current control programs?
- Is the national laboratory's capacity able to provide validated, high quality and timely routine and diagnostic laboratory support, with a committed budget, to facilitate this work?

Guidance checklist 7: Preparedness for outbreaks, including from extreme weather events. Describe current and planned programs in the following areas

- National command and control structure for managing an extreme weather event, including a national contingency plan for maintenance of non-health essential services during extreme weather, such as power supply, food distribution etc. Describe the extent to which the health sector is involved.
- National programs to detect initial cases of an infectious disease outbreak and to monitor the spread and impact.
- Regional/local planning and coordination structure for:
  - maintaining services during an extreme weather event; and
  - coping with an infectious disease outbreak.
- National vector abatement strategy.

- National vaccination strategy including procurement, distribution and targeting of vaccines.
- Programs to monitor the potential impact of measures taken by neighbouring countries and the EU (IHR).
- National system for surveillance in animals that meets EU requirements.
- National capacity for managing an animal disease outbreak with human health implications, developed in collaboration between health and veterinary authorities.

Guidance checklist 8: Climate change activities. Describe current and planned programs in the following areas

- National agency or committee to coordinate assessments of the potential impacts of, and response to, climate change. Describe the extent to which the health sector is involved.
- The extent to which health is included in national communications. Who is responsible for writing the health section?
- National adaptation strategy, including the extent to which:
  - the strategy for the health sector is sufficient;
  - a national planning committee/structure coordinates climate change preparedness; and
  - coordination and collaboration is ensured across agencies and institutions in developing, implementing and monitoring programs that could affect infectious diseases.
- Public education programs on the risks of and responses to climate change.
- Capacity of regional/local planning and coordination structures to address the health risks of climate change, including preparedness for extreme weather events and the detection of infectious disease outbreaks.

7.1.4 Land cover and land use*

The risk of various infectious diseases is associated with different geographic land cover and land use factors such as coastal zones, mountainous regions, water bodies, urban areas, agricultural areas, animal keeping areas, type of vegetation, etc. Guidance checklist 9 is meant to give a better understanding of different types of risk areas in a country.

The European Environment Agency (EEA) has developed high-resolution land cover/land use maps for each of the EU Member States, which are available for free online (Appendix 5).

Guidance checklist 9: Land use and land cover

- Identify rural and urban environments; note that different risks are dominant in different areas.
- Identify flood-prone areas.
- Identify areas with risks of landslides in the event of heavy rain.
- Identify areas with important infrastructure in at-risk locations: roads, power stations, water treatment plants, etc.
- Identify areas with important drinking water sources.
- Identify areas with waters used for recreational purposes. Are they close to animal grazing areas?
- Identify areas with land cover/vegetation that favour certain vector-borne diseases. For example, wetlands and irrigation ditches are important breeding grounds for many vector mosquitoes.

7.1.5 Sectors other than the health sector

Transdisciplinary approaches and cross-sectoral collaboration are often needed when assessing the impact of climate change on infectious disease risk in an area. Existing collaborations between sectors—other than the health sector—along with the sectors themselves often need to be included in the assessment (see below).

- Water management—water sources and infrastructure

* 'Land cover' refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. 'Land use' is a more complicated term. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity.

- Food industry—agriculture sector including animal keeping
- Veterinary medicine—domestic animals and wild-life
- Nature conservation and management—forestry
- Housing and planning—transport and energy sectors, etc.

7.2 Selection of time periods and climate variables

Regional climate scenarios are better to use than global scenarios when studying how the climate will change in different parts of any country. These scenarios give a better description of local topography and the region's sea, land, and lake distribution than global models. Regional scenarios should be based on two different IPCC emission scenarios (see Chapter 1 and Appendix 5).

Several national assessments, like Sweden's and Finland's as well as the European Commission's PESETA-study, used the A2 and B2 emission scenarios. Emissions from the B2 scenario will create atmospheric CO_2 concentrations by the end of the century that are slightly above the 2°C EC target (see Chapter 1), whereas concentrations from the A2 scenario will be twice as high.

Previous national assessments have used different time periods for their analysis. The most frequently used include the following:

- One time period: 2030 or 2050.
- Three time periods: 2011–2040, 2041–2070, 2071–2100 (Swedish national assessment) or 2020, 2050, 2080 (UK health assessment).

Guidance checklist 10: Climate scenarios, time periods and climate variables

- In order to evaluate how the climate will change in any country, policy makers need to choose regional climate scenario maps based on two different future scenarios: one emission scenario (IPCC) that represents medium-low GHG emissions (e.g. B2) and one representing very high GHG emissions (e.g. A2) at the end of the century.
- Providers of regional climate scenarios for Europe are listed in Appendix 5.
- Time periods, depending on the aim of the national assessment, need to be chosen.
  - If the aim is to show what can happen in different parts of the country, then a single time value, like 2050, is sufficient.
  - If the aim is to show at what time and to what degree different adaptive measures need to be implemented, then three time periods should be chosen.
- For each of the diseases that are assessed, known climate variables and parameters related to changes in disease risk should be looked up (see Table 1 and Appendix 1).
- Appendix 5 lists where to get climate variable/parameter scenario maps of interest for analysis purposes (see sections 7.3–7.4).
- To compare climate change impacts in different areas or use the analysis method described in section 7.4.2, select scenario maps that show predictions of each climate variable for each time period (such as the left map section in Figure 1).
- To analyse what will happen in a specific area, select scenario maps showing differences (like the right map section of Figure 1).
- For the analysis method described in section 7.4.1, it does not matter which type of scenario maps is chosen.

Table 1: Infectious diseases and possible links to different climatic variables

	Extreme rainfall	Flooding	Land slides	Daily precipitation	Humidity	Storms	Drought	Seasonal precipitation	Extreme temperature	Daily temperature	Temperature threshold	Vegetation season
Water-borne sewage related	X	X	X			X						
Water-borne zoonoses, environmental pathogens	X	X	X	X						X		
Water-borne outdoor baths	X	X		X					X	X		
Foodborne	X	X		X					X	X		
Lyme borreliosis, TBE		neg		X	X		neg	X		X	X	X
Dengue, chikungunya	X	X		X	X		neg	X		X	X	
Leishmaniasis					X					X	X	
West Nile fever	X	X		X			X		X	X		
Rodent-borne		X						X		X	X	X

7.3 Analysis

There are specific issues that need to be addressed for different types of infectious diseases when performing vulnerability, impact and adaptation assessments.

7.3.1 Foodborne diseases

The risks of foodborne disease outbreaks are defined by changes in climate (higher temperatures and humidity) in combination with either technical or human behavioural shortcomings—or both—under changing conditions.

Guidance checklist 11: Foodborne diseases: Current epidemiology and possible relationships between outbreaks and direct and indirect climate events/variables (baseline description)

Pathogen, if known	Reported outbreaks last ten years	Number of cases/outbreaks	Cause of outbreak*

** Contamination at production level; inadequate storage, transport, and handling of food products at higher ambient temperatures, see Appendix 1.*

Guidance checklist 12: Factors to include in the assessment

- Describe the current status of food production, transport, storage and food handling (baseline description).
- Describe the current supervision and inspection of the food industry and retailers (baseline description).
- Describe the current surveillance of disease outbreaks (baseline description).
- What are the implications of climate change for the above issues?

Outbreaks of foodborne diseases can also be linked to water if fruit and vegetables are consumed raw without proper washing or if washed in contaminated water. Such contamination can be exacerbated by changes in water flows due to climate change.

List 3: Specific risk groups: Foodborne disease outbreaks

- If food is inadequately stored, transported or handled under conditions with high ambient temperatures (food industry, restaurants, at home): Consumers.

- If irrigation waters get contaminated: People not washing vegetables or fruit in clean water before consumption.

7.3.2 Waterborne diseases

Climate change may cause outbreaks of diseases transmitted in different ways through drinking or recreational waters (see Chapter 3 and Appendix 1).

Adaptation measures, like increased use of cooling towers and air conditioning, may also create waterborne outbreaks through inhalation of contaminated air droplets and mists (e.g. legionellosis).

Guidance checklist 13: Current epidemiology and possible relationships between outbreaks and direct and indirect climate events/variables (baseline description, drinking water)

Pathogen, if known	Reported outbreaks last ten years	Number of cases/outbreaks	Cause of outbreak*

**Changes in water flows, flood or drought, higher temperatures, infrastructure damage, contamination from soil or animal sector and/or sewage leakages, see Appendix 1.*

Guidance checklist 14: Current epidemiology and possible relationships between outbreaks and direct and indirect climate events/variables (baseline description, recreational waters)

Pathogen, if known	Reported outbreaks last ten years	Number of cases/outbreaks	Cause of outbreak*

**Changes in water flows, flood or drought, higher temperatures, infrastructure damage, contamination from soil or animal sector and/or sewage leakages, see Appendix 1.*

Guidance checklist 15: Climate change and drinking water quality

- To what extent is tap water used as drinking water (baseline description)?
  - If a large proportion: Pay extra attention in the assessment to effects caused by damage to infrastructure, like water plants, water pipes, power outages from storms, flooding, landslides, etc; leakage of sewage into water sources/ water pies; and contamination of water sources with soil and animal pathogens from changes in water flows, etc.
- What proportion of the population uses private drinking water sources (baseline description)?
  - If a large proportion: Pay extra attention in the assessment to changes in water flows causing contamination of water sources with soil and animal pathogens.
- Describe current surveillance of disease outbreak (baseline description). What are the implications of climate change for future monitoring and surveillance?

List 4: Specific risk groups: Drinking water-related disease outbreaks

- If water sources get contaminated: Households and businesses using private water sources and wells for drinking water.
- If tap water gets contaminated: Household members and businesses using tap water as drinking water or for washing fruit and vegetables that will not be cooked.

Guidance checklist 16: Climate change and outdoor bathing water quality

- Identify sites frequently used for outdoor bathing (baseline description).
- In which of these areas will there be increases in heavy rain events and increased water and soil flows?
- Is the site close to pastures or other types of animal keeping areas (which increases the risk of pathogens leaking into the waters)?
- Are there any continuous water quality controls of water bodies used for swimming and bathing? Who is responsible for such controls (baseline description)?
- Describe current surveillance of outbreaks linked to recreational waters (baseline description).
- What are the implications of climate change for the above issues (assessment)?

7.3.3 Vector- and rodent-borne diseases

When assessing the impact of climate change on different vector- and rodent-borne diseases, any of the methods described in section 7.4 can be used. However, vector-borne diseases cannot be evaluated as a group. Each disease has to be assessed by itself as epidemiological and ecological conditions for each of the diseases differ markedly (see Chapter 3, Appendix 1) and the scientific literature.

For some vector-borne diseases—chikungunya, dengue fever, malaria, TBE, and Rift Valley fever, to name a few—different scientific groups have tried to developed scenario models that show changes in disease risk from climate change for different time periods, (see Appendices 1 and 5). The uncertainties of the outcomes are often significant and depend on the methods and variables used. However, such maps are a useful indication of what may happen in different parts of a country due to climate change.

Guidance checklist 17: Current epidemiological situation for different types of diseases and possible relationships between observed changes in incidence, seasonality, geographical distribution, and climate variables/variations (baseline description)

Tick-borne diseases: Disease	Incidence: Any trends?	Geographical distribution: Any changes?	Risk seasons: Any changes?

Insect-borne diseases: Human-vector-human transmission pathway disease	Incidence: Any trends?	Geographical distribution: Any changes?	Risk seasons: Any changes?

Insect-borne diseases: Zoonoses	Incidence: Any trends?	Geographical distribution: Any changes?	Risk seasons: Any changes?

Rodent-borne diseases: Disease	Incidence: Any trends	Geographical distribution: Any changes?	Risk seasons: Any changes?

List 5: Specific risk groups: Vector- and rodent-borne diseases

- Tick-borne diseases: People working and living in tick infested areas, such as forests and pastures. However, infected ticks are frequently found in city parks and sub-urban gardens in endemic regions as well.
- Dengue haemorrhagic fever: Children are more prone than adults to develop dengue hemorrhagic fever if re-infected with another dengue virus strain.
- Visceral leishmaniasis: HIV-infected individuals have a high mortality risk if infected with the parasite that causes visceral leishmaniasis. Mean survival is only 13 months.
- Toxoplasmosis: Immune-suppressed people are especially susceptible to toxoplasmosis.

7.4 Analysis methods

Often it is not necessary to perform specific epidemiological, laboratory or statistical analysis on the potential relationships between climate variables and different communicable diseases for the assessment. Scientific literature can often provide the background knowledge needed to proceed with the assessment of future risks from climate change. Nevertheless, knowledge gaps often exist; in particular when it comes to the combination of climate, disease and specific conditions prevailing in different parts of a country. If so, consider including such studies in the assessment process (see Chapter 5).

With enough background material to proceed with future projections, however, two main approaches can be used:

- theoretical extrapolations of weighted impacts based on local conditions; or
- forecasting by analogy, which includes learning from conditions in countries that currently have a climate that may develop in the assessed country in the future.

7.4.1 Theoretical extrapolations: expert judgements and risk plotting

The following method can be used to evaluate the risk for each infectious disease (whether water-, food-, vector-, or rodent-borne disease) or for a group of diseases based on causation (waterborne outbreaks related to contamination with sewage, for example). The method is easy to use and provides an outcome that gives the combined weighted risk of climate change based on the probability of an outbreak, or the strength of the climate-disease relationship, in relation to the burden on the society or for a specific risk group [20].

Guidance checklist 18: Theoretical extrapolations. Step 1: Identify which infectious diseases may be affected by climate change in different parts of the assessed country

- Using sections 7.1 and 7.3, Chapters 2–3 and Appendix 1, identify the following:
  - how the climate will change in different parts of the country being assessed over the chosen time periods; and
  - endemic, climate-sensitive diseases that should be included in the analysis.
- Are there any communicable diseases in neighbouring regions that may become established in the country being assessed due to climate change?
- For each disease/group of diseases, identify the climate variables/parameters that are related to this disease and get scenario maps for these climate variables (see section 7.2). Evaluate how the risk of this disease/group of diseases may change in the future with climate change by combining the following:
  - A) the baseline description in section 7.1
  - B) the findings in section 7.3
  - C) the climate scenario maps

If climate change is postulated, disease scenarios exist for the disease being evaluated (e.g. for chikungunya fever). Skip the previous suggestion and use the maps produced by these models instead.

Guidance checklist 19: Theoretical extrapolations. Step 2: Evaluate the seriousness of the disease

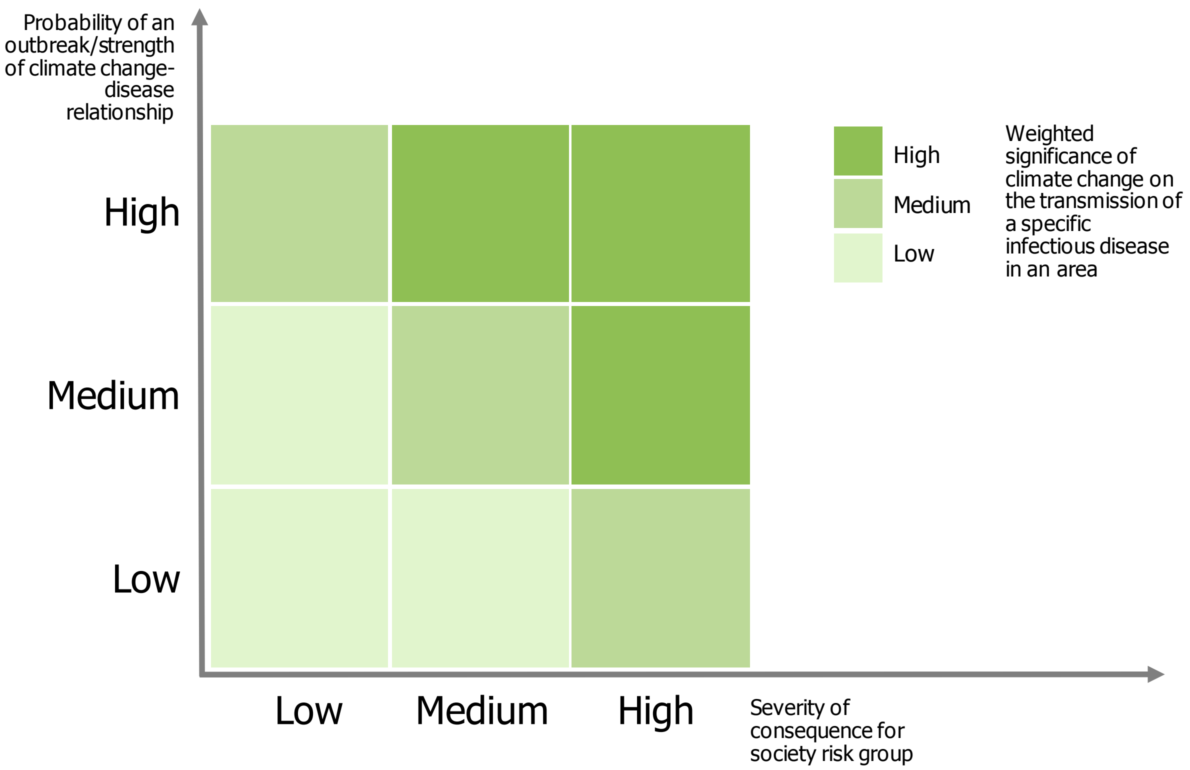
- Estimate how severe the disease is based on the following factors:
  - annual number of cases or outbreaks (food- and waterborne diseases);
  - incidence (vector- and rodent-borne diseases); and

  - severity and length of symptoms and symptoms at rest, need of hospital care, loss of disability-adjusted life years DALYs*, the costs for the society etc.
- Identify vulnerable and specific risk groups in different parts of the country being assessed, (see sections 7.1 and 7.3). Repeat the steps from the bullet points above.

Guidance checklist 20: Theoretical extrapolations. Step 3: Risk plotting

- Y-axis: Based on Step 1 above, estimate on a scale (low-medium-high) the strength of the relationship between climate change and the disease/group of diseases; that is, the strength of the possibility that climate change will affect the transmission of this disease/group of diseases in your country. Plot the value on the y-axis.
- X-axis: Based on Step 2 above, estimate on a scale (low-medium-high) the seriousness of the consequences of this disease; that is, the effect on society at large or for a specific risk group. Plot this on the x-axis.
- Combined impact: Note the colour-code and position of the mark (see Figure 6). This shows the combined weighted impact of climate change on the transmission of this disease/group of diseases giving local vulnerability (see section 7.3.3).

Figure 6: Diagram for plotting the weighted significance of climate change for different infectious diseases in a country.



* DALYs are a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health.

7.4.2 Forecasting by analogy: learning from current conditions in other areas/countries

Guidance checklist 21: Step-by-step instructions

- Step 1: Identify how the climate will change (monthly temperatures, length of seasons, precipitation amounts, extreme events, etc) in the country being assessed within the time periods chosen (Chapter 1 and section 7.2).
- Step 2: Identify a country, as close as possible to the one being assessed, that currently has the climatic conditions described in step 1, and that is similar to your country in important vulnerability aspects (based on your baseline description in section 7.1).
- Step 3: What are currently the main climate-sensitive infectious diseases in that country (Chapter 2, Appendix 1, section 7.1 and 7.3)?
- Step 4: How does this epidemiological panorama differ from current conditions in the assessed country?
- Step 5: How are the diseases identified in step 3 currently monitored and controlled in that country (step 2)?
- Step 6: Have there been any major infectious disease outbreaks in this country (step 2) that were climate-related (section 7.3.3)? How were these outbreaks managed?
- Step 7: Have there been any observed changes in geographical distribution, seasonality and incidence trends in vector- and rodent-borne diseases over the last 15 years (section 7.3.3)?
- Step 8: Combine the data and knowledge from steps 1–7 and analyse them. Draw conclusions and make theoretical projections on how climate change may impact infectious disease transmission in your country in the time periods included in the assessment (section 7.2).

8 Identifying and prioritising adaptation options and developing an action plan

Effective adaptation addresses both the current health risks of climate change and how these risks are likely to change in the future. The foundation of the adaptation assessment includes the current burden of infectious diseases, sources of vulnerability for these risks, programs and activities to address these risks and projections of the possible impacts of climate change on disease burdens. Therefore, the adaptation assessment builds on the questions raised in the previous sections.

Representatives of all potentially affected groups should be included in an adaptation assessment to ensure that all possible options are identified, provide input into prioritising options for immediate action and increase community buy-in for the options implemented.

8.1 Identifying adaptation options

The first step in an assessment is to identify possible adaptation options. In consultation with stakeholders, a portfolio of possible adaptation options can be developed. It is important to consider the robustness of programs concerning current climate variability and climate change. In many cases, current programs and activities are not sufficiently equipped to deal with extreme weather events; recommendations could include alterations, expanding their effectiveness under increasing climate variability.

Guidance checklist 22: Questions to address in the assessment of adaptation options reducing the current and future health risks of climate change

- Will current programs and activities be sufficient to address any additional health risks of climate variability change?
- If not, what adjustments to these programs and activities are needed? Where and when should these adjustments be implemented? Who is involved in implementing and maintaining these options? What human and financial resources are needed to implement these options?
- Are there new adaptation options that would increase resilience to climate change?
- Are there options that could become available with additional research and development?

The specific questions depend on the results of the baseline assessment for each of the infectious diseases included in the assessment.

If there have been outbreaks that have originated outside of a country's borders, the assessment may need to consider appropriate activities meant to increase infectious disease controls. For example, if there were outbreaks of foodborne diseases from imported food where changing temperature or precipitation patterns likely contributed to pathogen introduction or replication, then the assessment should identify possible options for reducing the risks of future outbreaks.

8.2 Foodborne diseases

Guidance checklist 23: Programs to evaluate in the assessment of adaptation options addressing the risks of foodborne diseases under a changing climate

- Regulations (and compliance with those regulations) controlling the introduction and spread of foodborne diseases during food production, processing, transport and storage.
- Surveillance programs for foodborne disease outbreaks.
- Education programs on appropriate food handling.

8.3 Waterborne diseases

Guidance checklist 24: Programs to evaluate in the assessment of adaptation options addressing the risks of waterborne diseases under a changing climate

- Regulations (and compliance with those regulations) to control the introduction and spread of waterborne diseases in public drinking water sources.
- Surveillance programs for waterborne disease outbreaks.
- Early warning systems for beach closings and other sources of waterborne disease outbreaks.

8.4 Vector- and rodent-borne diseases

Vector-borne diseases cannot be evaluated as a group; each has to be assessed individually, as noted previously.

Guidance checklist 25: Programs to evaluate in the assessment of adaptation options addressing the risks of vector-borne diseases under a changing climate

- Vector control programs.
- Educational campaigns to increase awareness of the risks of a particular vector-borne disease and the actions needed to protect individuals from exposure to vectors.
- Vaccination programs for tick-borne encephalitis (TBE) (see vaccination box below).
- Surveillance programs.
- Early warning systems.

Each program should be evaluated for its possible effectiveness under changing climatic conditions. For example, should the geographic coverage of TBE vaccination be changed to reflect changing risks? How can that be accomplished under current programs? Are there areas where such changes should be made sooner?

Box 9. Vaccination

- Currently, the TBE vaccine is the only commercially available vaccine for vector-borne diseases in Europe. Subsidised TBE vaccination programs in Austria have proven very successful.
- Four dengue virus strains exist. If re-infected with another strain, dengue haemorrhagic fever (DHF) may develop, which makes it difficult to develop a safe vaccine. DHF causes high mortality in children.

8.5 Prioritising adaptation options

Given the broad range of climate-sensitive health outcomes that communities face, priorities will need to be set for which issues to tackle first.

Guidance checklist 26: Criteria that can be used to set priorities

- Significance or the relative importance of the anticipated impact, such as the possible burden of additional cases of infectious disease.
- Benefits and effectiveness or the degree to which the option would likely reduce vulnerability to the anticipated health or culture impact.

- Costs including operation and maintenance, administration and staffing, required equipment, etc.
- Effectiveness or whether the option can realistically be implemented in the context of current and planned programs and activities.

The benefits of the interventions should exceed their cost; however, stakeholders should agree on the metrics for measuring benefit. Stakeholders may want to include additional criteria, such as whether the proposed adaptation will reduce social inequities.

For each priority option, it is helpful to write a brief description of the option, including the following aspects: benefits and effectiveness for reducing vulnerability; the human and financial resources required; feasibility; and constraints to implementation. There should be a discussion of the current programs and measures designed to address the health outcome, and where and when modifications are needed to increase their effectiveness. This discussion should consider how to ensure active and continued stakeholder engagement, how to address changes in climate and vulnerability over time, how uncertainties in climate projections and development pathways can be incorporated, and finally social justice concerns.

8.6 Developing an adaptation plan

In order for health decision-makers and policy-makers to take action they need a summary of the process—stakeholders included—and priority adaptation options, including the more detailed descriptions. The precise format of the adaptation plan should be agreed upon early in the process so that all necessary information is obtained. The health decision-makers and policy-makers then develop integrated health and well-being strategies, policies and measures for climate change at the national, regional and community levels to manage the risks to health identified in the assessment.

Appendix 1: Climate change-related infectious diseases

This section consists of an overview of different types of relationships between climate and disease, and projections of how climate change may impact the transmission of main communicable diseases of concern. For in-depth knowledge, please see the scientific literature and web links in Appendix 5.

Airborne diseases

Outbreaks of certain airborne infectious diseases like influenza, the common cold, invasive meningococcal disease, and human respiratory syncytial virus (RSV) in children normally occur during the winter season in temperate regions. This seasonal pattern is probably more due to human behaviour (e.g. more people crowding indoors during winter) than specific climate variables. Some studies have linked factors, like humidity and ultraviolet B (UVB) radiation, with outbreaks (e.g. Kinlin et al 2009) but more research is needed before any conclusions about links between climate change in Europe and airborne infectious diseases can be drawn. However, if shorter winter seasons resulted in less indoor crowding, the risk of disease transmission would decrease. On the other hand hotter summers could, for example, contribute to the risk of acquiring legionellosis if the heat causes an increased use of cooling towers. This risk could be managed by the use of filters and adequate maintenance of operating units.

Foodborne diseases

Heat waves, as well as longer periods with higher summer temperatures, will increase the risk of outbreaks of some foodborne diseases. Many foodborne pathogens will increase their growth rate at higher temperatures, although some pathogens, like *Listeria*, can start growing at refrigerator temperatures. Studies from the UK have shown linear relationships between ambient temperatures and outbreaks of salmonella infection [21]. In general, the link between climate and foodborne outbreaks are probably most often due to improper production, storage, transport, handling and preparation of food at higher ambient temperatures. For example, the capacity of freezers, refrigerators and other cold storage devices can be exceeded during heat waves. Restaurants and consumers may leave food out for too long in high ambient temperatures at buffet settings or outdoor barbeques, for example. Heavy rainfall may cause irrigation water or agricultural products to become contaminated with pathogens from both soil and the animal sector. Control measures and targeted information are important actions to take to ensure future food safety in Europe.

Waterborne diseases

Climate change may affect the risk of outbreaks of waterborne diseases in several ways (see Chapter 8). Droughts may have negative effects on both water quantity and quality. Increases in temperature will cause increased growth of certain pathogens/parasites in water sources (including private drinking and recreational water sources) and in water pipes. The growth of bacteria, like *Vibrio vulnificus* and *Vibrio cholera* (non-O1 and non-O139), in the sea and brackish waters substantially increases at higher temperatures. Longer and hotter summers will also increase the risk of direct pathogen transmission as more people use recreational bathing sites.

Heavy rain may cause leakages of zoonotic and environmental pathogens (such as *Campylobacter*, *Salmonella*, *Cryptosporidium*, and *Yersinia)* into drinking water sources and recreational waters. Flooding and landslides can damage infrastructure (water treatment plants, electrical substations, etc), overload capacity or cause the leakage of sewage into water sources. The last example causes problems in areas where drinking water comes from the tap or private water sources.

Surveillance of food- and waterborne diseases has improved in the EU. However, the true scope of the problem is difficult to ascertain as several frequently occurring pathogens are not being monitored. In addition cases are largely underreported as, unless severe, most people do not seek medical attention for gastroenteritis symptoms [22].

Vector-borne diseases

Insects and ticks, as well as many pathogens and parasites, are directly sensitive to temperatures as they have no thermostatic regulation of their own. Climate change affects risk of disease by impacting the life-cycles of vectors; it also has a significant effect on the vector's natural environment and ecology, animals that are reservoirs for the pathogen, and human behaviour. Insects may use standing water caused by flooding as breeding grounds, and invasions of disease vectors in the aftermath have been reported.

Climate change will affect the following factors:

- the geographical distribution of vectors (northern, southern and altitudinal distribution);
- seasonality (risk periods); and
- incidence of disease (i.e., the risk of being bitten by an infected vector and developing symptoms);

Climate change will impact various vector-borne diseases differently because of differences in epidemiology and ecology. The main diseases of concern are described more in detail in the following sections.

Table 2: Vector- and rodent-borne diseases and pathogens that may be affected by climate change in Europe. Source: ECDC 2008 a,b [22,28].

Tick-borne	Mosquito-borne	Other insect-borne	Rodent-borne
Lyme borreliosis/ Lyme disease	Chikungunya fever	Leishmaniasis, visceral and cutaneous	Hanta viruses
Tick-borne encephalitis	Malaria*	Chandipura virus	Haemorrhagic fever with renal syndrome (HFRS)
Human ehrlichiosis	West Nile virus	Sicilian virus	Leptospirosis
Crimean-Congo haemorrhagic disease*	Tularaemia	Tularaemia	Nephropathia epidemica
Tularaemia	Yellow fever*	Toscana virus	Tularaemia
	Sindbis virus	Phlebotomus fever (Naples virus)	Plague*
	Tahyna virus		Lymphocytic choriomeningitis virus
			Cowpox virus
			Lassa fever*

**This disease is currently not prevalent in the European Union*

Tick-borne disease

Lyme borreliosis (LB) is the most common vector-borne disease in the EU region. The disease is not notifiable at the EU-level, but about 100 000 cases of LB are estimated to occur in Europe each year; still, this is probably a gross underestimate. The widespread occurrence of the disease and the risk of secondary complications can cause substantial morbidity and economic losses for the affected society.

In Europe, **tick-borne encephalitis** (TBE) and LB are transmitted by the tick *Ixodes ricinus* and, in north-eastern Europe (Finland and the Baltic States), by *Ixodes persulcatus*. Ticks can live for three years or more and are active when temperatures rise above 4–5°C. Snow cover and ground vegetation protect them during colder winters. Ticks will continue to expand their distribution limits further north and into higher altitudes with climate change (see Textbox 2 in Chapter 3). The risk of LB follows, more or less, the distribution of ticks close to these limits, as host and reservoir animals are already present in these locations (Jaenson et al. 2009). In endemic areas that currently have long winter seasons, climate change will lengthen the risk season of both LB and TBE. Currently TBE has a more limited distribution, which can be explained by the virus not occurring as frequently in nature as the Lyme bacteria. In endemic areas with year-round tick activity, the risk of disease will increase with conditions causing high vector densities but other conditions are also important, including land use and human behaviour [23]. In Southern Europe vector density, and thus LB and TBE risks, may decrease when locations become too dry for tick survival.

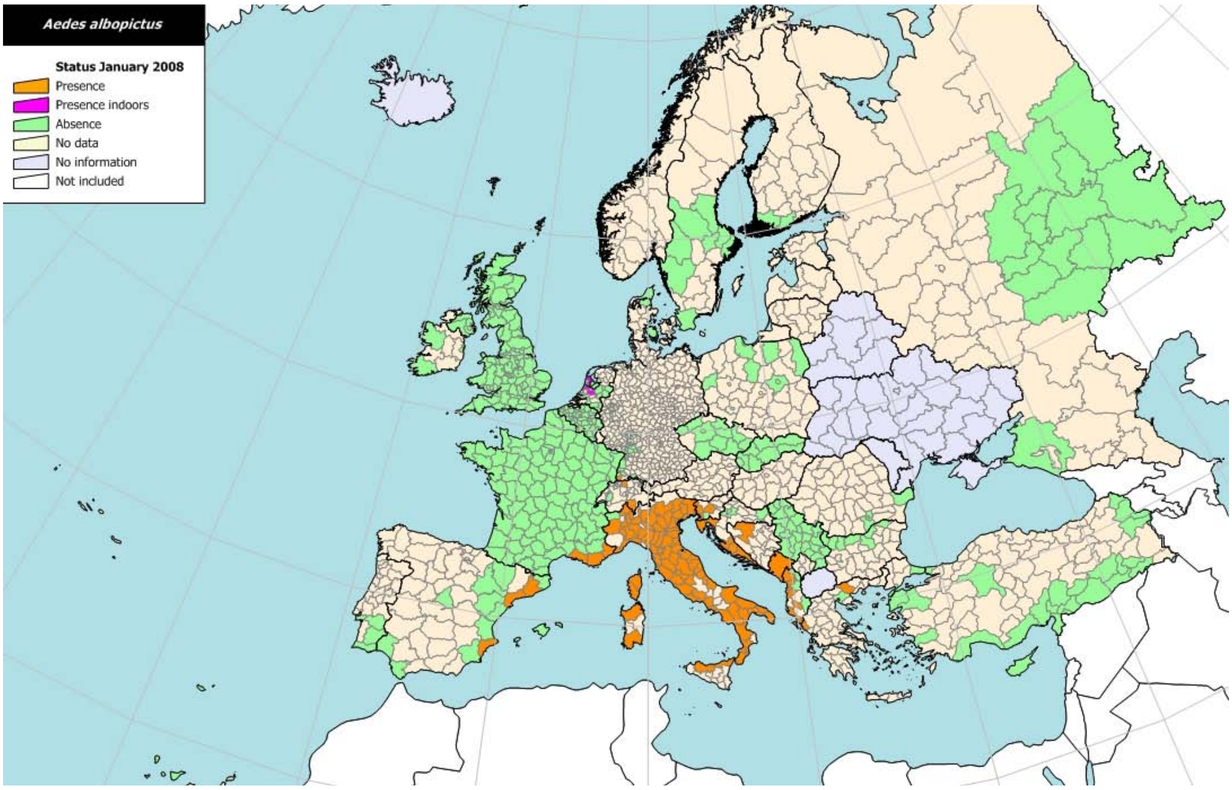
Mosquito-borne diseases: human-mosquito-human transmission pathways

Malaria has been eradicated from the EU and the prevalence of the disease is decreasing globally due to intense control programs. Several malaria mosquito species are still prevalent in Europe, including in southern Scandinavia where they overwinter indoors. Even if climate change would increase vector density and seasonal activity periods in parts of Europe, outbreaks of autochthonous malaria are not likely unless the region's health systems are collapsing. Malaria is notifiable at the EU-level.

The **chikungunya** virus caused an outbreak in Italy in 2007, and one of its vectors is now present in Europe (see Textbox 4, Chapter 3 for more details and ECDC 2008c). In endemic regions in Africa and Asia, the virus may be silent for decades and then cause epidemic outbreaks.

Dengue fever is transmitted by the same vector species as chikungunya. The main vector, *Aedes aegypti*, cannot survive in regions where the mean temperature of the coldest month is below 10°C (isotherm limit). A cold-resistant strain of another vector, the *Aedes albopictus* mosquito, is currently established in Europe (see Figure 7). It has been suggested that with the current climate this vector should be able to establish itself in the entire Mediterranean region and along the Atlantic coastal areas of Spain, Portugal and France [16]. Climate change will further increase the potential geographical distribution of this vector in Europe (web links to TIGER Maps in Appendix 5). However, for disease transmission to become established, long periods with temperatures that are high enough for virus replication within the vector population are required [15].

Figure 7: Distribution of *Aedes albopictus* in Europe 2008



Source ECDC 2008.

Mosquito-borne diseases: Animal-mosquito-human

West Nile virus (WNV) circulates among birds and mosquitoes, with many species involved. Humans are dead-end hosts. After an epidemic outbreak in Romania in 1996, West Nile fever (WNF) is now reportable at the EU level but only minor outbreaks (5–7 cases) have occurred in the region since. WNV was recently introduced into the US and is now spreading rapidly throughout the continent. Studies show that climatic conditions that favour high population densities of both birds and vectors in a location preceded major outbreaks [24].

Rift Valley fever is an African disease that can be transmitted by several mosquito species. Ruminants and humans are reservoirs. Surveillance is needed as Rift Valley fever may become a concern for Europe.

Sandfly-borne diseases

The visceral form of leishmaniasis (VL) is the most serious of the sandfly-borne diseases in Europe (see Textbox 3 in Chapter 3). Most VL cases are currently reported south of the 45°N latitude in Europe, but both sandflies and a few autochthonous cases have been recently found in mid-Western Germany. It is estimated that the geographical distribution of this disease will change in Europe and follow changes in January and July isotherms [19].

Co-infection with HIV and the *Leishmania* parasite that causes VL results in a mean survival of only 13 months. Effectiveness of treatment of leishmaniasis is markedly reduced if co-infection with HIV exists. However, HAART treatment of HIV infection reduces the incidence of co-infections, but not of relapses of visceral leishmaniasis. The total number of people living with HIV in the EU is estimated to be 700 000. About 25–70% of adult VL cases in the EU are HIV infected. About 400–500 cases of HIV/*Leishmania* co-infection are reported annually in Europe [25]. Since the early 1990s, WHO has several VL/HIV surveillance centres in Southern Europe (Appendix 5).

Rodent-borne diseases

Rodents are involved in the transmission of a number of human diseases. Standing water contaminated with infected rodent urine and faeces after flooding has been, for example, linked to outbreaks of leptospirosis [26]. Prolonged droughts may decrease rodent population density. Rodents can shed pathogens in their urine and faeces and humans become infected after inhaling contaminated air droplets (Hanta viruses, nephropathia epidemica, tularaemia), or if exposed to contaminated waters (leptospirosis, tularaemia). In addition, rodents act as reservoirs for pathogens transmitted by fleas (plague) and other vectors (TBE, LB, tularaemia).

Changes in land use and specific ecological conditions, like the inter-annual interactions between rodent-predator populations present at northern latitudes, are important rodent population modifiers. Rodent populations are also affected by seasonal climatic conditions. Milder winters and prolonged vegetation periods may contribute to increased food availability and boost the chances of the rodents' survival. However winter survival may, in some areas, be negatively impacted by decreases in snow cover depths.

Below are tables showing the climate-sensitivity of the infectious diseases that are reported to the ECDC by the EU Member States [27].

Table 3a: Diseases preventable by vaccination

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	No	
Diphtheria		X	
Invasive Haemophilus type B infection		X	
Influenza[a]		X	Seasonality: Crowding is important (Europe). Studies suggest that virus inactivation outside hosts may have linkages to humidity, temperature and UV light
Measles		X	
Invasive meningococcal disease[b]		X	Seasonality: Crowding is important (Europe). Africa: Outbreaks linked to Harmattan winds. Studies suggest outbreak linkages to humidity, temperature, and possibly UV light
Mumps		X	
Pertussis		X	
Invasive pneumococcal infection		X	Seasonality: unclear
Poliomyelitis		X	
Rubella		X	
Smallpox		X	
Tetanus	[X]		Unlikely, but cases are possible if injuries due to extreme weather events occur

[a,b] *See also section on respiratory tract infections below*

Table 3b: HIV, sexually transmitted infections (STI) and blood-borne viral infections

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	No	
Chlamydia infections		X	
Gonococcal infections		X	
Hepatitis B		X	
Hepatitis C		X	
HIV-infections		X	
Syphilis		X	

Table 3c: Respiratory tract infections

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	No	
Avian influenza in humans		X	
Influenza		?	See Textbox 9
Legionellosis	X		Link to adaptation: cooling towers, etc.
Invasive meningococcal disease	?	?	See Textbox 9
Invasive pneumococcal infection		X	See Textbox 9
Severe acute respiratory syndrome (SARS)		X	Seasonality unclear
Tuberculosis		X	

Table 3d: Food- and waterborne diseases

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	No	
Botulism	X		Foodborne. Temperature linkage. Small risk, only if inadequate cold storage (vacuum-packed food) High water temp (lakes, sea) that causes increased risk of *C. botulinum* type E in fish
Brucellosis		X	
Campylobacteriosis	X		Linked to heavy rain
Cholera	X		Linked to heavy rain
Transmissible spongiform encephalopathies (TSE)		X	
Cryptosporidiosis	X		Linked to heavy rain
Echinococcosis		X	
Giardiasis	X		Linked to heavy rain
Verocytotoxinproducing *Escherichia coli* (VTEC)	X		Linked to heavy rain

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	No	
Hepatitis A	X		Linked to heavy rain
Listeriosis	[X]		Foodborne: Temperature linkage. Very small risk, only if inadequate cold storage and transport (as bacteria can grow at refrigerator temperatures)
Salmonellosis	X		Foodborne: Temperature linkage Waterborne: Linked to heavy rain
Shigellosis	X		Linked to heavy rain
Toxoplasmosis		?	Waterborne: Only one reported major outbreak (Canada): water source was contaminated by run-off with cat faecal matter from soil nearby
Trichinellosis		X	
Typhoid/paratyphoid fever	X		Linked to heavy rain
Yersiniosis	X		Foodborne: Temperature linkage, but small risk only if inadequate cold storage. Waterborne: Linked to heavy rain

Table 3e: Other diseases of zoonotic and environmental origin

Disease	Climate-sensitive		Climate change-related transmission route
	Yes	**No**	
Anthrax		X	
Leptospirosis	X		See rodent-borne section of Appendix 1
Q-Fever		X	Hypothesis: Drought and increased wind-risk of aerosol transmission may increase
Rabies		X	
Malaria	X		See vector-borne section of Appendix 1
Plague	[X]		Not prevalent in Europe. Hypothesis: Risk may increase with more rodents moving closer to humans (flooding and seasonal changes leading to increases in rodent populations)
Tularaemia	X		See rodent-borne section of Appendix 1
Viral haemorrhagic fevers (VHF) Dengue fever Yellow fever Hantaviruses	X		See vector-borne section of Appendix 1
West Nile virus	X		See vector-borne section of Appendix 1

Appendix 2: Management deliverables and public health functions

Table 4: Key management deliverables

Policy development	Partnership development	Knowledge generation and exchange
Facilitate the organisation of interdisciplinary forums of policy-makers and decision-makers to identify policy questions and research needs	Secure external funding, technical assistance and data sources to initiate and conduct an interdisciplinary assessment of health vulnerability and adaptation	Assess the utility and efficiency of various methods and tools to conduct the assessment and identify capacity limitations, resource needs and information gaps
Facilitate the development of a comprehensive and interdisciplinary assessment of health vulnerability and adaptation at the national level	Facilitate the organisation of key national and international stakeholders for an overarching steering group and interdisciplinary forums of researchers, policy analysts and decision-makers for working groups	Facilitate the organisation of interdisciplinary forums of researchers, policy analysts and decision-makers to identify research needs for generating knowledge and for promoting formal and informal dialogue
Organise interdisciplinary forums to set up a structured dialogue bringing research results forward to inform policy on health and well-being	Provide training resources and services for working group assessors and researchers	Develop effective ways of communicating research results to facilitate decision-making
Develop integrated health and well-being policies for climate change that effectively manage the risks to health	Facilitate electronic access to the knowledge generated, surveillance and monitoring data, information sources, and opportunities for dialogue	Assess and synthesise research findings
Facilitate the development of monitoring and evaluation mechanisms to respond to changing climate conditions, evolving health impact concerns and opportunities for adaptation	Facilitate the organisation of a multidisciplinary network of researchers to conduct peer reviews of assessment findings	Develop mechanisms for storing and retrieving information

Table 5: Public health functions as they relate to climate change and infectious diseases. Source: United Nations Economic Commission for Europe [10].

Function	Selected examples
Monitoring	a) Indicator-based surveillance: collection, (trend) analysis and interpretation of data related to climate change: • Routine data analysis from mandatory notification (e.g. the 49 infectious diseases and conditions notifiable at the EU level). • Pharmacy-based monitoring of prescription and non-prescription drug sales or health-related data preceding diagnosis. • Sentinel surveillance (collection and analysis of high quality and accurate data at a geographic location (TBE, LB, etc)). • Vector surveillance (monitor distribution of vectors e.g. *Ae. albopictus*). • Real-time surveillance (instantaneous data collection with dynamic and sequential data analysis; e.g. hospital admissions or dead bird surveillance). • Mortality from ID (monitor cause-specific deaths from infectious diseases based on medical records, autopsy reports, death certificates, etc). • Syndromic surveillance (e.g. monitor emergency room admissions for symptoms indicative of infectious diseases). b) Event-based epidemic intelligence; early identification of infectious disease threats related to climate change: • screening of (international) news media and other sources; • case reports (e.g. clinician-based reporting); • science watch (e.g. screening scientific reports for discoveries and new findings); and • interdisciplinary reporting on ID threats (e.g. from agriculture, industry, environment, etc).
Outbreak investigation and response	Diagnose and investigate health problems (e.g. newly emerging tropical diseases). Respond effectively and rapidly to prevent dispersion of outbreak (e.g. though water boil notice or insecticide spraying). Multi-sectoral response (e.g. public, private, commerce, faith-based, etc). Logistical support and adequate supplies (e.g. provisions for unusual outbreaks including antivirals, medications, vaccines, etc).
Inform, educate, empower	Develop communication strategies to disseminate timely, accurate and well organised information. Health education and health promotion (e.g. reduce occupational or recreational exposure to ticks through health behaviour changes). Food handling under hot weather conditions (e.g. promote refrigeration, thorough cooking, use of uncontaminated water and food, separation of cooked and raw food, etc). Vector control measures (e.g. integrated pest management, window screens, eliminate standing water). Personal vector protection (e.g. bed nets, protective clothing, insecticide use).
Foster interagency/ community partnerships	Connect different sectors (e.g. civil engineering and sanitation for drinking water quality). Connect different disciplines (e.g. entomologists with agronomist for vector surveillance and control). Reach out to stakeholders (e.g. wildlife, fishing, or hunting clubs, etc). Media advocacy (e.g. mass media vaccination campaign). Engage community leaders (e.g. of susceptible populations).
Develop policies	Include climate sensitive IDs on list of notifiable diseases. Land use and housing codes to minimise exposure. Adaptation and mitigation strategies. Emergency preparedness and management procedures at local, national and international levels.
Access to care	Link infected patients to health services. Treatment of infected patients to prevent outbreak propagation (e.g. malaria treatment). Prevention (vaccination; prophylaxis; travel medicine).

Function	Selected examples
Enforce laws and regulations	**IHR 2005:** early identification and reporting of events related to climate change that could constitute potential international crises. **Water protocol:** Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE) calls upon countries to protect water resources, drinking water and human health by providing sanitation and monitoring waterborne disease outbreaks. Enact regulations to minimise harmful exposures, including land use zoning laws (flood risk areas, habitat encroachment, etc), the protection of water distribution systems, housing codes, limits to the introduction of non-native species and their pathogens, etc.
Assure competent workforce	Train healthcare workforce (e.g. ability to diagnose chikungunya fever). Implement emergency preparedness training across different sectors (e.g. housing, social services, health, etc). Strengthen capacity of public health professionals.
Evaluate	Assess interventions to protect communities from adverse events related to climate change. Evaluate effectiveness, accessibility and quality of public health services.
Research	Basic and applied research on the relationship between infectious diseases ID and climate (e.g. establishment of baselines and longitudinal seroprevalence studies for trends). Mapping vector ecology/competence relative to a changing climate (e.g. risk maps). Promote studies on susceptible populations in high-risk areas (e.g. TBE in hunters). Develop diagnostic tests, vaccines and innovative solutions for vector alleviation (e.g. development, evaluation, and introduction of a dengue vaccine). Models of projections in particular burden of disease studies under different climatic, developmental and policy scenarios.

Appendix 3: Previous national assessments

Table 6: Examples of European vulnerability, impact and adaptation assessments that address the health effects of climate change

Country	Sectors included/Commissioning body	Comments and best practices with emphasis on infectious diseases
Denmark 2008	Coastal management, buildings and infrastructure, water supply, agriculture and forestry, fisheries, land use planning, health, rescue preparedness, insurance. Commissioned by the Danish government, coordinated by Ministry for Climate and Energy.	**Type of health analysis:** Brief overview discussion on the topic in general. Infectious diseases were not the main focus.
Finland 2003–2004	Agriculture and food production, forestry, fisheries, reindeer husbandry, game management, water resources, biodiversity, industry, energy, traffic, land use and communities, building, health, tourism and recreation, and insurance. Commissioned by the Finnish Parliament, coordinated by the Ministry of Agriculture and Forests in collaboration with an inter-ministerial task force (six departments), the Finnish Meteorological Institute and the Finnish Environment Institute. A draft adaptation strategy was submitted to a public hearing. After feedback from the ministerial committee, the strategy was adopted.	**Type of health analysis:** Literature review and expert judgement. Main focus on health impacts of extreme temperatures, but some main infectious diseases discussed.
France 2007	A national Observatory on the impacts of Climate Change (ONERC) was created in 2001 and reports each year directly to the prime minister and to Parliament ONERC includes all sectors, but the latest health report came in 2007.	**Type of health analysis:** Extensive literature review, expert judgement. Systematic evaluation of potential impacts for more than 20 main zoonoses.
Germany 2003–2005	Water management, agriculture, forestry, nature conservation, health, tourism and transport. Commissioned and financed by the Federal Environmental Agency. Conducted by the Potsdam Institute for Climate Impact Research.	**Type of health analysis:** Literature review. Expert judgement based on sector as well as regional-specific expertise. In-depth expert surveys from six federal states (representing different environmental zones) on sector-specific assessments of direct and indirect impacts, including specified infectious diseases. Questionnaire answers gave expert rating of possible impacts.
Italy 2007	Health sector. The assessment was a collaborative project between the Italian Agency for Environmental Protection and Technical Services and the WHO European Centre for Environment and Health.	**Type of health analysis:** Literature review. Expert judgement by the assessment team, and through two external expert meetings in the beginning and in the end of the project. No specific analysis for infectious diseases.
Netherlands 2005	Specific assessment for low-lying coastal regions and river basins. Sectors included: Natural environment, agriculture, recreation and tourism, transport sector, energy, water use, insurance, health. Compiled by the Environment Assessment Agency in collaboration with the Royal Netherlands Meteorological Institute, several scientific institutions, and coastal and inland water management institutes, at the request of the State Secretary for the Environment, with financial contributions from the Dutch research programme on climate change.	**Type of health analysis:** Expert judgements based on baseline epidemiology and literature review. No specific analysis for infectious diseases.
Norway 2009	Will start early autumn 2009	Planned to be finished in December 2009
Portugal 1999–2006	The health assessment is part of a large national scientific assessment, SIAM, first funded by national scientific funds and later also by the Portuguese Ministry of Cities, Spatial Planning and the Environment. SIAM has developed national climate scenarios and assessed the following sectors: fisheries, forestry and biodiversity, human health, water resources, agriculture, coastal zones, and energy. In 2006, the project added outreach sessions to its scientific activities where adaptation measures were discussed with representatives of government, academia, environmental NGOs, industry and other representatives of civil society.	**Type of health analysis:** The assessment consisted of an extensive literature review, a comprehensive baseline description and the expert judgement of health effects. This included infectious diseases and scenarios for selected vector-borne diseases: malaria, schistosomiasis, leishmaniasis, Lyme disease, and Mediterranean spotted fever (in addition to heat and air pollution). See also Textbox 7.

Country	Sectors included/Commissioning body	Comments and best practices with emphasis on infectious diseases
Spain 2005	The assessment covered climate change impacts on different natural systems as well as the following sectors: Terrestrial, inland aquatic and marine ecosystems, biodiversity, water resources, natural resources, coastal zones, climate-related hazards, fisheries, forestry, agriculture, energy sector, tourism, insurance, health. Performed by the Ministry of Environment in collaboration with the Spanish Office for Climate Change.	**Type of health analysis:** Expert judgement on general health topics. No specific analysis on infectious diseases.
Sweden 2005–2007	Transport and telecommunications, energy and technical support systems, development and buildings, tourism and rural businesses (forestry, agriculture, fishery, reindeer herding), the natural environment and environmental goals, health sector. The work was commissioned and funded by the Swedish Government, and coordinated by the Ministry of Environment. The working groups, steering committee and reviewers consisted of representatives from different ministries, governmental agencies, local stakeholders, policymakers, technical experts, and scientists from different disciplines.	The health group consisted of experts from the human and animal health sectors, animal keeping, and water management and water resources sectors (Textbox 6). **Type of health analysis:** Literature review, extensive baseline description, and expert judgement (statistical analysis performed only for heat waves). Cost assessments were included. Part 1 based the health assessments on the magnitude of climate change and its impacts on infrastructure, ecosystems, and on air, water and food quality. In Part 2 all infectious diseases in the country and surrounding regions were systemically evaluated and theoretical projections made.
Switzerland 2004	Health sector Commissioned and funded by the Federal Office for Environment, Forests and Landscape and the Federal Office of Public Health, and carried out by the Institute of Social and Preventive medicine.	**Type of health analysis:** Extensive literature review and general expert judgements.
United Kingdom 2001–2002 Update 2008	Health sector The Department of Health asked the Expert Group on Climate Change and Health in the UK to advise on the likely effects of climate change on health.	**Type of analysis:** Extensive literature review. Spatial analogies (used mainly for vector-borne diseases), predictive modelling (involving both biological and empirical-statistical models, used mainly for air pollutants) and the use of expert judgement throughout.
	The Department of Health commissioned a group of independent scientists to update the earlier report on the health effects of climate change published in 2001/2002.	A comprehensive updated review. Several new studies performed for the up-date, including predictive modelling for several vector-borne diseases.

Table 7: Examples and website access to national assessments

Country	Name of assessment report	Website to access the report
Denmark	Danish strategy for adaptation to a changing climate	http://193.88.185.141/Graphics/Publikationer/Klima_UK/klimatilpasningsstrategi_UK_web.pdf
Finland	Finland's National strategy for adaptation to climate change	http://www.mmm.fi/attachments/ymparisto/5kghLfz0d/MMMjulkaisu2005_1a.pdf
	Research project FINADAPT	FINADAPT
France	Changements climatiques et risques sanitaires en France. (in French) ONERC Report 2007 on health	http://www.ecologie.gouv.fr/IMG/pdf/Rapport_ONERC_version_site_27-09-07_-_1.67Mo.pdf
Germany	Climate change in Germany: Vulnerability and adaptation of climate sensitive sectors	http://www.umweltdaten.de/publikationen/fpdf-l/2974.pdf
Italy	Environment and health risks from climate change and variability in Italy	http://www.euro.who.int/document/E90707.pdf
Netherlands	The effects of climate change in the Netherlands	http://www.rivm.nl/bibliotheek/rapporten/773001037.pdf
Portugal	National assessment of human health effects of climate change in Portugal	http://www.siam.fc.ul.pt/SIAM_Book/8_HumanHealth.pdf
Spain	Principales conclusions de la evalución preliminar de los impactos on Españа por efecto del cambio climatic (Summary report in Spanish)	http://www.mma.es/portal/secciones/cambio_climatico/documentacion_cc/divulgacion/pdf/conclusiones_impactos.pdf
Sweden	The Commission on Climate and Vulnerability. Sweden facing climate change – threats and opportunities. (Summary in English, 700 pages)	http://www.sweden.gov.se/content/1/c6/09/60/02/56302ee7.pdf
	Health report in Swedish (Appendices 3 and 4)	Bilageforteckning B
Switzerland	Gesundheitliche Auswirkungen der Klimaänderung mit Relevanz für die Schweiz (in German)	http://www.bafu.admin.ch/klima/00509/00514/index.html?lang=de&download=NHzLpZig7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDd319hGym162dpYbUzd,Gpd6emK2Oz9aGodetmqaN19XI2IdvoaCVZ,s-.pdf
United Kingdom	Health effects of climate change in the UK	http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4108061.pdf
	Health Effects of Climate Change in the UK 2008. An update of the Department of Health report 2001/2002	http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_082836.pdf

Appendix 4: Alaska, a sub-national assessment

In the United States, the state of Alaska created a Climate Change Sub-Cabinet committee to advise the governor on the preparation and implementation of an Alaskan climate change strategy (for more info, click Alaskan climate change). A key activity included developing an assessment to address the following issues:

- building the state's knowledge of the actual and foreseeable effects of climate warming in Alaska;
- developing appropriate measures and polices to prepare communities in Alaska for the anticipated impacts from climate change; and
- providing guidance regarding Alaska's participation in regional and national efforts addressing causes and effects of climate change.

The Sub-Cabinet formed the Adaptation Advisory Group and asked it to focus on public infrastructure, health and culture, natural systems and economic activities. For each technical working group, a wide range of stakeholders were identified including state officials, researchers, clinicians, NGOs and private citizens. Over approximately one year, the health and culture working group identified all possible adaptation options to address current and likely future risks from climate change; prioritised the options into those requiring urgent and immediate action by the State; and wrote a description of each option for consideration by the Governor and legislature. The following three high priority adaptation options were identified for health:

- Augment surveillance and control programs for vector-, water- and foodborne diseases likely to become greater threats because of climate change. Develop educational programs for the public, healthcare providers, environmental staff and others on approaches to reduce emerging disease threats.
- Community health impact evaluations. Develop a tiered approach to evaluate recommended adaptation and mitigation options to determine whether they could result in adverse health impacts and, if so, to recommend approaches to reduce these risks.
- Assess sanitation and infrastructure risks from climate change. Assess sanitation infrastructure and practices at risk from flooding, thawing permafrost, and other risks or that is otherwise subject to changed conditions that significantly reduce performance in environmental health protection. Consider modification, rebuilding or relocation of sanitation infrastructure to protect human and environmental health.

Appendix 5: Data sources and web links

Table 8: Agencies, web links and data

Data	Agencies, registries	Web links
National data	WHO: National data	http://apps.who.int/whosis/data/Search.jsp
Demography	Eurostat: Population 2008	Total population
	Eurostat: Population projections 2008-2060	Population projections
	Eurostat: Population density	Population density
Land use/land cover	EEA: Corine data base	http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=3211
Bio-geographical regions	EEA	http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=3641 http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=221
Health systems	WHO: European Observatory on Health Systems and Policies: Country profiles	http://www.euro.who.int/observatory/Hits/TopPage
Epidemiology	ECDC: Data on infectious diseases reported to ECDC	http://ecdc.europa.eu/en/publications/Publications/0910_SUR_Annual_Epidemiological_Report_on_Communicable_Diseases_in_Europe.pdf
	WHO disease statistics	
	WHO: HIV/Leishmaniasis surveillance, LeishNet	http://www.who.int/leishmaniasis/surveillance/en/ http://www.who.int/leishmaniasis/home_leishnet/en/
	WHO: DengueNet	http://apps.who.int/globalatlas/default.asp
	WHO: Malaria surveillance and control	http://apps.who.int/malaria/ http://www.emro.who.int/rbm/index.htm
IPCC emission scenarios	IPCC	http://www.ipcc.ch/ipccreports/sres/emission/index.htm http://www.ipcc.ch/ipccreports/sres/emission/031.htm
Regional climate scenario maps	IPCC	http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf
	Hadley Centre	http://www.metoffice.gov.uk/climatechange/science/projections/
	EC: Climate, Ensembles project	http://www.ensembles-eu.org/
Maps: Climate parameters	EC: Climate, Ensembles project	http://www.ensembles-eu.org/
	Rossby Centre	http://www.smhi.se/sgn0106/if/rc/RC.htm
Climate change and infectious disease risk in Europe	ECDC	http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Food_Borne_Diseases.aspx http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Water_Borne_Diseases.aspx http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Vector_Borne_Diseases.aspx http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Rodent_Borne_Diseases.aspx
	Scientific data base	
	WHO	http://www.who.int/globalchange/en/ http://www.euro.who.int/eprise/main/WHO/Progs/GCH/Assessment/20070403_1

Data	**Agencies, registries**	**Web links**
Maps: Climate-disease scenario	ECDC Dengue maps	
	EDEN project Emerging diseases in Europe	http://www.eden-fp6project.net/
Scientific search engines		http://www.ncbi.nlm.nih.gov/sites/entrez?db=PubMed http://www.sciencedirect.com/
National reports	UNFCCC	http://unfccc.int/national_reports/items/1408.php
National assessments	WHO	http://www.euro.who.int/globalchange/Assessment/20020925_1

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