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This deliverable is based on a literature review of the health economics of climate change in Europe. It specifically reviews studies on the economic evaluation of health damage attributable to climate change impacts, as well as the benefits of adaptation and mitigation.

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List of Abbreviations

BAU: business as usual
BCR: benefit to cost ratio
CAFE: Clean Air for Europe
cCASHh: Climate Change and Adaptation Strategies for Human Health in Europe
CGE: computable general equilibrium
COI: cost of illness
CORDIS: European Commission Community Research and Development Information Service
CRED: Center for Research on the Epidemiology of Disasters
CSIRO: Commonwealth Scientific and Industrial Research Organization
DFO: Dartmouth flood observatory
ECDC: European Centre for Disease Prevention and Control
EEA: European Environment Agency
EEFSU: eastern Europe and former Soviet Union countries
EFAS: European Flood Awareness System
EFFIS: European Forest Fire Information System
EFSA: European Food Safety Authority
EU: European Union
EUMETNET: European Meteorological Services Network
EWS: early warning system
FUND: Climate Framework for Uncertainty, Negotiation and Distribution
GBP: British Pound
GDP: gross domestic product
GEM: generalized equilibrium model
GHG: greenhouse gases
GWP: gross world product
HVAC: heating, ventilation and air conditioning
ICS: improved cook stoves
IPCC: Intergovernmental Panel on Climate Change
LDCs: least developed countries
MEU: management effort units
NAPs: national adaptation plans
NAPAs: national adaptation programmes of action
NCAR: National Center for Atmospheric Research
NPV: net present value
OECD: Organisation for Economic Co-operation and Development
ONERC: Observatoire national sur les effets du réchauffement climatique
PESETA: Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis
PHASE: Public Health Adaptation Strategies to Extreme Weather Events
PHEWE: Assessment and prevention of acute health effects of weather conditions in Europe
PM2.5: particulate matter under 2.5 microns in diameter
PPM: parts per million
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analyses
RCP: representative concentration pathways
RIA: regulatory impact assessment
SRES: special report on emissions scenarios
TBE: tick-borne encephalitis
ULSJ: ultra low sulphur jet fuel
UN: United Nations
UNDESA: United Nations Department of Economic and Social Affairs
UNFCCC: United Nations Framework Convention on Climate Change

USD: United States dollar
VBD: vector-borne disease
VOLY: value of a life year
VSL: value of a statistical life
WASH: water, sanitation and hygiene
WHO: world health organization
WTP: willingness to pay

Executive Summary

Climate change is already affecting human health in Europe, directly, by changing weather patterns, and indirectly, by disrupting basic determinants of health such as safe drinking-water, clean air and food security and quality, and also by shifting patterns of both disease vectors and disease transmission. Because of the characteristics of urban agglomerations, city dwellers are especially vulnerable to some of the health impacts of climate change. Even while continuing to engage in significant greenhouse gas emissions reductions, governments and institutions, businesses and individuals must engage in adaptation and adequate responses in order to avert or minimize the share of health effects of climate impacts that are no longer avoidable. Many of the preventive actions needed to deal with the additional risks of climate change are fairly clear and agreed upon, and basically entail widening the coverage of proven and effective health interventions. Current shortfalls in health and public health systems at the global and European level leave several populations and groups exposed to climate impacts on health. Thus, strengthening basic public health services is critical to the efforts to adapt to climate change, particularly for vulnerable groups and poorer cities and countries of the European Region.

In addition to the human cost of climate change in terms of additional premature mortality and illness, the health impacts, if not averted, will entail a significant component of economic stress and loss to society. Policy-makers at the local and national levels need enough information to appraise the magnitude and nature of current and projected impacts of climate change and their implications for health: this enables preparation and implementation of a variety of responses to ensure optimal adaptation, coherent across different sectors and levels of government. Such a strategic approach requires an objective understanding of the full economic and financial impacts of climate change and the alternative and complementary actions available to respond to these health threats.

Hence, there is a crucial need for evidence on the economic cost of the health impacts of climate change and on the benefits and costs of health adaptation. To address this need, a literature review has been conducted within work package 6 (health) of the RAMSES study (Reconciling Adaptation, Mitigation and Sustainable Development for Cities). In this review of the economics of the health impacts of climate change and health-relevant adaptation, the traditional methodologies featuring systematic searches of scientific peer-reviewed literature databases were complemented with grey literature and additional search strategies. We found that despite the relative increase from previous reviews, the evidence base on the health economics of climate change remains scarce. Moreover, a substantial proportion of the evidence featured in reviews of the topic deals with the economics of past climate-induced health impacts, the economics of climate-sensitive exposures and outcomes, or with the economic implications of factors that are related to climate change, but are not a major direct cause or consequence thereof. A sizeable share of the relevant existing studies and reports are published in outlets and/or formats that can be categorized as “grey literature”, meaning published by entities whose primary activity is not publishing, including reports by national and international organizations, think-tanks and non-profit organizations.

With regard to the findings of these studies, we found that:

- most studies on the cost of health damage of climate change show very steep health costs of climate change impacts in the absence of adaptation;
- most studies on the cost, cost–benefits and/or cost–effectiveness of health adaptation (measures to reduce or avert health damage from climate change) tend to show high health benefits per unit invested, with higher returns the earlier the action; and

- studies estimating economic benefits from health gains attributable to the reduction of pollutants associated with greenhouse gas emissions reductions tend to show substantial economic benefits due to reduced illness and premature deaths attributable to air pollution, although the break-even point can be approached quickly as investments tend to be substantial in this policy area.

These conclusions are in line with the published reviews on this topic. However, comparisons across studies in this area are difficult. Differences in geographical scope, outcomes considered, timeframes, evaluation metrics, discounting, population dynamics, and other parameters make generalizations and the ascertainment of patterns virtually unfeasible.

Despite its shortcomings, the existing evidence clearly indicates that more resources need to be allocated to averting the health impacts of climate change, particularly in the poorer countries of the region, which suffer from the highest vulnerability and the least climate resilience.

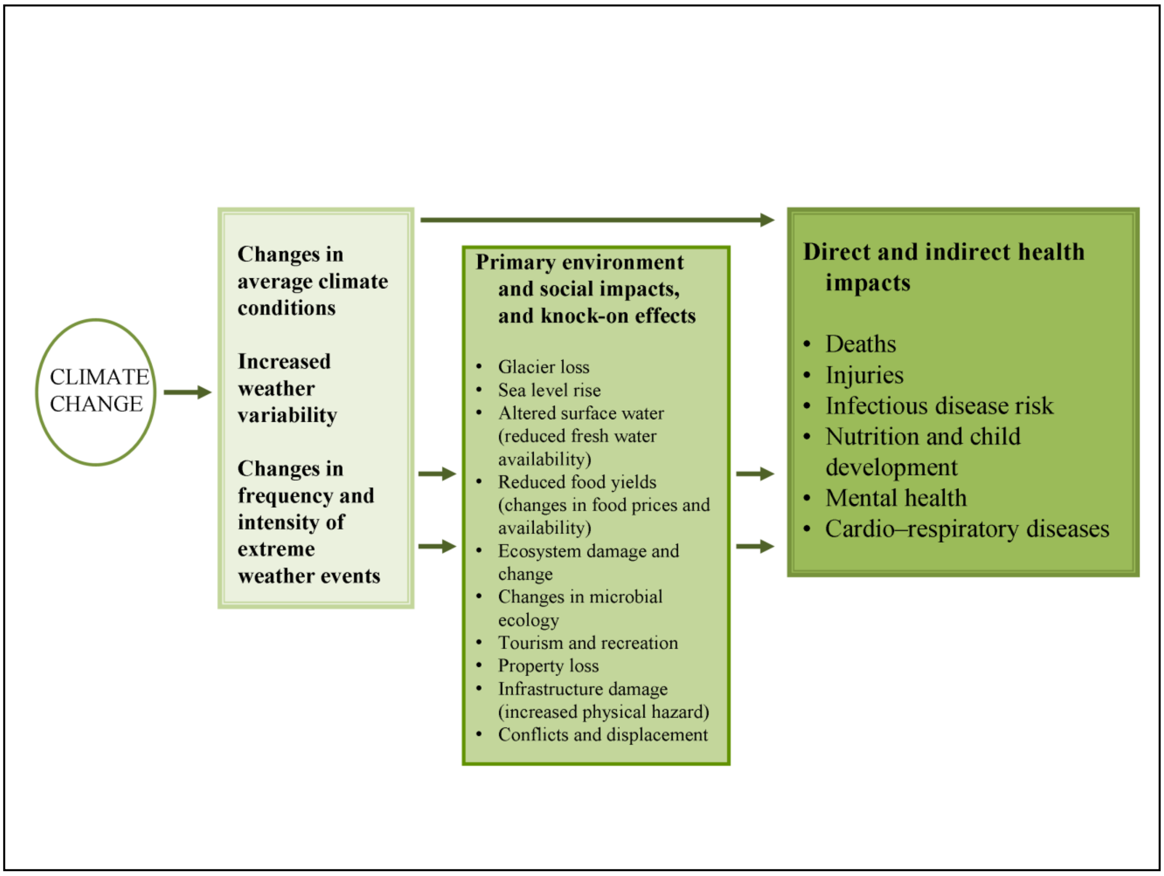
In summary, the evidence base on the health economics of climate change is scarce, incomplete and inconsistent. This is the case not only at the national and local level, but also at the European Union (EU) and pan-European level, in particular when including eastern Europe and former Soviet Union countries (EEFSU). A weak knowledge of the association of climate and climate change with several health outcomes partly explains the scarcity of economic evidence on the topic. While general trends are confidently predicted by increasingly accurate climate models, the evolution of several exposures and outcome-specific causal pathways in a context of high uncertainty still proves challenging for current modelling capabilities. In conclusion, more resources and attention are needed for research on this topic.

1 Introduction

1.1 Health, climate variability and climate change

Human health is sensitive to shifts in weather patterns and other climatic variability. While this association has long been known and studied by scientists, anthropogenic climate change has added a new dimension in terms of magnitude and urgency of action. Climate change has already affected human health over the last decades, directly by changing weather patterns (temperature, precipitation, rising sea levels and more frequent extreme events); indirectly by disrupting basic determinants of health like safe drinking-water, clean air and food security and quality; and also by shifting patterns of disease vectors and other effects in disease transmission (Smith et al., 2014; WHO, 2008). Fig. 1 illustrates some of the observed and expected health impacts of climate change.

Fig. 1 – Health impacts of climate change



Source: adapted from (McMichael, 2013)

Globally, the increases in some adverse health impacts are already large enough for reasonably certain attribution to recent climate change, while more significant effects are projected for the coming decades and centuries (Confalonieri et al., 2007). WHO (WHO, 2002) estimated a significant global burden of disease attributable to climate change by the year 2000, and extrapolated to 2010, 2020 and 2030. According to the Intergovernmental Panel on Climate Change (IPCC), if climate change continues along the projected "Representative Concentration Pathways" (RCP) scenarios, the major increases in climate-related illness will occur through (Smith et al., 2014):

- increased risk of injury, disease, and death due to more intense heat waves and fires;

- increased risk of undernutrition through diminished food production in poor regions;
- health consequences of reduced work capacity and labour productivity in vulnerable populations; and
- increased risk of water-borne, foodborne and vector-borne infectious diseases.

Along with these increased risks, small reductions in mortality and morbidity are expected due to fewer cold extremes, some decrease in vectors due to thermal exceedance, and geographical shifts in food production. These gains, however, will be outweighed by the other, globally negative health effects of climate change.

This list of health effects has changed little over time in the successive IPCC assessment reports (Confalonieri et al., 2007; Hashimoto et al., 1990; McMichael et al., 2001; Smith et al., 2014; Watson, Zinyowera, & Moss, 1995). Moreover, the main pattern of change regarding the evidence on health impacts of climate change in the IPCC report is the increase in the amount and quality of such evidence, and the ensuing progressive increase in certainty in the overall conclusions. Hence the health chapter in the fifth and latest IPCC assessment report (Smith et al., 2014), in which the main area of progress lies in the increased evidence on climate-related lost productivity and the potential health consequences of so-called “high-end” climate change scenarios (Woodward et al., 2014).

As climate change is by nature a global phenomenon, it is not easy to establish accurately its effect on determinants of health at regional or subregional levels. Moreover, with no correlation between bioclimatic and political subdivisions, there is no homogeneity in the climate change research publications about what falls within regional labels such as “the European Region” or “Europe”. Indeed, the geopolitical scope that lies within the regional labels is almost as varied as the studies in the available literature. This issue is addressed in the Discussion section. For the purposes of this introductory section, either “the European Region” or “Europe” refer to the World Health Organization (WHO) European Region because of its wide geographical scope. The WHO European Region comprises 53 Member States[1] with a very wide range of situations regarding climate impacts and influences, vulnerability and baseline population health status.

1.2 Urban health impacts of climate change in the European region

Urban populations are increasing in absolute numbers and relative to rural populations in every part of the world, including the European Region and the EU (EEA, 2014). Europe, with 73% of its population living in cities, is expected to become even more urban, reaching 80% by 2050 (UNDESA, 2014). In this context, it is worth exploring how this urbanization trend may interact with the complex causal network linking climate change and population health. However, this review does not focus on the health impacts of climate change in cities *per se*, but rather on the economic consequences thereof. Hence, the impacts and their expected change as a result of climate change are mentioned only for illustrative purposes; an extensive review of these impacts can be found through the references.

Against that background, the defining characteristics of urban agglomerations and to a certain extent urban populations could make city dwellers more vulnerable to some of the health impacts of climate change. Several cities are constructed in areas vulnerable to current and projected climate hazards, like coastlines or river banks. In addition, the materials and design of many cities (with reduced vegetation, large areas with sealed impermeable soil, and limited drainage channels) make city dwellers more vulnerable to

[1] List of countries available at http://www.euro.who.int/en/countries

climate extremes, including heatwaves and floods. Moreover, because of the concentration of population in cities, climate extremes in urban areas are likely to affect much larger numbers. In turn, this concentration lengthens supply lifelines of food, water, and energy, thus increasing their chances or disruption during or after climate extremes (Barata et al., 2011). Moreover, broader urban social determinants can further contribute to urban health vulnerability to climate impacts, including financial constraints in local governance, growing populations and income disparity, and informal settlements with poor or non-existent services (Hoornweg et al., 2011).

Researchers largely agree on the categories of health-relevant climate exposures that are likely to affect this region most (Smith et al., 2014; WHO, 2008): 1) heat and cold; 2) vector-borne diseases; 3) floods; 4) foodborne and water-borne infections; 5) poor air quality; 6) heavily human-mediated impacts such as mental health and occupational health issues. These categories are largely valid for both urban and rural areas, although the characteristics of urban agglomerations and populations influence the relevant causal pathways. Below is a short overview of the evidence by category.

1) Heat and cold: With regard to the study of the association between ambient heat and morbimortality in Europe, the 2003 summer heat waves were a defining event, leading to a considerable surge in research projects in this area. Section 5.2.1. of RAMSES deliverable 5.1 (Review of climate change losses and adaptation costs for case studies) provides more information on heat waves in the EU and surrounding countries (Robine et al., 2007) estimate these heat waves could have led to 70,000 excess deaths. The evidence from these studies of the association between heat and health impacts is robust (Analitis et al., 2014; D'Ippoliti et al., 2010; Leone et al., 2013; Michelozzi et al., 2009) especially concerning the observed increase in mortality and the risk factors that increase population vulnerability in cities. Exposure to environmental heat is exacerbated in urban agglomerations due to the comparative abundance of heat-absorbing surfaces and materials, a phenomenon known as "urban heat island" effect (UHI, 2014). Other factors, like household insulation and access to air conditioning, socioeconomic factors, and individual vulnerability, may be exacerbated for some specific urban populations or areas (Wolf, McGregor, & Analitis, 2009; Wolf & McGregor 2013). As to what proportion of these outcomes is driven by climate change, IPCC (Smith et al., 2014) acknowledges that climate change-driven increases in daily maximum temperatures may have already increased the number of heat-related deaths. (Christidis, Stott, & Brown, 2011) estimate that climate change might have at least quadrupled the risk of extreme summer heat events in the decade 1999-2008. Moreover, climate change scenarios almost unanimously project rising temperatures and an increase in frequency and intensity of heat waves globally (IPCC, 2013) and specifically in the WHO European Region. It is unclear how much the resulting health impacts might be minimized due to acclimatization (Baccini et al., 2011; Honda et al., 2013). It is also unclear whether milder winter temperatures in an overall more variable climate might lead to decreased cold-related deaths; the IPCC (Smith et al., 2014) concludes that by mid-century heat-related deaths will outweigh health gains due to fewer cold periods in temperate areas like Europe.

2) Vector-borne diseases: Diseases transmitted by the bite of blood-sucking arthropods, known collectively as vector-borne diseases (VBDs), are in general highly sensitive to climatic conditions, and thus affected by climate change. VBDs of current or potential concern in Europe include malaria, chikungunya, dengue, leishmaniasis, Crimean-Congo haemorrhagic fever, West Nile virus, tick-borne encephalitis and Lyme Borreliosis, among others. Rodent-borne diseases may also be affected by climate change (see Table 1 below).

Lyme Borreliosis, a disease transmitted by ticks, is the most common vector-borne disease in the EU region, with about 100,000 cases estimated to occur annually (Lindgren, Ebi, & Johannesson, 2010). The last decade has seen the first outbreaks of the mosquito-borne disease chikungunya fever and the first local transmission of dengue fever in Europe. Local transmission of dengue in Europe was reported for the first time in France and Croatia in 2010. In 2012, an outbreak of dengue in Madeira resulted in over 2,000 cases and imported cases were detected in 10 other countries in Europe (WHO, 2014). (Schaffner & Mathis, 2014) predict a further spread of *Aedes albopictus*, particularly under climate change conditions. The effect of urbanization in vector-borne diseases is still uncertain; on one hand, some vectors –notably ticks and several mosquito vectors- thrive less in urban areas. On the other, suburban sprawl might increase human-vector interaction in some cases. In addition, the mosquito vector of dengue fever breeds well in urban environments, particularly in poor and densely populated areas with deficient water supply (Beebe et al., 2009).

Regarding the projected impact of climate change on VBDs, this effect is highly dependent on the vector and disease themselves, aside from various other factors, and therefore generalizations are to be avoided. However, some trends can be reasonably expected. Warmer temperatures will facilitate an expansion of ticks northwards (in latitude) and upwards (in altitude) thus expanding the risk of infection to new areas (Lindgren et al., 2010).

Wherever tick activity happens year-round, conditions leading to higher vector density will increase disease risk, although actual disease occurrence will continue to depend on other factors including human behaviour (Sumilo et al., 2008). Similar patterns might affect mosquito populations, although transmission in both cases is highly dependent on the presence of other animal hosts.

Table 1 – Climate-sensitive Vector-borne and rodent-borne diseases in Europe.

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

Source: adapted from (Lindgren et al., 2010) * Disease not currently prevalent in Europe

Aedes albopictus, a mosquito vector of dengue and chikungunya currently present in southern Europe, may expand its range eastwards and northwards (Caminade et al., 2012; D Fischer, Thomas, Neteler, Tjaden, & Beierkuhnlein, 2014; Dominik Fischer et al., 2013), but that alone does not entail a high risk of dengue introduction. The northward expansion of vectors for visceral and cutaneous leishmaniasis (sandflies of the genus Phlebotomus) may be facilitated by climate change in the long term (Medlock et al., 2014; Ready, 2010).

3) Floods: Flooding is by far the most frequent of natural disasters in the WHO European Region, which has experienced in recent years some of the largest flooding events in its history (WHO, 2013a). Flooding has occurred in 50 of the 53 Member States in the WHO European Region during the past decade, with the most severe floods in Romania, the Russian Federation, Turkey and the United Kingdom of Great Britain and Northern Ireland (CRED, 2013). Section 3.2.1 of RAMSES deliverable 5.1 (Review of climate change losses and adaptation costs for case studies) provides more information on flooding in the EU and surrounding countries. The effects of flooding on health can be extensive and significant, ranging from mortality and injuries resulting from trauma and drowning to infectious diseases and mental health problems, both acute and long-term. However, the factual evidence of this association remains inadequate; the WHO Regional Office for Europe (WHO, 2013b) recently published a review of the health effects of floods in Europe, with extensive detail on the overall weakness of the existing epidemiological base. During the past 30 years, flooding has killed more than 200,000 people and affected more than 2.8 billion others worldwide. In the past 10 years, in the European Region, 1000 persons are reported to have been killed by floods and more than 3.4 million affected (Jakubicka, 2010). A review of European data for the years 2000–2011 shows that the number of deaths from flooding was highest in central Europe and the former Soviet Republics (CRED, 2013; DFO, 2013). Increased runoff due to large impermeable areas and limited drainage channels may increase the severity of flooding in cities. In addition, urban flooding tends to affect larger populations due to agglomeration (Ahern & Kovats, 2006).

It is unclear how much past flooding is directly related to climate change. However, models generally predict that heavy precipitation is likely to become more frequent throughout Europe. Even in summer, when the frequency of wet days is projected to decrease, the intensity of extreme rain may still increase. In addition, the frequency of precipitation over several days is projected to increase (Feyen et al., 2011; Frei et al., 2006; Kundzewicz et al., 2010). If no measures are taken, river flooding may affect 250,000–400,000 additional people per year in Europe by the 2080s, more than doubling the numbers from those in 1961–1990. The populations most severely affected will be those of central Europe and the British Isles (Ahern & Kovats, 2006). Coastal flooding due to increasing storms and rising sea levels may affect 775,000 to 5.5 million people annually by 2085 (J. C. Ciscar, 2009).

4) Foodborne and water-borne infections: Climate change may influence foodborne and water-borne diseases by influencing the pathogens, for example their growth, survival, transmission and virulence, or their environment, in local ecosystems or the habitat of zoonotic reservoirs (Smith et al., 2014). The evidence of climatic influence on food and water safety has increased in the last few years (Kovats et al., 2013). There is no clear distinctive pattern of foodborne and waterborne disease in urban versus rural areas. A positive relationship has been established between surface sea temperature and the abundance of Vibrio bacteria (the causal agent of cholera) in the North Sea (Vezzulli et al., 2012). Moreover, extreme weather conditions could foster the presence of harmful toxins or bacteria in seafood (Miraglia et al., 2009). Both the incidence of salmonellosis and its sensitivity to temperature have declined in recent years (Lake et al., 2009; Semenza & Menne, 2009). Post-harvest production of fungal toxin may be influenced by climate change, but the evidence is inconclusive (Paterson & Lima, 2010).

5) Poor air quality: Urban air pollution is the environmental factor that causes the largest burden of disease worldwide. WHO estimates that 3.7 million premature deaths annually were attributable to ambient air pollution in 2012; about 200,000 of those deaths occurred in the WHO European Region (WHO 2014). Several air pollutants have climate-altering properties, and conversely climate change is projected to enhance exposures to some air pollutants, notably tropospheric ozone (IPCC, 2013) of which even small increases of effective exposures may affect health (Bell, Peng, & Dominici, 2006). Aside from a direct effect in ozone production, climate change is projected to increase heat waves and drought in Europe, which in turn will increase the risk of wildfires and their associated acute episodes of exposure to particulate matter and other pollutants (Smith et al., 2014). In addition, warmer conditions favouring the production and release of air-borne allergens may have an effect on asthma, other allergic respiratory diseases, conjunctivitis and dermatitis (Beggs, 2010).

6) Mental health and occupational health issues: Harsher weather conditions may aggravate existing mental illness and increase its overall occurrence. Disaster-related conditions like post-traumatic stress and longer-term impacts such as generalized anxiety or depression may be affected either directly or indirectly by climate change related impacts (Berry, Bowen, & Kjellstrom, 2010). Further compounding the complexity of the association, the baseline status of mental health might be worse in communities that are more vulnerable to climate impacts such as extreme weather. Additionally, climate change can potentially increase several occupational exposures, including heat, resulting in heat exhaustion and/or heat stroke and possibly injuries, and exposure to vectors, resulting in vector-borne infections(Smith et al., 2014).

1.3 Protecting health from climate change in Europe

Albeit incomplete, the evidence clearly suggests that the atmospheric concentration of greenhouse gases will rise to levels that will have significant, wide-ranging, net negative health impacts in the WHO European Region during the 21st century. Even while continuing to engage in significant greenhouse gas (GHG) emission reductions, governments and institutions at all levels, businesses and individuals must engage in adaptation and adequate responses in order to avert or minimize the share of health effects from the climate impacts that are no longer avoidable. Specific responses include, for example, emergency response, disaster recovery and support to environmental refugees; strengthening health systems to treat diseases and health conditions as they occur; and preventive measures, such as safer housing, flood protection, vector control, improved surveillance, early warning information systems and community-based disaster risk reduction. However, beyond specific interventions, no effective protection can be achieved without a general framework for policy action.

Much has been written about what should be done to protect health from climate change (European Commission, 2013; Samet, 2009; Smith et al., 2014; WHO, 2008) and there is a relatively wide consensus among the specialized research community and institutional stakeholders on the main priorities and key interventions. These priorities and key interventions have been translated into policy commitments that can serve as frameworks for analysis and action. In the case of the WHO European Region, the European Regional Framework for Action “Protecting health in an environment challenged by climate change” (WHO, 2010a) is designed to support action by WHO Member States to protect health, promote health equity and security and provide healthy environments in a changing climate. Its five strategic objectives address all key aspects for health adaptation and healthy mitigation, and are fully consistent with other major strategies policy documents in the area (European Commission, 2013) despite obvious differences in scope and focus. Below is a summary of the main key strategic priorities.

1.3.1 Ensuring the integration of health in all relevant sectoral and climate policies

Health protection needs to be integrated as a key consideration from inception in all sectoral policies with potential to either aggravate or reduce climate change impacts, and specifically all current and future mitigation and adaptation climate change measures. In the words of the IPCC (Smith et al., 2014): "Other sectors, including ecosystems, water supply and sanitation, agriculture, infrastructure, energy and transportation, land use management, and others, play an important part in determining the risks of disease and injury resulting from climate change." Examples include urban planning to reduce outdoor and indoor heat exposure, community-based programmes that can increase climate resilience as a by-product, and revegetation of watersheds to improve water quality.

The case for the effect of general adaptation on health, and conversely for the integration of health considerations in all policies is particularly relevant for cities, since local policies affect city dwellers directly and often times the competencies of the local authorities are limited by regulations. Clear examples include the incorporation of climate change projections in building and land use local regulations and codes; hazard risk mapping and minimization; green urban landscaping for increased resilience and reduced climate impacts; and activities related to awareness and public education.

Throughout all possible interventions, the role of vulnerability and health impact assessments is crucial to ensure that health benefits are maximized and health impacts averted. Assessments should be carried out at all relevant levels, but especially at the national level, where evidence is crucial to enable policy-makers to plan for measures, strategies and policies to cope with climate change. Moreover, such information and assessments at national level are needed to feed into the international policy processes as national communications to the United Nations Framework Convention on Climate Change (UNFCCC). All relevant evidence should feed into government-approved national adaptation strategies, including health adaptation strategies and plans which could be standalone or part of the larger national strategy. In the WHO European Region, such strategies have been developed in Albania, Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Kyrgyzstan, Lithuania, Norway, Poland, the Russian Federation, Slovakia, Spain, Sweden, Switzerland, the former Yugoslav Republic of Macedonia, and the United Kingdom[2].

1.3.2 Strengthening health, social and environmental systems

Many of the preventive actions needed to deal with the additional risks of climate change are fairly clear and agreed upon, consisting basically of widening the coverage of proven and effective health interventions. Current shortfalls in health and public health systems at the global and European level leave several populations and groups exposed to climate impacts on health. Thus strengthening basic public health services is critical to the efforts to adapt to climate change particularly in poorer countries of the WHO European Region (WHO, 2008).

A very important adaptation measure entails enhanced surveillance of climate-sensitive diseases, including vector-borne, foodborne, water-borne, and zoonoses. At the EU level, the European Centre for Disease Prevention and Control (ECDC) coordinates the epidemiological surveillance of communicable diseases, including many climate-related diseases such as vector-, food- and water-borne diseases. In this regard, ECDC has undertaken vulnerability mapping for vector-borne diseases (Lindgren et al., 2010) (Rogers &

[2] The list is available at http://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/country-work/national-adaptation-strategies.

Hay, 2012), and has set up a European Environment and Epidemiology Network that will facilitate European early warning for climate-related disease events by supporting the risk assessment and rapid detection of emerging public health threats related to environmental factors. ECDC has also published a comprehensive risk assessment on the impact in the EU of climate change on food- and water-related diseases including salmonellosis, listeriosis, cryptosporidiosis and campylobacteriosis (ECDC, 2012). This work is supported by the European Food Safety Authority (EFSA), which is charged with coordinating data collection on zoonoses, antimicrobial resistance in food an animals, as well as food- and water-borne outbreaks. The role of local authorities in surveillance is highly variable, and generalizations for health adaptation are thus difficult. Another important element to protect health from climate-related impacts, specifically extreme weather, are early warning systems (EWSs). Currently, several of these systems for extreme weather exist at the national and regional level. Some examples include:

- flood risk forecasts, a key tool for effective health protection from flooding, are routinely prepared by many national meteorological services already. The European Flood Awareness System (EFAS)[3] is an EWS that uses satellite remote sensing to provide European overviews on ongoing and forecasted floods up to ten days in advance;
- heat wave EWSs successfully implemented in a number of European countries although the comprehensiveness of such plans varies widely (Bittner, Matthies, Dalbokova, & Menne, 2013).
- the European Forest Fire Information System (EFFIS)[4], which provides maps of forecasted fire danger in Europe up to six days in advance;
- These and other EWSs for extreme weather events are integrated in some general regional tools, for instance Meteoalarm[5] which provides severe weather warnings for Europe, and is maintained and operated European Meteorological Services Network (EUMETNET). In addition, the World Meteorological Organization (WMO) Public Weather Services web site[6] provides information on different forecasts and warning systems around the world.

EWSs are designed to deliver alerts at pre-set thresholds for national, subnational and local authorities and communities to take action. However, they are of limited use if ensuing measures are not planned for in advance. Comprehensive, all-hazard emergency plans are a fundamental basis for health protection during all emergencies, not just during extreme weather. Plans need to focus on health protection, and it is important that the health sector is involved from the inception phase. At the local level, it is important that authorities encourage proactive action by individual households and communities to reduce vulnerability.

Of particular importance for poorer countries in the WHO European Region is the improvement of basic social and environmental determinants of health. Environmental factors, notably air pollution, account for a large burden of disease in the Region, more so in the eastern Europe and central Asian areas. The complete provision of safe water and sanitation services and household disinfection in the poorest cities and countries of the Region would also decrease water-related burden of disease. In general, improving social welfare, promoting universal health coverage and particularly educating and empowering

[3] https://www.efas.eu/
[4] http://forest.jrc.ec.europa.eu/effis
[5] http://www.meteoalarm.eu
[6] http://www.wmo.int/pages/prog/amp/pwsp/index_en.html

women in developing countries, are not only fundamental to improving health standards, but are also essential for strengthening community resilience to climate change.

1.3.3 Encouraging healthy sectoral mitigation and adaptation

As mentioned earlier, health must be a key consideration in climate policy. Moreover, measures that both promote health and cut GHG are likely to gain broader support and be cost-beneficial if health benefits are considered in the evaluation. Several cities throughout the region have developed and implemented schemes to reduce GHG emissions, including energy conservation programs for buildings; renewable energy installations; promotion of modal shifts from private vehicles towards public transportation; revegetation and green roofing; pedestrianization; and bicycle lanes, among other initiatives. Measures that reduce GHG emissions could bring important health "co-benefits", for example through reduced air pollution. The IPCC (Smith et al., 2014) distinguishes the following categories of co-benefits:

- Reduced emissions of health-damaging pollutants in association with changes in energy production, energy efficiency, or control of landfills;
- Increased access to reproductive health services;
- Decreased meat consumption (especially from ruminants) and substitution of low-carbon healthy alternatives;
- Increased active transport particularly in urban areas; and
- Increased urban green-space.

However, sectoral climate-friendly policies can also bring collateral damages, for instance, the potential health side effects of certain mitigation measures, such as geo-engineering or biofuel expansion. In order to boost health co-benefits and minimize health co-damages of climate-friendly policies, strong intersectoral coordination is needed both for mitigation and adaptation.

In principle, every productive sector has potential for improvement in terms of mitigation. Health care is not an exception; it is a large sector of the economy in the WHO European Region, and it is energy-, resource- and carbon-intensive. There is potential for carbon reduction in health care improvement without compromising any of the core mandates of the health system. A recent survey by WHO (Wolf et al., 2014) showed that most countries in the WHO European Region are reporting activities pertaining to the "greening" of health services, meaning the improvement of services' overall, but mainly environmental, sustainability). This may suggest an increasing realization of the exemplary potential of the health sector in improving environmental performance. A better and more frequent evaluation of the effectiveness of the measures taken is needed, however. In addition, beyond resources and planning, it is crucial to engage in capacity building the health workforce, supported by the institutional environments.

1.3.4 Sharing best practice, research, data, information, technology and tools

In an increasingly integrated Europe (within and beyond the EU), sharing knowledge, data and tools is gaining importance as relevant inputs for policy planning. A recent WHO survey (Wolf et al., 2014) showed that the internet and regional platforms such as ClimateADAPT from the European Environment Agency (EEA)[7] seem to be preferred channels for the sharing of best practice in climate and health policy. City authorities in the European region have also been proactive in collectively engaging in climate action and sharing lessons learnt. Several of these initiatives (e.g. the covenant of mayors) are supported by

[7] http://climate-adapt.eea.europa.eu/

supranational organizations or international non-profit organizations. This is an important consideration when designing knowledge-dissemination strategies in this area. In line with this transnational flow of research and data, several EU-funded research projects addressing health impacts of and adaptation to climate change make results and tools freely and publicly available through institutional repositories. Examples of such projects are Improving Public Health Responses to extreme weather/heatwaves (EuroHEAT), Assessment and prevention of acute health effects of weather conditions in Europe (PHEWE), Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis (PESETA), and Public Health Adaptation Strategies to Extreme Weather Events (PHASE).

1.4 The economic dimension of the health impacts of, and adaptation to, climate change

Besides their inherent human cost, ill health and premature mortality represent real and significant economic costs to society. The health impacts of climate change, if not averted, will thus add a component of economic stress and losses. For adequate evidence-based planning of health protection under a changing climate, data need to include economic costs and benefits, and the research community has a responsibility to develop and apply appropriate methods and communicate findings.

In this regard, the basic techniques and methodologies used for the health economics evaluation of climate change impacts and adaptation have a relatively solid basis, since they greatly overlap with those routinely used in environmental health economics. These, in turn, are for the most part adapted from commonly used tools for the economic evaluation of disease and injury, which have been used for several decades with little conceptual change. (WHO, 2009) published a few years ago a methodological guide featuring a summarized overview of the most relevant methodologies in the field, which is the basis of this subsection. A detailed overview of tools and models is beyond the scope of this review and featured extensively elsewhere, so no further basic methodological discussion is addressed.

From the “microeconomic” perspective, health economics tools often rely on the valuation of the cost of morbidity and of premature mortality risk. The cost of morbidity, in turn, typically includes treatment and ancillary costs such as facilities and transportation as well as the cost of lost productive time either on account of sickness or care giving. The cost of premature mortality can be evaluated in several ways, but ultimately these methodologies either assume a loss of welfare to society associated to premature death (measured through willingness to pay), or an opportunity cost of such premature death in terms of foregone income, capital formation or both. In a so-called “full income” approach, health economics evaluations sometimes pool morbidity and mortality costs. However, given that the conceptual foundations of the measurement of lost welfare associated to premature mortality through willingness to pay are disputed, in principle the best practice would be to separately report market costs such as treatment and lost income, and nonmarket costs such as mortality.

As applied to the topic of the health economics of climate change, these tools change little, if at all; the climate change health impact and vulnerability assessment is a previous step, normally formally separate from the economic evaluation. The main current alternative analytical approach to the mentioned “microeconomic perspective” is to assess, for a whole economic system, the aggregate impact of climate-related disease and injury across different economic agents. These agents are individuals, firms and the government, who bear health costs to various extents. Typically, three areas related to current and future economic welfare

are included: health status, non-health consumption possibilities, and leisure time. In simple terms, the macroeconomic impact of disease and injury can be understood in terms of injections into and leakages out of the economic system. If the system is in equilibrium, the aggregate income by all economic agents should be equal to aggregate expenditure. For the total system output to remain constant, all leakages and injections should even out. So if injections are greater or smaller than leakages, the total output would increase or decrease respectively. Such interactions can be modelled in different ways. The most common categories are:

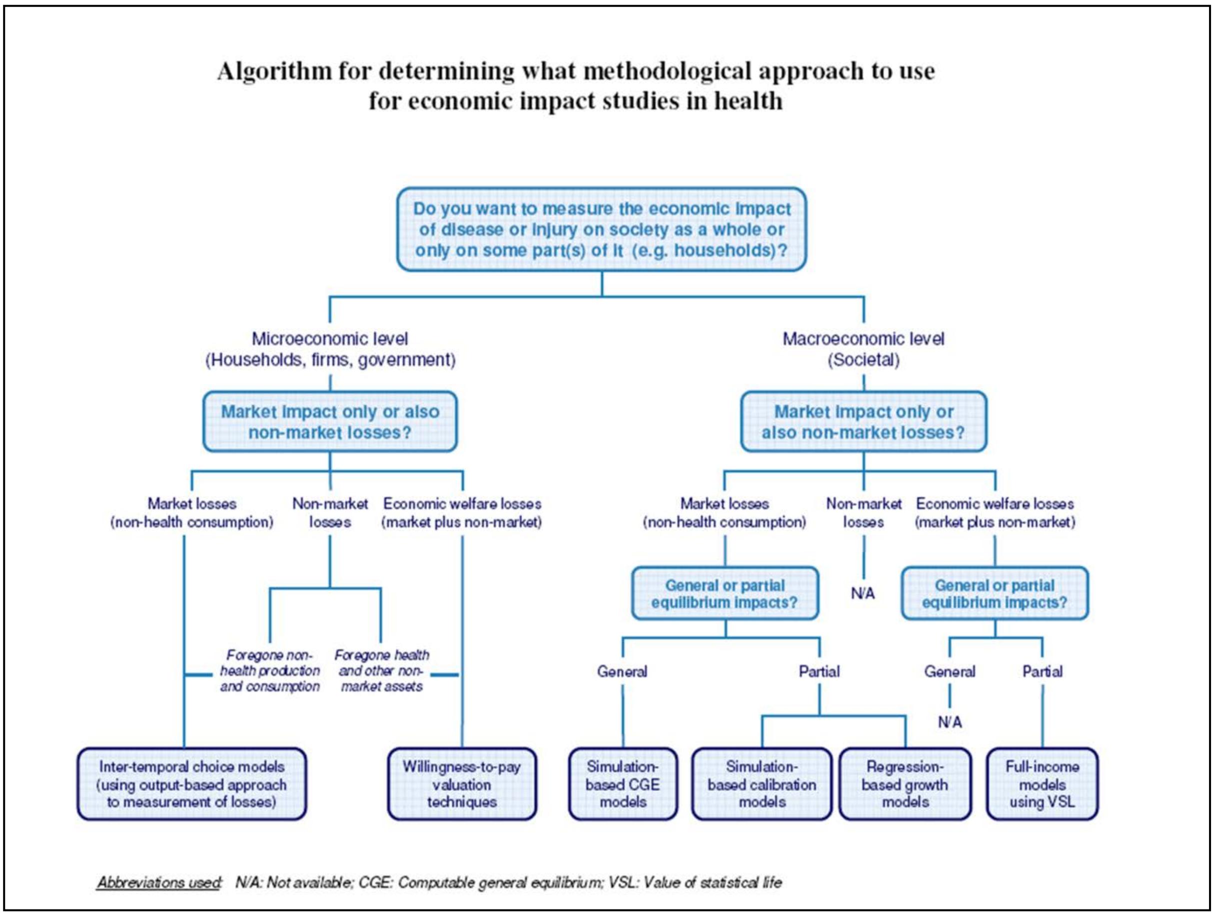
- regression-based estimation models, which try to derive empirical relations between health indicators and growth or GDP;
- simulation-based calibration models, which include intermediate factors such as labour supply or savings rates in the relationship between health and economic growth; and
- computable general equilibrium models, which attempt to simulate the impact of health "shocks" across all sectors of the market economy.

Ultimately, the health outcomes, behaviour and decisions of individuals determine the overall economy. What techniques are used for the valuation depends crucially on the availability of data, as well as on the scope of the study and ultimately the intended use of the results. An algorithm to determine which methodological choice is better suited for each analysis is presented in Fig. 2.

Once the economic valuation has taken place, whatever the methodological approach, the results will be welfare losses, monetized or unmonetized, and data on the distribution in time, space and society of the economic impacts analysed. However, data on losses and costs constitute only the starting point for evaluation and action. Policy-makers need enough information to appraise the magnitude and nature of the current and projected impacts of climate change and their implications for health and to prepare and implement a variety of responses to ensure optimal adaptation. Moreover, it is fundamental that the implemented adaptation measures are planned in a way that is coherent across different sectors and levels of government. This strategic approach requires an objective understanding of the full economic and financial impacts of climate change and the alternative and complementary actions available to respond to these health threats.

Specifically, adaptation planners should have estimates of the costs of inaction, the costs of action (health adaptation) and the costs of residual damage where relevant. This means taking account of the costs and benefits incurred by the various stakeholders, their interests and the relationships and flow of resources among them. It also means clarifying the types of economic impact: distinguishing between measures that require additional cash outlay, those requiring additional budget allocations or displacement of budget, and those that do not require additional cash outlay but have a clear and identifiable opportunity cost, in that the resources could be used in alternative activities. As for the specific tools to ascertain utility, value for money or effectiveness, the traditional frameworks of cost-utility analysis, cost–effectiveness analysis and cost–benefit analysis are also in this area the most widely used and methodologically appropriate tools.

Fig. 2 – Methodological approaches in health impact economic evaluation.



Source: (WHO, 2009) p.7

Many additional considerations, not specific to climate change but exacerbated by the nature of the problem, compound the economic analysis of health impacts of climate and adaptation. A very important one is the multiplication of uncertainty in the modelling steps involved: 1) modelling future climate change scenarios without certainty of human interventions; 2) the attribution of health impacts to climate influences via complex causal pathways; and 3) the uncertainties associated to economic estimations themselves. In addition, methodological choices like time preference and discounting can have very significant effects on results and their interpretation, particularly when dealing with very long-term scenarios and the welfare of future generations. Moreover, the distribution of climate change health impacts and economic consequences is a potentially very important aspect of the results on account of its important ethical and practical consequences, yet it is often ignored because of scarce data availability and analytical difficulties. All these challenges and methodological complexity characterize the research field explored in this review.

2 Methods

To identify relevant articles regarding the economics of the health impacts of climate change and health-relevant adaptation and mitigation, a systematic literature search was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) methodology (Moher et al., 2009) (Liberati et al., 2009). The PRISMA Statement was modified for use in this review (see Annex 1). Items pertaining to meta-analyses have been excluded and assessment of risk of bias across studies has also been removed, as this point is of little relevance to health economic literature. Unlike medical science literature, where negative studies can be commercially detrimental, health economic analyses can be valuable whether they show negative results (costs), positive results (benefits) or null results (no costs, no benefits). Therefore it is unlikely that publication bias is a significant issue for this review. The traditional methodologies based on a systematic search of peer-reviewed literature through scientific and technical databases were complemented in this review with grey literature and additional search strategies.

2.1 Eligibility criteria

Studies including economic analyses of the health impacts of climate change and health-relevant adaptation and mitigation within the 53 Member States of the WHO European Region were considered. The review included studies in the English language that involved economic modelling of a) the impacts of climate change and climate on health and b) health-relevant adaptation to climate change, both within and outside health services. Studies published between January 2004 and March 2014 were included. No publication status restrictions were imposed. We selected for analysis only studies that provided quantitative economic results on a) health impacts (monetized costs); b) health-relevant adaptation (monetized costs and benefits) to climate and climate change; c) monetized health benefits of mitigation or d) relevant methodological contributions.

2.2 Information sources

2.2.1 Scientific and technical journal databases

Scientific and technical peer-reviewed books and articles were identified by searching the following electronic databases:

- PubMed (http://www.ncbi.nlm.nih.gov/pubmed),
- Ovid MEDLINE (http://ovidsp.ovid.com),
- Web of Science (http://www.webofknowledge.com),
- Scopus (http://www.scopus.com/home.url),
- EconLit (http://www.ebscohost.com/academic/econlit), and
- RePEc IDEAS (http://ideas.repec.org).

2.2.2 Grey literature

In the topic of this literature review, a substantial amount of valuable evidence can be found in sources other than scientific commercially published peer-reviewed journals or books; in a category of publications often known collectively as “grey literature”. Several definitions of “grey literature” exist. For operational purposes, we used the one proposed by (Schöpfel, 2010): “…manifold document types produced at all levels of government, by academics, business and industry in print and electronic formats that are protected by intellectual property rights, of sufficient quality to be collected and preserved by library holdings or institutional repositories, but not controlled by commercial publishers i.e., where publishing is not the primary activity of the producing body".

Thus, not being published by "primary publishers" is the condition that defines grey literature in this review, and not whether it has been peer-reviewed or not, the latter being a trait commonly perceived as associated to grey literature. In fact, grey literature may include peer-reviewed and non-peer reviewed literature. Examples of peer-reviewed grey literature are documents published by agencies of the United Nations (UN), multilateral development banks and other international organizations. Non-peer reviewed grey literature are, for instance, blog entries or newspaper articles. Other examples of grey literature are conference proceedings, articles in newspapers, doctoral dissertations, master theses, blog entries, technical standards, patents, web objects, lecture notes, pre-prints, and statistics (Benzies et al., 2006; Newbold & Tillett, 2006). Relevant grey literature studies were identified through the following databases:

- OpenGrey (http://www.opengrey.eu), and
- the Grey Literature Report (http://www.greylit.org).

2.2.3 Additional sources of information

Publicly available databases and publications of international and European organizations were reviewed for relevant articles, including the World Bank, the UN, WHO, OECD, the EU[8], European Investment Bank, Economic Commission for Europe and the European Bank for Reconstruction and Development. In addition, we performed a "backward snowballing" search (Wohlin & Jalali, 2012) starting from the few available literature reviews in the field. That is, we identified from these articles relevant citations which we then searched for in the mentioned databases.

2.3 Search strategy and study selection

Databases for both peer-reviewed books and articles, and grey literature were searched from March to April 2014, with the last search run on 11th April, 2014. The following search terms were used to search all databases: climate change, health, health economics, economic, health impacts, health damage, costs, damage costs, economic costs, health adaptation, public health adaptation, adaptation costs, adaptation savings, adaptation planning and adaptation benefits. The results for each database and the combination of keywords used in the search strategy are presented in Annex 2.

Initially, all titles and abstracts of the retrieved articles were screened by a single reviewer using pre-defined eligibility criteria, described above. If no abstract was available for the retrieved article, then the full text was reviewed. If there was any uncertainty regarding appropriateness of the paper after reading the title and abstract, the full text was retrieved and checked for fulfilment of the eligibility criteria by two reviewers. Disagreements between reviewers were resolved by consensus; if consensus was not reached, the final decision on inclusion was to be taken by the lead author.

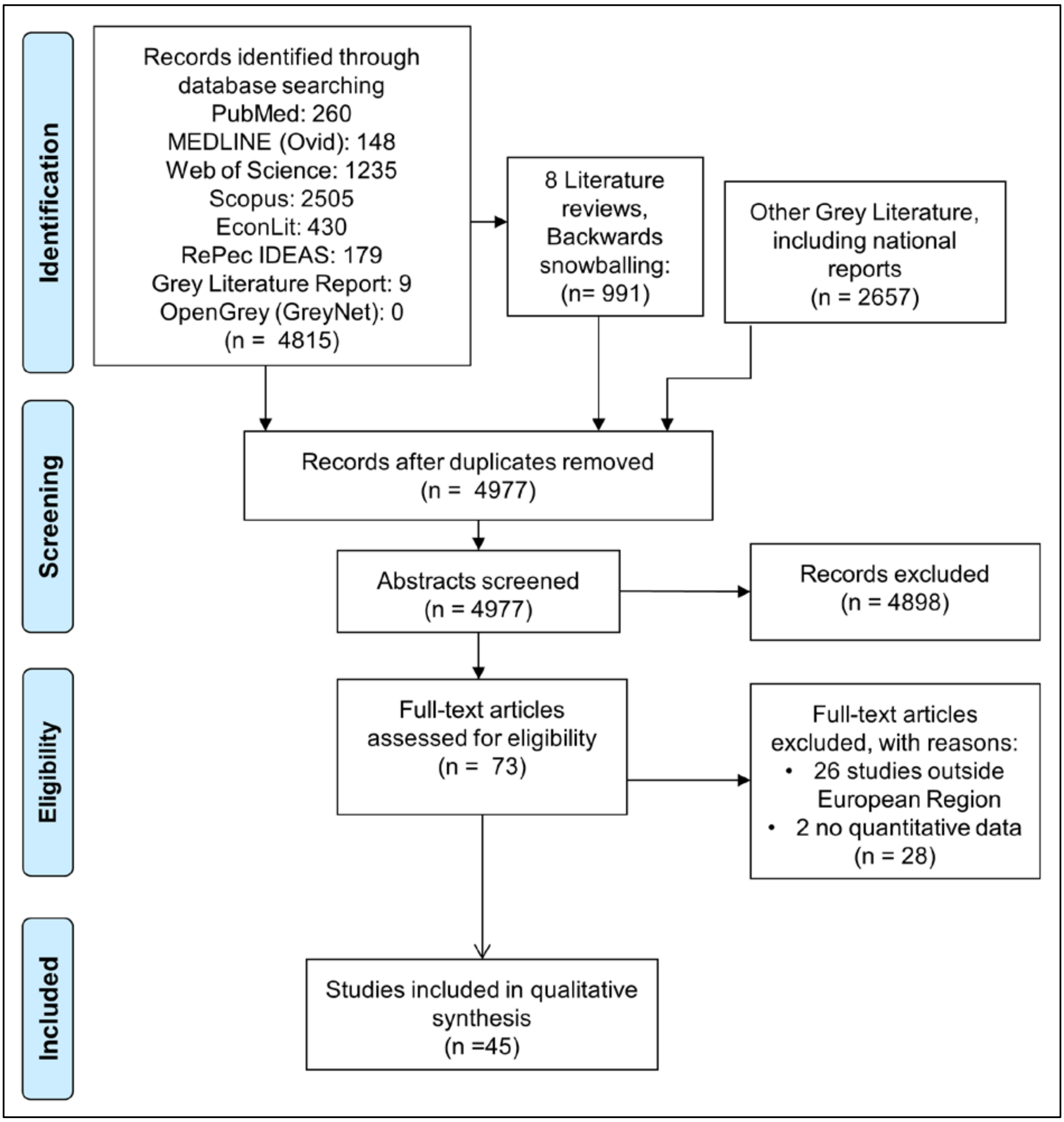
[8] The reader might be surprised to see EC-funded research results categorized as "grey literature". As long as these results are not published by primary publishers, they fit the operational definition of the methods section.

3 Results

3.1 Search results

After removing duplicates, a total of 4977 records were obtained through the combination of database searching and other sources (a combination of snowballing from other literature reviews and grey literature). Once those records were screened against eligibility criteria - see Methods section- only 73 records remained eligible. From those, 26 had a geographical focus outside the WHO European Region and 2 had no quantitative results and were thus discarded from further analysis. A total of 45 studies were included in the final qualitative assessment; the flow diagram of this process is represented in Fig. 3 below.

Fig. 3 – PRISMA flow diagram of the review



Source: adapted from (Liberati et al., 2009)

3.2 Study characteristics

The studies gathered through the search were categorized through a generic framework fitting the scope of the RAMSES project (reconciling adaptation and mitigation), distinguishing the following categories:

- Studies on the cost of health damage of climate change;
- Studies on the cost, cost–effectiveness and/or benefits of health adaptation, that is measures to reduce or avert health damage from climate change);
- Studies estimating economic benefits from health gains associated to the reduction of GHGs
- Reviews of the literature.

Granted, there are several more characteristics they could be classified by. For instance, they could be grouped according to their geographical focus (global, regional, national or subnational). Or they could be looked at from the methodological standpoint, namely whether health impacts and their economic consequences are ascertained through a bottom-up, largely microeconomic, methodology, or whether such impacts and economic consequences are modelled as factors affecting and being affected by whole economic systems. However, with the small final number of valid studies, all those characteristics could and were explored within the proposed framework. In addition, the means of publication of the studies also provides interesting information. Table 2 shows some details about such ancillary information on the studies:

Table 2 – Details of studies included in the analysis

Publishing category	Type of document	Number of studies
Published by primary publishers	Original research articles in scientific journals	19
	Review articles in scientific journals	4
	Other commercially published peer-reviewed studies	3
Grey literature	Reports authored or commissioned by international or supranational organizations	10
	Reports authored or commissioned by national organizations	4
	Other grey literature studies (think tank reports, reviews, working papers, etc.)	5

Very few of these studies could be categorized as specific to cities, although some focused more on impacts that are more severe in urban agglomerations (like exposure to heat waves and outdoor air pollution). It is noteworthy that almost half (19 out of 45) of the included references can be categorized as “grey literature” of various sorts, of which most were reports authored or commissioned by international organizations or national governmental agencies. On the other hand, obvious possible sources, like the national communications of governments to the UNFCCC, did not include valid evidence on this topic (see Annex 3).

3.3 Synthesis of results

3.3.1 Studies on the cost of health damage of climate change

The literature review identified a number of studies that, with a focus on the European Region, calculated either the economic cost of multiple health impacts, or those of a specific set of outcomes linked to climate change via a more or less direct causal pathway.

A key seminal reference in the European evidence base on the cost of the health impacts of climate change is the project Climate change and adaptation strategies for human health in Europe (cCASh) in which a contingent valuation survey (Alberini, Chiabai, & Nocella, 2006) was conducted in a sample of adults aged from 30 to 75 years old in the Czech Republic and Italy. More details on this and follow-up studies are analysed in RAMSES deliverable 5.1, Annex I, section 2.5. For the city of Rome, the monetized mortality damages of heat-waves in the absence of planned adaptation programmes in 2020 are estimated at €281 million (in 2004 euros). Capitalizing on the experience of contingent valuation for climate-related willingness to pay for mortality risk reduction, (Scasny & Alberini, 2012) conducted another contingent valuation relying on face-to-face and online administration of discrete choice experiments, obtaining a value of a statistical life (VSL) between €2.25 million and €2.55 million.

Further exploring the issue of the economic benefits of mortality risk reduction during heat waves, the PESETA project looked at exposure-specific single outcomes, specifically temperature (heat and cold) related mortality as well as salmonella infections and mild depression due to flooding. PESETA researchers projected about 27 000 annual heat-related additional deaths in the 2020s and 106 000 additional ones per year in 2071–2100 for 27 EU member states under a global mean temperature increase of 3.9 ^{0}C, compared to the baseline period 1961–1990, not taking into account possible acclimatization. For the 2020s without acclimatization, heat-related effects are valued at either €13 billion annually, using the value of a lost life-year (VOLY) method, or €30 billion applying the VSL approach (assuming that on average, eight years of life is lost per case). These costs drop to between €2 and €4 billion when acclimatization is included. In 2080, the annual cost of excess deaths is estimated at €50 billion annually (when valuing each excess death) and €120 billion (when valuing the loss of a year of life), dropping with acclimatization to €8 billion and €19 billion respectively. By 2100 under an A2 projection, the values range from €50–180 billion without acclimatization, and €8–80 billion a year with acclimatization. The greatest impact is in central southern Europe. Conversely, the decrease in cold-related mortality brings about annual savings of between €24 billion and €56 billion by the 2020s and between €41 billion and €96 billion by the 2080s (3.9 ^{0}C scenario) without acclimatization (i.e. decline in sensitivity of mortality to cold). The greatest gains in cold-related mortality reduction are in northern Europe and the British Isles (Ciscar, 2009), (Ciscar et al., 2011). For foodborne diseases, the PESETA study (Watkiss et al., 2009) estimates an average increase in the annual number of temperature-related cases of salmonella of almost 20,000 by the 2020s and 40,000 by the 2080s (Scenario A2) as a result of climate change in Europe (EU 27). That would lead to an increase in the valuation of the average annual number of temperature related cases of salmonella of between €70 billion and €140 million, by the 2020s. By the 2080s (Scenario A2) the increase in the valuation could be between €142 million and €284 million (Watkiss et al., 2009). These values are based on a cost per case of €3 500 and €7 000 respectively, in turn based on a review of willingness to pay studies to avoid foodborne disease in the literature. With regard to mild depression following coastal flooding, PESETA predicts 13,000 additional cases by the 2020s and up to 5 million additional cases by the 2080s (A2 scenario, high sea level rise). This could lead to potential costs of €1–1.4 billion a year (Watkiss et al., 2009).

The health assessment and health economic analysis in the PESETA II (J. Ciscar, Feyen, Lavalle, Soria, & Raes, 2014) project roughly confirmed those of the first PESETA, with slightly higher results: over 200,000 additional heat-related deaths under the reference scenario, and about 180,000 with a 2^{o}C scenario, with strongest impacts in central and southern Europe. Cold-related deaths were not included in the assessment. Importantly, from the overall calculated GDP impact of the eight sectors considered (around 1.8% net loss under the reference scenario, about 1.2% under a 2^{o}C scenario) about two thirds are related to health. That is to say, health losses are the largest net contribution to welfare loss brought about by climate change.

With many similarities to the PESETA methodologies, the final ClimateCost project report (Kovats et al., 2011) disaggregates effects by type of exposure.

- The Economic costs of heat-health effects, without acclimatization:
  1) using VOLY metrics are €2.8 billion per year in the 2050s for EU25 (A1B, no adaptation) rising to €4 billion per year in the 2080s, falling to €2.4 billion and €2.3 billion per year respectively under an E1 scenario; and
  2) using VSL metrics rather than life-years and VOLYs, the numbers are 30 to 50 times higher . For example, under the A1B scenario, the economic costs rise to €102 billion per year (2050s) and €146 billion per year (2080s).
- The economic costs of additional foodborne illnesses (in this case Salmonella) for the 2050s are estimated at €45 million per year for the EU for the A1B scenario under current baseline assumptions, falling to €30 million per year if a baseline decline in incidence is assumed.
- The estimated welfare costs associated with premature mortality due to coastal flooding are €700 million per year for the EU by the 2080s under the A1B scenario. These fall significantly under a mitigation scenario to 180 million under E1 for Europe in the 2080s, equivalent to €200 million per year.
- The estimated welfare costs associated with productivity losses in the 2080s, under the A1B scenario, are equivalent to around €750 million per year, though these fall to around €300 million if the workforce is assumed to move towards less intense occupations over time. These impacts are significantly reduced under the E1 scenario, to around 150 million per year (2080s, baseline).

Applying a General Equilibrium Model (GEM), (Bosello, Roson, & Tol, 2006) estimate health economic impacts within the economy-wide impacts of climate change globally and by region. The time horizon is 2050 and the types of outcomes considered are cardiovascular and respiratory disorders, diarrhoea, malaria, dengue fever and schistosomiasis. In the model, mortality and morbidity are traduced into changes in labour productivity and health care expenses, which in turn disturb the overall economy, as modelled in the GTAP-E computable general equilibrium model. For the European region, which in this model comprises the EU plus EEFSU, as defined in the original study, no cases of malaria, dengue or schistosomiasis cases are predicted, but around 176 000 net deaths are predicted from higher temperatures, of which the avoidance is valued at €38 billion annually in the EU area, and the approximately 284 000 avoided annual deaths in the EEFSU valued at €4 billion. The significantly lower economic value of morbimortality in the EEFSU is explained by the use of GDP per capita (significantly lower than in the EU) to value mortality risk reductions. An effect of reduction in cold-related cardiovascular death exceeding the increase in heat-related deaths is reported, but there is no intra-region distributional analysis to evaluate the true meaning of this “compensation”. As an overall result of the macroeconomic model, the study reports that the health impact on GDP is greater than the sum of the damage cost estimates of the three diseases.

On the health economics of air pollution under climate change, a recent report (Hutton, 2011a) analyses global air pollution health damage costs throughout a 150-year period, from 1900 to 2050. The study estimates the total damage costs of air pollution at $US 3 trillion in 2010, or 5.6% of the Gross World Product (GWP). Damage costs are divided almost equally between indoor and outdoor air pollution at the global level. The losses are equivalent to US$ 430 for every person on the planet, and around two thirds of the damages are to populations of developing countries. Health related damages account for 85% of the total. Global damage costs are on a decreasing trend, starting from around 23% of GWP in the year 1900, the damage costs are predicted to fall to below 3% of GWP by 2050.While results are not disaggregated for Europe, this study provides an interesting framework to look at other, Europe-specific results.

(Selin et al., 2009) estimated the population-weighted exposure to tropospheric ozone under the IPCC A1B scenario in 2000 to 2050, and the associated health and health economic consequences thereof. Health impact was calculated using the Massachusetts Institute of Technology Emissions Prediction and Policy Analysis – Health Effects (EPPA-HE) model, in combination with results from the Goddard Earth Observing System (GEOS) GEOS-Chem global tropospheric model. Health costs are based on cost of illness (COI) (direct and willingness to pay (WTP)) and mortality (value of a statistical life (VSL)) of respiratory diseases attributable to climate change. By their estimates, health costs due to global ozone pollution above pre-industrial levels by 2050 will be US$ 580 billion annually (year 2000 US dollars) and mortalities from acute exposure will exceed 2 million. The welfare loss associated with ozone concentrations over 10 ppb in western Europe by 2050 was calculated at US$ 96 billion (year 2000 US dollars) annually, in eastern Europe at US$ 14 billion, and in the former Soviet Union at US$ 33 billion.

On the health economics of climate-aggravated pollen exposure (assumed to increase the prevalence of allergic diseases), a noteworthy example of pragmatic evaluation is the study by (Richter et al., 2013). It models the climate change related spread of invasive ragweed (whose pollen is highly allergenic), the related increased in pollen exposure and the associated costs of treating allergic conditions triggered by the pollen, as well as lost work days. The authors estimated allergy-related costs of €291 million a year for the period 2011–2050. Then adaptation measures are proposed (ragweed survey and eradication) which would cost €15 million a year at an effort level of 50 management effort units (MEUs) defined by researchers. This adaptation would in turn reduce allergy costs to €82 million a year. Of additional interest in this study is the exploration of the diminishing returns of adaptation: researchers found that adaptation beyond 75 MEUs did not further reduce allergy costs. Regarding evidence on current costs and benefits of interventions against allergenic pollen, the clinical and treatment aspect is substantially better researched than environmental interventions, making the cost–effectiveness of the latter difficult to assess. Regarding vector-borne diseases, (Tol, 2008) applied the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model and projected no increase in morbimortality related to climate change influence on malaria, and consistently no negative effect in growth in western Europe, eastern Europe, or central Asia (definitions of these subregions were determined by the model and explained in the original study). This result is roughly confirmed in a subsequent application of the same model for both the 20th and 21st centuries (Tol & Estrada, 2013).

A national assessment was carried out by (Kovats & Lachowyz, 2006; Kovats et al., 2006) who estimated the cost of climate change-induced heat mortality at between £13 015 million and £37 040 million by the 2080s. On methodological matters, other examples of published studies addressing mortality costs from heat waves also provide very little value. A case in point is, as part of the project “Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects” (PRUDENCE), by (Halsnaes, Kuhl, & Olesen, 2007),the study of the health impacts of heat waves in Europe in which the attempt of monetization relies on a previous estimate of the 2003 heat waves’ additional mortality and a purely theoretical example VSL of €4 million. Thus, there is no research value in either component of the estimation. A better “back of the envelope” calculation is featured in another national-level study in Sweden (SCCV, 2007) where at least a sensitivity analysis is performed for heat-related deaths and infections.

3.3.2 Studies on the cost, cost–effectiveness and/or benefits of health adaptation

A subset of the studies addressed the health economics of adaptation (i.e. measures to reduce or avert health damage from climate change). Some of the studies addressing the cost of health adaptation in Europe are in fact global, with Europe being one region in a general worldwide model. Depending on the study, “Europe” denotes either the European Union member states, a broader concept including basically the WHO European Region minus Israel and Turkey, or an ad hoc regional definition.

For instance, (Ebi, 2008) looked at projected cases of diarrhoea, malnutrition and malaria by WHO subregions, proposing a methodology subsequently used by the World Bank and the United Nations. Three climate models are considered: an “unmitigated emissions” scenario, one where carbon dioxide concentrations stabilize globally at 750ppm, and one where carbon dioxide concentrations stabilize globally at 550ppm. Neither malnutrition nor malaria was projected to increase on account of climate change by 2030 in any European subregions (Eur A, Eur B, Eur C) although diarrhoea was projected to increase. The reported global total investment needs in 2030 for combating diarrhoeal disease was US$ 67 billion, malnutrition US$ 2 billion, and malaria US$ 36–50 billion. By applying the unit costs of providing preventive services (immunization and improvements to water and sanitation), the costs are estimated at US$ 217 million per year.

A global study inspired by the Ebi (2008) methodology was conducted by the United Nations Framework Convention on Climate Change (UNFCCC, 2008) but it does not provide a regional breakdown of costs. By contrast, in the “Economics of Adaptation to Climate Change study” conducted by the World Bank (World Bank, 2010) Europe is represented by the World Bank’s Europe and Central Asia (ECA) subdivision. The health sector is one of eight considered, along with infrastructure, coastal zones, water and river flood protection, agriculture, fisheries, forestry and extreme weather events. The outputs of two alternative global circulation models are used to predict conditions leading to future disease cases: the National Center for Atmospheric Research Community Climate System Model Version 3 (NCAR CCSM-3) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO)-3. The only two categories of outcomes considered are diarrhoea and malaria and adaptation includes only the costs of averting treatment of these outcomes. Average annual adaptation costs in the health sector for diarrhea and malaria prevention and treatment are globally in the range of US$ 1.3–1.6 billion over the 40-year period 2010–50. However, for the ECA region the only costs are for the NCAR scenario, US$ 100 million a year from 2010–2019: there are no costs for the CSIRO scenario. A follow-up publication (Narain, Margulis, & Essam, 2011) slightly modifies the health sector adaptation cost estimates to between US$ 1.45 billion (CSIRO) and US$ 1.97 billion (NCAR) globally, but does not disaggregate by region.

Some noteworthy research studied and monetized links between social determinants of health and vulnerability to climate impacts. (Blankespoor et al., 2010) suggest a direct link between flood mortality and female education in developing countries and propose "climate-neutralizing female education" as an adaptive additional value to the human capital gains. They calculate an additional need for primary and secondary education with costs of between US$ 500 million and US$ 1.5 billion by 2050 in the eastern Europe and central Asia region.

In a similar vein, (de Bruin, Dellink, & Agrawala, 2009), using the Adaptation in Dynamic Integrated model of Climate and the Economy (AD-DICE) model for reference scenarios and the Adaptation in Regional Integrated Model of Climate and the Economy (AD-RICE) model for regional differences, report on adaptation costs for various sectors and while they do not report on specific health adaptation costs for Europe, they suggest that these would be a very small proportion of the total. (Bosello, Carraro, & De Cian, 2009) used the Adaptation in World Induced Technical Change Hybrid model (AD-WITCH) model, a macroeconomic climate-economy interaction simulation, and estimated disease treatment costs would be US$ 2.4 billion with a doubling of carbon dioxide concentrations for western Europe (from a total of US$ 84 billion, itself equivalent to only 0.2% of GDP).

The low predicted overall impact of vector-borne diseases in the WHO European Region (at least in comparison with other world regions) has likely limited the attention of researchers with regard to the economic evaluation of related adaptation. In addition, beyond vector management and behavioural issues, uncertainties abound with regard to how exactly this adaptation will play out. Currently, few vaccines exist for VBDs (e.g. yellow fever, Japanese encephalitis, etc.). From the VBDs with the highest climate-driven risk expansion in Europe, only tick-borne encephalitis and Lyme disease are vaccine-preventable, and even then tick bite avoidance may be a more practical approach. Whatever the reasons, we found no studies estimating the costs under climate change projections of vaccinating at-risk or high-risk populations in Europe against vaccine-preventable VBDs.

3.3.3 Studies estimating economic benefits from health gains through mitigation

While the studies included in this section do not properly qualify as "health adaptation", it would be a mistake to ignore the existing research into the ancillary health and economic benefits of the reduction of GHG emissions, which, along with land use management and forestry interventions, is the most important mitigation strategy. In practice, the causal network that links the causes and consequences of climate change with the social and environmental determinants of health is less clear than the usual distinctions in the international climate policy processes. One example of blurred distinctions relates to the links between air pollution, climate change and health. The sources of local air pollutants tend to correlate relatively well with the main sources of GHGs (excluding land use and deforestation, of course); moreover, some local air pollutants (e.g. black carbon) have influence in climate balances. Whereas several of the studies listed in this review look at air pollution abatement as a "cobenefits" of climate change mitigation, in reality most policies and programmes considered intend to reduce health risks of air pollution, and so GHG mitigation is the real “ancillary benefit” or “cobenefit”. Whatever the interpretation, a proportion of studies deals with the health and economic effects of mitigation through GHG emission reductions in Europe. Sometimes these are region-wide, others national, sector-wide or case studies. Below is a selection of some recent examples.

A recent analysis by the European Commission (European Commission, 2012) concludes that reducing GHG emissions in Europe by 25% by 2020 (a more ambitious target than the 20% currently addressed by approved EU directives) would yield health benefits of €3.4–7.9 billion a year due to reduced mortality.

(Holland et al., 2011) estimated the air pollution abatement health benefits of a mitigation scenario equivalent to an average global increase of 2^{o}C stabilization and calculated that up to 480 000 life years could be gained annually by 2050 in the EU27, resulting in monetized health cobenefits of €44–95 billion a year, which translates into about €24 of cobenefits per Tm of carbon dioxide equivalent emissions avoided.

(Shindell et al., 2011) estimated the climate, health, agricultural and economic impacts of tighter standards for non- carbon dioxide motor vehicle emissions (NOx, CO, SO2, black carbon, organic carbon, methane, PM2.5 and ozone) from 2015 until 2050 globally. In the analysis, former Soviet Union countries are a separate region to western Europe (all of the EU and eastern European countries that were not part of the former Soviet Union). The health economic damage considered is due to mortality (VSL) secondary to cardiopulmonary disease and lung cancer. Valuations of reductions in deaths account for annual benefits of US$ 3–6 billion in western Europe and US$ 18–28 billion in countries of the former Soviet Union. In addition, the climate benefits accrued globally are equivalent to a mitigation of 0.2^{o}C of northern hemisphere extra tropical warming from 2040 to 2070.

(Jensen et al., 2013) studied the possible cobenefits from 2011 to 2030 of the United Kingdom’s greenhouse gas (GHG) emission reduction strategies. They applied an economy-wide dynamically-recursive computable general equilibrium (CGE) model based on the ‘International Food Policy Research Institute (IFPRI) standard model’ and calculated net present value of different alternatives using a 3.5% nominal discount rate (0.6% real discount rate). The policy scenarios are descriptively termed “active travel”, “healthy diet” and “household energy”. The 2011–2030 accumulated net present value (NPV) for healthy travel” is estimated at around £4.7 billion; for “active travel” at around £19 billion; and “household energy” at £448 million. A wealth of macroeconomic effects is analysed, providing a complete overview of net gains and trade-offs.

(Crawford-Brown et al., 2013) analysed the health implications of global PM reduction accompanying GHG emission reductions in the 180 national economies of the global macro economy. Their analysis showed that a substantial reduction can be achieved in excess lifetime mortality risk through air pollution abatement associated with GHG mitigation, accruing global annual cost savings of around US$ 10 billion if GHG reduction is applied uniformly across the globe, or US$ 2.2 billion if only Annex I nations reduce. Thus, they conclude that co-reduction of PM_{10} within a climate policy framework harmonized with other environmental policies can be an effective driver of climate policy.

(Barrett et al., 2012) assessed the public health, climate and economic impacts of desulfurizing jet fuel, reducing sulphur from average levels of 600 ppm to ultra-low sulphur (15 ppm) jet fuel standard (‘ULSJ’). They estimate a global ULSJ implementation cost of US$ 1−4 billion per year, which would prevent 900−4000 air quality-related premature mortalities per year, yielding health economic benefits of around US$ 2.5 billion (undiscounted). With regard to the climate impacts, jet fuel desulfurization would actually yield disbenefits by increasing the radiative forcing. The radiative forcing associated with reduction in atmospheric sulphate, nitrate, and ammonium loading is estimated at +3.4 mW/m^2 (equivalent to about $1/10^{th}$ of the warming due to carbon dioxide emissions from aviation) and ULSJ increases life cycle carbon dioxide emissions by approximately 2%. The central monetized climate damage estimate is US$ 2.1, 1.5 and 0.7 billion a year for a discount rate of 2%, 3%, and 7% respectively. Most of the pollution emissions happen over Europe and the United States, but affect the surface (and the population) elsewhere through subsidence. Most jet fuel emissions from flights over Europe affect mostly northern Africa and the Middle East, where most health benefits would likely be accrued.

(de Serres & Murtin, 2011) estimated the impact of climate change mitigation on life expectancy, GDP per capita and welfare. They calculated that, compared with a “business as usual” (BAU) scenario, a 50% GHG reduction by 2050 would yield an extension of life expectancy of 0.3 years in OECD EU countries, and of 0.6 years in non-EU eastern European countries. These extensions, however, would not completely compensate economically for the net GDP losses of 0.05% and 0.18% respectively. Large compensations would mostly happen in other regions such as China and India.

(West et al., 2006) studied the global health benefits of mitigating ozone pollution with methane emission controls, specifically by reducing global anthropogenic methane emissions by 20% beginning in 2010. As determined by the **M**odel for **OZ**one **A**nd **R**elated chemical **T**racers model version 2 (MOZART-2), this would decrease the average daily maximum 8-h surface ozone by 1 ppb, thereby preventing 30 000 premature all-cause mortalities globally in 2030, and 370 000 between 2010 and 2030. Decreases in O_3 due to CH_4 reductions were greatest over the Middle East, northern Africa and Europe. The marginal cost–effectiveness of this 20% methane reduction is estimated at US$ 420 000 per avoided mortality. If avoided mortalities are valued at US$ 1 million each, the benefit is US$ 240 per tonne of CH_4, or US$ 12 per tonne of carbon dioxide equivalent.

(Eboli, Parrado, & Roson, 2010) use the Inter-temporal Computable Equilibrium System (ICES) model, a CGE model based on the previous Global Trade Analysis Project model (GTAP) to ascertain how climate change impacts may affect growth and wealth distribution in the world. The EU and EEFSU are two separate regions among the eight considered (further details are available in the original study). The health impacts considered are malaria, dengue, schistosomiasis, diarrhoea, and cardiovascular and respiratory outcomes. These impacts are included in the model and monetized through variation in working hours, reflecting changes in mortality and morbidity (modelled through productivity changes), and variation in the expenditure for health care services, undertaken by public administrations and private households. They find that neither region’s GDP will be negatively affected by health costs by 2100, in contrast with other world regions, which will be affected to different degrees.

(Markandya et al., 2009) studied the public health benefits of reducing GHG emissions through low-carbon electricity generation. Specifically, they modelled the effect in 2030 of policies to reduce total carbon dioxide emissions by 50% by 2050 globally compared with emissions in 1990. They used three models: Prospective Outlook on Long-term Energy Systems (POLES) for carbon dioxide reductions and costs, GAINS for resulting PM2.5 concentrations; and WHO’s comparative risk assessment methods for the effects of PM2.5 on mortality. By pursuing a climate target the EU would, ceteris paribus, save 104 life-years per million people every year in the EU (48 000 in total). Direct costs per tonne of carbon dioxide not emitted reach US$ 137 in the EU in the full-trade scenario. Health benefits, however, are in the range of US$ 2 per tonne of carbon dioxide not emitted in the EU. Although health benefits by themselves do not outweigh the cost of mitigation, cleaner electricity might yield other benefits that could make it more cost-beneficial, notably the mitigation benefits of the substantial reductions proposed. Rather, the health benefits should be interpreted as subtracting from the net cost of implementation of mitigation.

(Anthoff et al., 2011) produced regional estimates of the social cost of carbon through the FUND 3.5 general equilibrium model. Europe is disaggregated into three regions: western Europe, central Europe and EEFSU. The health effects considered are cardiovascular and respiratory disorders influenced by cold and heat stress, malaria, dengue fever, schistosomiasis, and diarrhoea. The total cost of carbon in this study changes with the discount rate, being negative at 3% for several regions (including central and eastern Europe) and becoming positive (i.e. a true cost) under 1%. Western Europe and EEFSU countries bear a substantial proportion of the social cost of carbon currently and in the future. The share of that cost accounted for by health effects is small, and the direction somewhat inconclusive. Infectious diseases are brought under control (in the model) by rapid economic growth. For cardiovascular and respiratory disorders, positive and negative impacts tend to balance.

3.3.4 Reviews of the literature

Besides having been used to identify additional sources, the literature reviews on the health economics of climate change provided interesting information on their own. Admittedly, the focus on the specific topic is marginal in some. For instance, (Grasso et al., 2012) provide an overview of quantitative methods in climate change modelling including adaptation, in which economics is just one more topic. The same applies to the review by (Hope, 2009) in a qualitative format. (Remoundou & Koundouri, 2009) deal with the topic of environmental health economic evaluation, and consider climate change as one more environmental exposure

Others, however, deal with the topic extensively. Regarding methodology, (Fankhauser, 2006) notes the high uncertainty of the economic estimates of both health damage and adaptation, with moderate improvement from the first generation of assessments to the second. In the macroeconomic literature, (Bosello & Shechter, 2013) note the overall low vulnerability in terms of GDP loss from all impacts, including health, in European countries, a notion confirmed by our own review of the literature regarding generalized equilibrium models. (Hutton, 2011b) highlights the comparatively high costs of health damage (including mortality) when those are counted in overall economic evaluations of climate change impacts. He also notes that the omission of important causes of health costs (omitted health outcomes, omitted economic impacts, and the costs of health actions in other sectors) is likely to result in a severe underestimation of the health economic impact of climate change. (UNFCCC, 2009) reviewed the literature on climate change adaptation economics by sectors, including health, although the report does not feature any European study, a national case study mentioned (SCCV, 2007) includes rough calculations of health.

On the mitigation side, (Bell et al., 2008) as well as (Deichmann & Zhang, 2013) arrive at a similar conclusion, concluding that the short term public health and economic benefits of ancillary benefits related to GHG mitigation strategies are substantial. Moreover, as in the case of adaptation, the results of current research are likely to be underestimates because of important unquantified health and economic endpoints. Conclusions derived from

(Markandya A and Chiabai A, 2009) tend in a similar direction, after trying to extract some general figures on cost–effectiveness, and insist on the need to engage in further research to narrow the estimates for the cost of adaptation. In that regard, the conclusions of earlier reviews (EEA, 2007) have not been modified substantially by later work.

4 Discussion

4.1 Status and summary of the existing evidence

Despite the relative increase in available studies from previous reviews, the evidence base on the health economics of climate change remains scarce. In fact, much of the evidence collected by previous reviews on this topic actually deals with past or current economics of climate-sensitive health outcomes and exposures, or with the economic implications of factors that are related to climate change, but are not a major direct cause or consequence thereof (e.g.. air quality). In neither case is the influence of climate change taken into account. For instance, there is no discussion in such studies as to whether past heat waves could be attributed to climate change, or on the influence of climate change on the air quality scenarios considered for regulatory purposes. Whereas these studies are valuable in their own right and to establish baselines for the ascertainment of climate change influences, they cannot be considered to be within the pool of research on the health economics of climate change. It is noteworthy that many of the references found through backwards snowballing starting from literature reviews were actually of this kind (See Annex 4 for a selection of relevant references on the matter). The results of these studies are as disparate as the factors and endpoints considered. In general, prevention tends to show good returns, although in some cases environmental interventions are far less studied than “clinical” ones.

With regard to the proper pool of studies accounting for climate change scenarios, comparisons are challenging (see Section 4.3 on comparability) but some patterns arise:

- Studies on the cost of health damage of climate change tend to show significant costs (sometimes at the level of entire GDP percentage points) due to mortality and morbidity attributable to climate change. Those costs, measured on a yearly basis, tend to increase with longer timeframes and under more severe climate change scenarios. However, the nature of these studies tends to be partial (with only a few health outcomes considered) and the results plagued by uncertainty, particularly for outcomes in which a solid dose-response function has not been ascertained. The issue of “additionality”, or discerning what outcomes are due to climate change and which ones would be expected under a no-change scenario, is in general solidly addressed and embedded in the modelling from inception.
- Studies on the cost, cost–effectiveness and/or benefits of health adaptation tend to show moderate costs of adaptation in the short term with a marked increase in the long term. Evaluations frequently stop short of full cost–benefit analyses on account of adaptation costing difficulties: specifically, some of the adaptation costs in other sectors (notably water and extreme weather events) could have been considered health adaptation, but frequently are not, despite their purported goal of protecting human life and welfare. Without a full adaptation costing, the all-society scope of a cost–benefit evaluation is not attainable. This is a discussion left frequently unaddressed in adaptation costing studies.
- Studies estimating economic benefits from health gains associated with the GHG reduction show very strong benefits from technology and regulatory changes resulting in net mitigation, almost always through the reduction of air pollutants. However, not all options are equally beneficial: gains are more limited for the European region (however defined in the study) than in other world regions, and discount plays a pivotal role in terms of the benefits obtained from investment.

- The reviews of the literature commonly reflect the paucity of existing evidence, lack of comparability and gaps, but tend to confirm the general patterns in the mentioned types of studies.

Few of these studies focus specifically on exposures that are aggravated by urban characteristics or any other city-specific factors. Moreover, there are no distinctions with regard to the economic valuation, conceptually or methodologically, between national and subnational scopes. This lack of focus contrasts with an extensive theoretical development of urban economics in the last decades (McCann, 2013) and points at the need for further interdisciplinary work in both areas of research.

4.2 Evidence from grey literature and case studies

A sizeable share of the relevant existing studies and reports are published in outlets or formats that can be categorized as "grey literature". Such categorization does not necessarily diminish the value of these studies; indeed, their quality as assessed in this review is not necessarily lower than that of peer-reviewed studies published by commercial publishers. However, some of the grey literature reviewed does suffer from some of the usual issues with this category of publications (Benzies et al., 2006; Mahood, Eerd, & Irvin, 2014): unclear authorship, lack of bibliographic control, heterogeneous standards of referencing, and disparate document structure, among others. Lack of peer review is unlikely to be a major issue; most of the organizations publishing the reviewed studies (for example United Nations agencies and development banks) have formalized validation and review processes for scientific publications, frequently involving external authors. Moreover, the reviewed grey literature studies featured interesting case studies and insights, arguably more directly relevant for policy-making than those in the peer-reviewed books and articles released by commercial, primary publishers.

4.3 Comparability of results

With regard to the proper pool of studies on the health economics of climate change, comparisons are extremely difficult, since most useful reference parameters vary across studies. Differences in geographical scope, outcomes considered, timeframes, evaluation metrics, discounting, population dynamics, and other parameters make generalizations and the ascertainment of patterns highly challenging, if at all feasible. Even in studies that are clearly linked in terms of methodology, for example large EU-funded research studies such as cCASHh, PESETA, PESETA II and ClimateCost, cross-comparisons are virtually unfeasible. Thus it is worth discussing briefly the issue of incomparability by topic.

Geographical scope

A variety of geographical scopes are included within the "Europe" and "European region" labels. For studies focusing on the EU, the number of countries considered varies according to membership at the time. Different international organizations have their own, differing, classifications, frequently including all or part of central Asia, or even countries in the Middle East. Finally, researchers often propose subdivisions based on the models used or geopolitical considerations, for example "former Soviet Union" countries). Since studies are often conducted at the regional level, disaggregation for the sake of comparison is frequently unfeasible.

Coverage of climate-sensitive health outcomes

A wide range of health outcomes are covered in the reviewed studies, although the specificity and range vary greatly. Health outcomes covered in studies linking climate change with physical impact and economics include:

- Noncommunicable diseases: heat-related mortality and morbidity, cardiovascular and respiratory disorders, flood-related mortality and depression, allergic rhinitis and asthma;
- Water-borne and foodborne diseases (specifically salmonellosis and diarrhoea);
- VBDs (tick-borne encephalitis, Lyme diseases, malaria, dengue fever and schistosomiasis).

Although typically no information is given as to the rationale for the choice of health outcomes, the consistency in the choice points at two reasons, the availability of a more or less solid climate-response relationship and the availability of past health economics data on these outcomes.

Timeframes and time horizons

Some studies begin with the present or even in the past, whereas others provide only time slices under different climate change scenarios. Often, for illustrative purposes, a reference year in the future is chosen to report average annual costs due to one or more health outcomes: 2020, 2050, 2080 and 2100 are common milestone years, but rarely do two studies share timeframes or time slices of analysis.

Evaluation metrics

The most common reporting metric of economic outcomes is currency with a reference year, for example billions of US dollars of 2010, millions of euros of 2000, and other local currency units). However, percentage changes in national or regional GDP, or even GWP, are also used, particularly as outputs from the CGE and other macroeconomic models.

Methods and discounting

The usual methods for economic evaluation of environmental and transport policies are commonly used in the “bottom-up” studies. For instance, mortality risk reduction is valued through VSL, or the VOLYs lost, while other methodologies such as the human capital approach are notably absent. With regard to the valuation of the cost of morbidity, the “cost of illness” approach is frequent, including health care expenses and other treatment-related costs. Lost productivity is commonly valued through the opportunity cost of time measured as foregone wages. In the “macroeconomic” type of studies, the labour productivity effects of mortality and illness, as well as the related health care expenses, are the main health-related “shocks” into the model. Discount rates are rarely mentioned in the pure climate change impact studies, and costs are often reported undiscounted. This reluctance to discount health benefits over climate change-relevant periods is common and is deemed to be the least undermining for? the welfare of future generations (Agrawala et al., 2010). On the other hand, discount rates are frequently used in cost–benefit evaluations of adaptation or studies on the health costs and benefits mitigation. Still, these tend to be comparatively small, usually between 0% and 3%. For instance, Anthoff et al.,(2011); Bosello et al., (2009); and Waldhoff et al., (2011) use 0.1%, 1% and 3% as pure rates of time preference. Markandya et al., (2009) used 3%; Rafaj et al., (2012) used 4% and West et al.,(2006) used 5%. Jensen et al., (2013) used a 3.5% nominal discount rate (0.6% real discount rate) specifically mirroring that of United Kingdom treasury bonds. The highest reported rate is 7%, used as maximum by Barrett et al., (2012), and Blankespoor et al., (2010). Some studies also explicitly use declining rates (OECD, 2008; U.K. Department for Environment Food and Rural Affairs, 2006) although constant rates are the norm.

Population dynamics

Almost every study considers demographic projections, a reasonable analytical choice since population change is arguably the single most important driver of baseline incidence and prevalence of disease and mortality, and a significant driver of global environmental change. Such projections are widely different and will not be summarized here. However, common references are the population scenarios considered in the IPCC Special Report on Emission Scenarios (SRES) (van Lieshout et al., 2004) as well as the United Nations Department of Economic and Social Affairs (UNDESA, 2013).

4.4 Relevance for key groups and stakeholders, distributional issues and other considerations

Although the majority of the reviewed studies are ostensibly intended to inform public policy-making, their general format and language are better suited to other researchers and technical profiles. This is especially so for the pool of peer-reviewed journal articles and books, where usually only the abstract features nontechnical language. On the other hand, grey literature outlets and reports commonly include lay language executive summaries that can serve directly or indirectly as policy briefs. The direction of the results in terms of policy is rather uniform:

- Studies on the cost of health damage of climate change tend to confirm the notion of very steep health costs of climate change impacts in the absence of adaptation;
- Studies on the cost, cost–benefits and/or cost–effectiveness of health adaptation (i.e. measures to reduce or avert health damage from climate change) tend to show high health benefits per unit invested, with higher returns with earlier action; and
- Studies estimating economic benefits from health gains associated to the reduction of greenhouse gases tend to show substantial economic benefits due to reduced air pollution morbimortality, although the breakeven point can be approached quickly as investments tend to be substantial in this policy area.

Distributional effects according to socio economic status, gender or age tend to be absent from the discussion. The grey literature outlets provide for some exceptions in this regard, although the quantitative analysis of these distributional issues is extremely infrequent.

4.5 Limitations of this review

The primary focus of this review has been on maximizing the retrieval of information through the combination of search techniques (databases, backward snowballing and grey literature). However, it is likely that a proportion of relevant studies have not been captured. Moreover, the boundaries of the topic (the health economics of climate change) are far from clear. It could be argued that the health economics of climate-sensitive health outcomes under current or past climate variability are relevant to this discussion, since they constitute the baseline against which models and projections can be compared. However, we have adopted a conceptually conservative approach by including only research that explicitly modelled climate change effects, thus acknowledging the key issue of additionality both in health damage and response. A certain risk of reporting bias cannot be ruled out; almost all studies on the health damage of climate change report positive results, that is to say significant economic costs, as do a majority of cost–effectiveness and cost–benefit studies.

Studies on mitigation also report average high monetized health benefits, although depending on the specific model assumptions, health benefits can be overshadowed by those in other sectors.

5 Conclusions

The literature retrieved in this review suggests that the evidence base on the health economics of climate change is scarce, incomplete and inconsistent. This is the case not only at national and local levels, but also at the EU level and especially at the pan-European level when including EEFSU. The focus on urban agglomerations is minimal regarding causal pathways between climatic exposures and health outcomes, and largely absent from the economic evaluations and methods. A substantial proportion of potentially relevant evidence is available in “grey literature” outlets, some of which suffer from transparency, quality and/or comparability issues. However, given the scarcity of peer-reviewed scientific journals and books on the matter, researchers, practitioners and policy-makers would miss important information if grey literature studies and reports were to be systematically excluded from the relevant evidence base.

The weak knowledge on the association of climate and climate change with several health outcomes partly explains the scarcity of economic evidence on the topic. While general trends are confidently predicted by increasingly accurate climate models, the evolution of several exposures and outcome-specific causal pathways in a context of high uncertainty still proves too challenging for current modelling capabilities. This explains the major gaps of evidence with regard to water-borne diseases, VBDs, and health outcomes from flooding and storms. It also partly explains the rarity of proper sensitivity analysis in health damage cost studies, where the compounded uncertainty of climate models, health impact models and economic estimates would provide unacceptably wide confidence intervals. On the other hand, the association between high temperatures and health, and the economic consequences thereof, are comparatively well represented in the literature, particularly as a result of EU-funded research projects.

Even for better explored sets of health outcomes, the lack of homogeneity or standardization makes proper comparisons, such as meta-analyses, all but impossible. Such lack of homogeneity applies to virtually all steps of the research modelling steps, from the specific exposure indicators, health outcomes, climate change models, timeframes, discounting and economic outcome measures. Importantly, economic methods are also different; some focus only on mortality or on health care costs, others on lost productivity, and yet others in all of them. Valuation approaches vary with regard to mortality, either by applying the VSL approach or VOLYs lost approach. When both mortality and morbidity costs are included, the former typically largely outweighs the latter, especially if VSL is used rather than VOLY. Since VSL is based on a nonmarket valuation, the largest proportion of the resulting costs is nonfinancial in nature, with potential implications for advocacy and policy-making.

In fact, some characteristics of the available evidence base limit its potential to inform decision-making. Firstly, the time horizons necessary for adequate impact ascertainment are typically beyond the usual planning cycles. Secondly, poorly defined baseline scenarios blur the “additionality” component; this is particularly important for poorer European and central Asian countries where there is still a major “adaptation deficit”. Thirdly, the lack of comparability across results minimizes the certainty associated with researchers’ messages to policy-makers. And fourthly, the emphasis on nonfinancial benefits such as those of mortality risk reduction may potentially undermine the overall impact in the practice of the economic argument.

Despite its shortcomings, the existing evidence clearly indicates that averting the health impacts of climate change would be cost-beneficial, particularly in the poorer countries of the region, both featuring the highest vulnerability and the least climate resilience. Investing in health adaptation and early mitigation clearly will pay off in terms of avoided premature mortality, saved health care costs and gained work productivity. This argument, generally valid in spite of the uncertainties, can be used by the health sector to promote adaptation both internally and in other sectors. Moreover, the health sector could benefit from a systematic use of the economic argument for protecting health from climate change, as well as more generally health protection from environmental factors. Economics can be used as a common language for agenda promotion in a context of scarce resources and competing priorities, without compromising in any way the core mission of health systems. However, strong efforts in capacity building are needed for this shift to be effective.

Next steps in this research area should include the establishment of consensus with regard to basic prerequisites for comparability of results, as well as increased effort regarding the projection under climate change scenarios of the health economics of climate-sensitive exposures and outcomes.

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Annex 1. PRISMA checklist

Section/topic	#	Checklist item
TITLE		
Title	1	Identify the report as a systematic review, meta-analysis, or both.
ABSTRACT		
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.
INTRODUCTION		
Rationale	3	Describe the rationale for the review in the context of what is already known.
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).
METHODS		
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.
RESULTS		
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).

Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).
DISCUSSION		
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.
FUNDING		
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.

Source: Adapted from (Moher et al., 2009). Note: highlighted items were not used in this review.

Annex 2. Detailed search results

Search algorithm	PubMed	MEDLINE	Web of Science	Scopus	RePec IDEAS	EconLit	Grey Literature report	Open Grey
Climate change + health + economics	19	14	80	390	100	15	10	0
Climate change + economics + health + impacts	7	5	32	164	50	5	4	0
Climate change + economic + health + impacts	58	1	417	631	50	45	4	0
Climate change + economics +health + damage	1	0	7	20	9	0	0	0
Climate change + economic + health + damage	7	5	47	68	9	7	0	0
Climate change + economics + health + benefits	3	0	21	92	29	6	3	0
Climate change + economic + health + benefits	40	28	160	250	29	28	3	0
Climate change + economics + health + damage + costs	1	0	4	16	5	0	0	0
Climate	2	1	20	26	5	1	0	0

change + economic + health + damage + costs								
Climate change + health + economics + costs	3	1	28	115	36	7	4	0
Climate change + health + economic + costs	31	24	163	284	36	25	4	0
Climate change + health + economics adaptation	2	0	7	40	18	1	4	0
Climate change + health + economic + adaptation	42	35	131	181	18	23	4	0
Climate change + public + health + economics + adaptation	1	0	2	17	6	1	3	0
Climate change + public + health + economic + adaptation	14	11	38	73	6	8	3	0
Climate change + health + economics + adaptation + costs	1	0	2	6	6	1	2	0

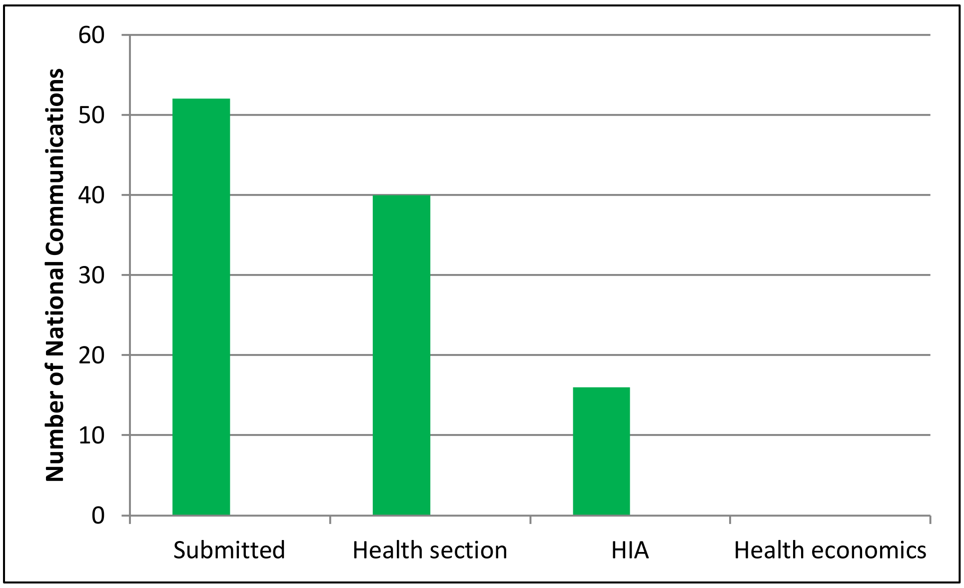
Climate change + health + economic + adaptation + costs	9	6	25	33	6	3	2	0
Climate change + health + economics + adaptation + savings	0	0	0	1	0	0	0	0
Climate change + health + economic + adaptation + savings	0	0	2	1	0	0	0	0
Climate change + health + economics + adaptation + planning	0	0	1	14	2	0	3	0
Climate change + health + economic + adaptation + planning	8	8	26	41	2	1	3	0
Climate change + health + economics + adaptation + benefits	1	0	1	7	4	0	1	0
Climate change + health + economic + adaptation	10	9	21	35	4	2	1	0

+ benefits								
Total	260	148	1235	2505	430	179	58	0

Annex 3. Health economics in the national submissions to the UNFCCC

Parties to the United Nations Framework Convention for Climate Change (UNFCCC) must submit national reports to the Conference of the Parties (COP, held yearly) on the status of implementation of the Convention. The required contents and timetable for submission of national communications are different for Annex I and non-Annex I Parties to the Convention, in accordance with the principle of "common but differentiated responsibilities". In their technical guidelines for reporting, neither Annex I parties (UNFCCC, 1999) nor non-Annex I parties (UNFCCC, 2003) are required to include health as a topic in their submissions, although they are encouraged to use guidelines (UNEP, 1998) that address the health impacts of climate change among many other sectors. Therefore, the analysis of the health impacts of climate change in their national communications to UNFCCC is largely left to the discretion of the parties, as is any economic analysis thereof.

The WHO European Region encompasses 53 countries including both Annex I and non-Annex I parties. We reviewed the UNFCCC online repository (UNFCCC, n.d.) for national communications to the convention. Neither National Adaptation Plans (NAPs) nor National Adaptation Programmes of Action (NAPAs) were reviewed, since these are meant to be produced by Least Developed Countries (LDCs) of which there are none in the region. Our review showed that 52 of the 53 countries in the region have submitted at least one national communication to the UNFCCC. Of these, 41 included a health section; however, only 16 featured any type of quantitative health impact assessment. None of the reviewed national communications included an economic evaluation of either the health damage of climate change or of health adaptation measures (see graph below).



Although financing considerations and/or full evaluations are present in most national communications, economic analyses are rare and tend to be very partial, dealing at best with the evaluation of marginal abatement cost for greenhouse gas reductions. However, no economic evaluation of the health benefits of GHG mitigation is found in any of the national communications. This entails a range of relevant implications. Firstly, the omission of potentially important evidence for decision-making in national communications with regard to health adaptation could undermine the importance of the sector in the climate policy debate at the national level. Secondly, where economic evaluations would be included, not accounting for health economic impacts may imply a significant underestimate of the true costs of climate change. And thirdly, a potential argument for advocacy is foregone if the health impacts of climate change are described strictly in terms of the magnitude of the outcome and not its socioeconomic consequences.

Annex 4. Health economics of climate-sensitive exposures and outcomes

A substantial body of scientific literature deals with the health economics of climate-sensitive exposures and outcomes, without taking into account climate change scenarios or effects. Whether they should be part of a literature review on the health economics of climate change impacts and adaptation is arguable, but it is clear that these studies can provide the basis for others that would properly qualify to enter such review. We thus selected the main results in this category that resulted from the backwards snowballing exercise, as well as from the grey literature search. We complemented this search with a hand search in an internet search engine; this additional review was not meant to be systematic, so we only feature the results we thought had the most illustrative value. In addition, we relaxed the timeframe filters in this search in comparison with the systematic one; in this case, we included studies from the year 2000 onwards. Below are the main results categorized by topic.

Heat waves: on the 2003 European summer heat-waves, (Hunt et al., 2007) report for the United Kingdom a total of 2,157 attributable excess deaths at a cost of £2.6 billion using a VSL of £ 1.2 million, or £32 million using valuation of a saved year of life of £15,000; and 1,650 excess hospital admissions at a cost of £15 million (with an upper threshold of £9,120 per admission). The French “National observatory for the impacts of global warming” (ONERC, 2009) reports 14,800 excess deaths due to heat in August 2003, with a cost of € 500 million using a value per life saved of €37,500. By comparison, the same study estimates the cost of their heat-wave and health alert system in 2005 was calculated at €287,000 and the summer operating cost was calculated at €454,000, adding up to an annual cost of cost of €741,000. (Roldán, Gómez, Pino, & Díaz, 2014) reported for Spain a total of 107 (95 %CI:42-173) heat-attributable deaths were estimated for the period 2002-2006, with an in-hospital estimated cost of these deaths of € 426,087 (95 %CI.€167,249 – €688,907). Despite the high costs of heat-related morbimortality and anecdotal evidence of low establishment and operation costs of prevention, only 18 out of the 53 countries in the WHO European Region have heat-health action plans. Moreover, the quality and scope of these plans is highly uneven; the main identified gaps in terms of plan coverage are in the areas of (intersectoral) long-term measures, surveillance and plan evaluation.

Air pollution: the evaluation of cost, effectiveness and benefits of air quality improvement strategies and policies have long been and institutional requirement for regulatory agencies in the US and the EU, producing a wealth of reports and literature on the matter. A full review of the research on the health economics of air pollution in Europe is besides the scope of this document and would merit a large document of its own; however, some important studies at the European level can be cited. The EU-commissioned studies on the Clean Air for Europe (CAFE) Programme (Watkiss, Pye, & Holland, 2005) estimates a benefit-cost ratio of between 6 and 19 for achieving air quality targets for Europe, and subsequent studies estimate that achieving a “maximum technically feasible reduction” would yield an annual net present value benefits of around €60 to 200 Billion a year by 2030 for the EU 28 (Holland, 2014). At the national level, several economic evaluations of the health costs of air pollution and benefits of intervention have been conducted. For instance, the economic analysis of the United Kingdom Air Quality Strategy (U.K. Department for Environment Food and Rural Affairs, 2006) review estimated a benefit-cost ratio of meeting European standards of between 1.5 to 3.8 for ‘low intensity’ interventions and 0.9 to 2.3 for ‘high intensity’ interventions. An evaluation of costs and benefits of pollution emission reduction in the oil extraction industry in Kazakhstan (Netalieva, Wesseler, & Heijman, 2005), estimating a BCR of 5.7. Many other references could be cited, but overall conclusions are highly consistent: air pollution abatement provides large returns on investment in almost every form. A large proportion of those returns come from the reduction of premature mortality risk, and are thus largely determined by the method of evaluation.

Airborne allergens: the prevalence of pollen-related allergic rhino conjunctivitis has increased dramatically in the last decades throughout the European Union, with around seventeen million people in the United Kingdom, Germany, the Netherlands, Sweden, Denmark, Norway and Finland suffering from grass pollen induced allergic rhinitis (Bachert, Vestenbaek, Christensen, Griffiths, & Poulsen, 2007). Climate change has the potential to affect aeroallergens such as pollen and mould spores, and consequently, affect diseases such as asthma and allergic rhinitis. Possible adaptation measures include aeroallergen monitoring and forecasting; allergenic plant management; planting practices and policies; urban planning; building design and heating, ventilating, and air-conditioning (HVAC); access to health care and medications; education; and research. Due to rising associated health care costs, some economic evaluations have been conducted with regard to diagnostics (Lewis, Franzese, & Stringer, 2008), asthma interventions (Campbell, Spackman, & Sullivan, 2008; Navarro & Parasuraman, 2005), and drugs (Bachert et al., 2007; Canonica, Poulsen, & Vestenbaek, 2007; Nasser, Vestenbaek, Beriot-Mathiot, & Poulsen, 2008; Ronaldson, Taylor, Bech, Shenton, & Bufe, 2014). Studies in general show general cost–effectiveness of treatment; for instance (Ronaldson et al., 2014) report a cost per quality-adjusted life year gained of £12,168 for enhanced treatment for allergic rhino conjunctivitis while improving patient outcomes.

Vector borne diseases: Some vector-borne diseases established in Europe (TBE, for instance – see (Donoso Mantke, Schädler, & Niedrig, 2008)) can be economically very burdensome on the health care system, a fact that has already led to current evaluations of cost–effectiveness of vaccination (Smit, 2012). A prospective analysis of TBE vaccination for French troops based in Kosovo resulted in a cost over 80,000 Euros per case prevented. An American study for vaccination of Lyme disease (Meltzer, Dennis, & Orloski, n.d.) shows a lower average cost per case averted of about US$ 4 500. These numbers are far beyond usual cost–effectiveness figures for most vaccine-preventable diseases, which explains the mainstream notion that tick bite avoidance may be for the time being a more practical approach. However, the main variables at play (namely incidence, vaccine price and treatment procedures) might change the economics of VBD vaccines in Europe under climate change.

Foodborne diseases: A small but solid body of literature reveals that the health costs of foodborne illnesses are significant at the European level. A recent review by (Belaya, Hansen, & Pinior, 2012) categorizes the available literature into four methodological groups: COI approach, WTP approach, non-health cost assessment, and Regulatory Impact Assessment (RIA). The European Food Safety Agency (EFSA, 2014) calculates the cost of campylobacteriosis to public health systems and to lost productivity in the EU be around EUR 2.4 billion a year, and the equivalent cost of salmonella at around EUR 3 billion a year. With regard to the economic evaluation of interventions, different salmonella control programs at the farm or food industry level in various European countries have been analysed. In Denmark, the only cost-beneficial alternative for the reduction of salmonella in pork was hot water decontamination (Goldbach & Alban, 2006) whereas public salmonella control in table eggs probably avoided societal costs during 1998-2002 of 23.3 million Euros, with a continuous decreasing cost–benefit ratio reaching well below 1 in 2002. In Finland (Kangas, Lyytikäinen, Peltola, Ranta, & Maijala, 2007) the benefits from the national salmonella control program in broiler chickens outweighed costs by four to one. Several other national studies exist with regard to this kind of interventions, and most show cost-beneficial figures for alternative strategies for the prevention of the most common severe foodborne illnesses. There are also studies on end-use food preparation, but these are far fewer and less consistent than the industry- and public-sector targeted ones.

Water borne diseases: There is a large amount of literature regarding the health costs of unsafe water, sanitation and hygiene; as well as the cost-utility, cost–effectiveness and cost–benefits of various interventions, although such evaluations have been uncommon for decades for western Europe, where the coverage of improved water and sanitation is almost complete. For the areas of the European Region where water and sanitation-related illnesses are still comparatively common (WHO epidemiological strata B and C – mainly non-EU, non-OECD countries), the World Health Organization found that the economic benefits (including health and time savings) outweighed the costs of the provision of safe water and sanitation by about 20 to one, and that the cost per lost disability-adjusted life-year (DALY) averted was around $ 9,500 (Haller, Hutton, & Bartram, 2007; Hutton, Haller, & Bartram, 2007). As an example of an economic evaluation of a WASH-related vaccine preventable illnesses, a vast amount of literature is now available on the costs and benefits and cost–effectiveness of rotavirus vaccination in almost every country of the WHO European Region, including Germany (Aidelsburger et al., 2014) the United Kingdom (Atkins, Shim, Carroll, Quilici, & Galvani, 2012), the Netherlands (Rozenbaum et al., 2011), Armenia (Jit, Yuzbashyan, Sahakyan, Avagyan, & Mosina, 2011), and the Russian Federation (Kostinov & Zverev, 2012) among others.

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