The Lancet Countdown: Tracking Progress on Health and Climate Change – 2017 Report

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Introduction

Climate change brings severe implications for our health, wellbeing, livelihoods and the structure of organised global society. It threatens to undermine many of the social and environmental determinants of health. Its direct effects result from rising temperatures, and changes in the frequency and strength of storms, floods, droughts, and heatwaves – with the physical and mental health consequences that result. Its effects are also seen in the form of changes in crop yields and in the burden and distribution of infectious disease, and in population displacement.[4-6] Whilst many of these effects are being experienced today, it is a future with unmitigated climate change, wherein the effects worsen and exacerbate existing challenges and global health inequalities, that is particularly concerning.[7] The links between climate change and human health is clearly complex, and heterogeneously mediated through various economic, environmental, and social factors.

However, a comprehensive and ambitious response to climate change will transform the health of the world's population populations and the way they live their lives. The potential benefits are enormous, including cleaning up the air of polluted cities, delivering more nutritious diets, ensuring energy, food and water security, and alleviating poverty and social and economic inequalities.

Monitoring this transition – from threat to opportunity – is the central role of the *Lancet Countdown: Tracking Progress on Health and Climate Change*.[8] The collaboration exists as a partnership of 24 academic institutions from every continent, and brings together individuals with a broad range of expertise, including climate scientists, mathematicians, geographers, engineers, energy, food, and transport experts, economists, social and political scientists, and health professionals. Ultimately, the Lancet Countdown tracks a series of indicators of progress, publishing an annual 'health check', from now until 2030, on the state of the climate, and progress made in meeting global commitments under the Paris Agreement, and adapting and mitigating to climate change.

The initiative was formed following the 2015 Lancet Commission, which concluded that "tackling climate change could be the greatest global health opportunity of the 21st century".[7] It builds on the foundations from by many in the space, including work from the World Health Organization's (WHO) Department of Public Health, Environmental and Social Determinants of Health and the Intergovernmental Panel on Climate Change (IPCC). It also follows a growing body of evidence supported by The Lancet, including the Lancet Series on the health co-benefits of mitigation, the 2009 Lancet Commission on managing the health effects of climate change, the Rockefeller Foundation-Lancet Commission on Planetary Health, and the recently launched Lancet Planetary Health Journal.[9-12]

Indicators of Progress on Health and Climate Change

The Lancet Countdown's indicators, summarised in Table 1 below, are divided in to five broad themes: health impacts of climate change; health adaptation and resilience; the health co-benefits of mitigation; economics and finance; and public and political engagement.

Following its 2016 report, presenting proposed indicators, the Lancet Countdown launched a global consultation to determine the indicators it can and should track. A number of factors determined the eventual selection of these indicators, including: their relevance to public health, both in terms of the impacts of climate change on health, and the health effects of the response to climate change; and their relevance to the anthropogenic drivers which contributed the most to climate change; their geographical coverage and relevance to a broad range of countries and income-groups. Throughout this report, the results and analysis of each indicator have been presented in full, alongside a brief description of the data sources and methods. A more complete account of each indicator can be found in the corresponding appendix (one section per indicator).

Thematic Group	Indicators	
1. Health Impacts of Climate Change	1.1 Exposure to temperature change	
	1.2 Exposure to heatwaves	
	1.3 Changes in labour productivity	
	1.4 Exposure to climate-sensitive infectious diseases	
	1.5 Food security and undernutrition	1.5.1 Vulnerability to undernutrition
		1.5.2 Marine Primary Production
	1.6 Migration due to climate change	
2. Health Resilience and Adaptation	2.1 Deaths from climate- and weather-related disasters	
	2.2 Trends in selected climate-sensitive diseases	
	2.3 Number of countries with a national adaptation plan for health	
	2.4 Number of cities with climate change risk assessments	
	2.5 Implementation of IHR Core Capacity Requirements	
	2.6 Proportion of national meteorological and hydrological agencies providing services tailored for the health sector	
	2.7 Number of countries that have conducted a national assessment of vulnerability, impacts and adaptation for health	
	2.8 Number of countries implementing activities to build health resilient infrastructure	
	2.9 Spending on adaptation for health and health-related activities	
	2.10 Health adaptation funding from global climate financing mechanisms	
3. Health Co-Benefits of Mitigation	3.1: Carbon intensity of the energy system	
	3.2 Coal phase-out	
	3.3: Zero-carbon emission electricity	
	3.4: Access to clean energy	
	3.5 Exposure to ambient air pollution	
	3.6: Fuel use for transport	
	3.7 Active travel infrastructure and uptake	
	3.8.1: Total food supply for human consumption	
	3.8.2: Supply of ruminant meat for human consumption	
	3.9: Healthcare sector emissions	
4. Economics and Finance	4.1: Change in Annual Investments in Renewable Energy and Energy Efficiency	
	4.2: Change in Annual Investment in Coal Capacity	
	4.3: Value of Funds Divested from Fossil Fuels	
	4.4: Economic Losses due to Climate-Related Extreme Events	
	4.5: Valuing the Health Co-Benefits of Climate Change Mitigation	
	4.6: Employment in Low-Carbon and High-Carbon Industries	
	4.7: Fossil Fuel Subsidies	
	4.8: Coverage and Strength of Carbon Pricing	
	4.9: Use of Carbon Pricing Revenues	
5. Public and Political Engagement	5.1 Media coverage of health and climate change	
	5.2 Coverage of health and climate change in scientific journals	
	5.3 Inclusion of health and climate change in high-level statements of the UNGA	

Table 1. Thematic groups and indicators for the Lancet Countdown's 2017 report.

In all cases, a pragmatic approach was taken, which took in to account the considerable data availability constraints, and the resource and timing constraints. As a result, the indicators represent what is feasible for 2017. The data sources and methods used will be actively developed over time, with the express purpose of moving from exposure-, state-, and process-based indicators, to health outcome-based indicators, and drawing closer attribution to climate change. For a number of areas – such as the mental health impacts of climate change; or hydrological mapping of flood exposure – the collaboration is currently unable to report a robust methodology for an annual indicator. This reflects the complexity of the topic and the paucity of data, rather than a lack of importance.

The Lancet Countdown is committed to an open and collaborative approach to the improvement of its current indicator set and the development of new indicators, and welcomes new academic partners with the expertise and capacity to support this. This process is one of many currently tracking various aspects of the response to climate change. Appendix 1 provides a short overview of a number of parallel and complementary processes currently underway.

Delivering the Paris Agreement for Better Health

The Paris Agreement, which was adopted by 195 countries and as of May 2017 was ratified by over 55% of countries representing 55% of global emissions, has set out a commitment of ambitious greenhouse gas (GHG) reduction to limit climate change to well below a global average temperature rise of 2°C above pre-industrial levels, with an aim to limit temperature increases to 1.5 °C.[13]

The potential health benefits of implementing the Paris Agreement are immense. As with all policy interventions, it is important to note that unintended side effects – both positive and negative – may occur.

Most countries (187) have committed to near-term GHG reduction actions up to 2030, through their Nationally Determined Contributions (NDC). Article 4 paragraph 2 of the Paris Agreement states that each signatory "*shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve*".[13] However, at the present, the NDCs of the 147 parties that have ratified the agreement fall short of the necessary reductions by 2030 to meet the 2 °C pathway. **Error! Reference source not found.** below shows a ~13 $GtCO_2$ emission gap for 2030 for meeting a 2°C pathway when examining the stated actions of the submitted NDCs.

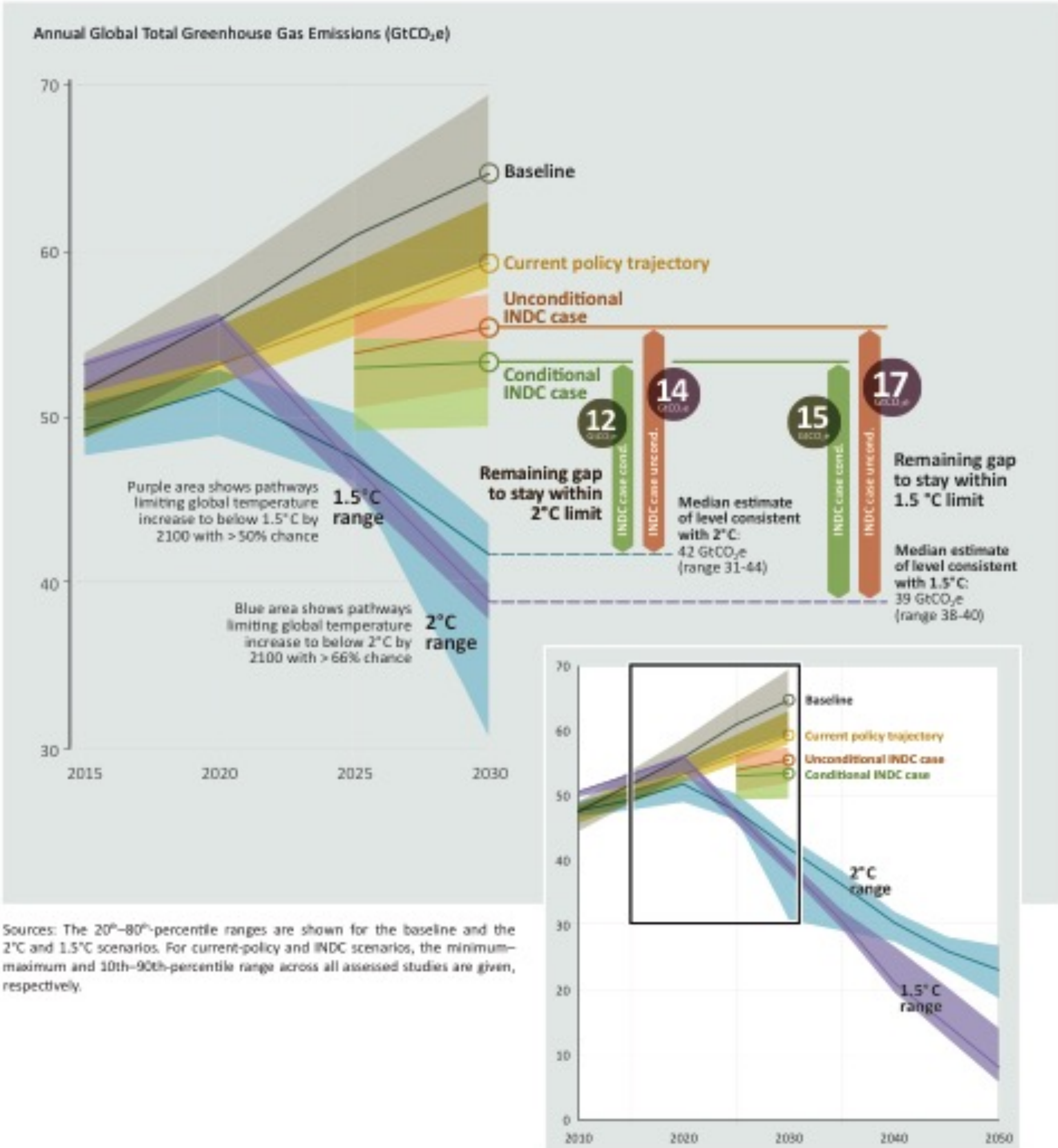


Figure 1. Global greenhouse gas emissions under different scenarios and the emissions gap in 2030.[14]

The recent steps taken by the United States' Trump Administration to leave the Paris Agreement are concerning, with their NDC responsible for as much as 20-25% of the global pledge.[15] National policies focusing on encouraging coal-fired power are short-sighted, and damaging not only to the Paris Agreement, but also to the health of Americans who breathe in the polluted air that results.

The Lancet Countdown's indicators place that decision within a broader context. They highlight the fact that globally, total power capacity of 'pre-construction' coal has halved from 2016 to 2017 alone; that every year since 2015, more renewable energy has been added to the global energy mix than all other sources combined; that electric vehicles are poised to reach cost-parity with their petrol-based counterparts; and that in 2016, global employment in renewable energy reached 9.8 million, over one million jobs more than are employed in fossil fuel extraction.

These positive examples in recent years must not mask the dangerous consequences of failing to meet the Paris Agreement, the past two decades of relative inaction, the sectors currently lagging behind, and the enormity of the task ahead. Indeed, much of the data presented should serve as a wake-up call to national governments, businesses, and civil society.

However, as this report demonstrates, the world has already begun to embark on a path to a low-carbon and healthier world, and the direction of travel is set.

1. The Health Impacts of Climate Change

Introduction

This section provides a set of indicators that track health impacts of hazards (both rapid onset shocks and slow onset stresses) related to anthropogenic climate change. Such impacts are dependent upon the nature and scale of the hazard and on the extent and nature of human exposure to them. Much of the progress made in global health has been as a result of developing and implementing systems to reduce populations' vulnerabilities to various parts of the environment. Yet climate change threatens to undo this progress, rendering the systems used to manage existing exposures potentially insufficient in the future.

The indicators in this section cover a selection of the health impacts of climate change which, in turn, inform protective adaptation and mitigation interventions (sections two and three), the economic and financial tools available to enable such responses (section four), and the public and political engagement that facilitates them (section five).

Climate change affects human health primarily through three pathways: direct; ecosystem-mediated; and human-institution-mediated.[16] Direct effects are diverse, being mediated (for instance) by increases in the frequency, intensity, and duration of heatwaves, and by rises in average annual temperature experienced (leading to heat-related mortality and reductions in manual labour capacity). Rising incidence of other extremes of weather such as flood and storms risk drowning and injury, the spread of water-borne disease, and mental health sequelae.[17] Ecosystem-mediated impacts of climate change include changes in the distribution and burden of various vector-borne diseases, such as malaria and dengue, and food and water-borne infectious disease. Human malnutrition from crop failure, population displacement from sea-level rise, and occupational health risks are examples of human-institution-mediated impacts. Forced displacement, as opposed to migration as an adaptive response, is associated with negative health outcomes, including increased risk of water and food insecurity, infectious disease outbreaks, undernutrition, and elevated rates of mental ill-health.[18]

Both direct and indirect indicators are tracked by the Lancet Countdown, monitoring the extent to which populations are exposed to, and thus could be harmed by, extremes of weather (indicators 1.1-1.3), the spread of vector-borne climate-sensitive disease (indicator 1.4), food insecurity (indicator 1.5), and population displacement (indicator 1.6).

In selecting these indicators, the reality of data limitations and the tensions and linkages between mitigation efforts and subsequent adaptation costs are important to consider. The indirect indicators each provide a 'proof of concept', rather than being fully comprehensive, focusing variably on a specific disease, population, or location.

The choice of indicator, and particularly the extent to which an indicator focuses on exposure or socio-economic vulnerability, influences the extent to which attention is drawn to climate change mitigation or adaptation, and thus could influence where governments focus their efforts. Implicit in this choice are efficiency and equity considerations, across time and spatially across different communities and countries. Governments make choices between the more immediate and known costs of mitigation activities and the delayed and more uncertain costs that will be imposed in the future by the need to adapt to climate change, or indeed the inability to adapt.

A number of challenges associated with choosing indicators to track the health impacts of climate change are recognised, specifically: dealing with signal-to-noise ratios; attribution to climate change;

and the role of institutions and policies in determining the impact of a climate hazard on labour productivity, food security, nutrition, and migration. Signal to noise ratios are of particular concern here for two reasons. First, with respect to climate warming and climate hazards, annual natural climate variability introduces noise into the system, whereas an important signal is the long-term climate trend.[19] Attribution, "the process of establishing the most likely causes for a detected change with some level of confidence"[20], thus becomes important when selecting indicators. Second, with respect to identifying the impact of a climate hazard on human wellbeing and health, as reflected in disease, nutrition, and migration, the ultimate impacts on health are heavily mediated by institutions and policies, such that the signal-to-noise ratio between climate hazard and health impact decreases.

Six indicators were selected and developed for this section:

- 1.1 Exposure to temperature change
- 1.2 Exposure to heatwaves
- 1.3 Change in labour capacity
- 1.4 Exposure to climate-sensitive infectious diseases
- 1.5 Vulnerability of food systems and undernutrition
- 1.6 Migration and climate change

Corresponding Appendix 2 provide more detailed discussion of the data and methods used.

Indicator 1.1: Exposure to temperature change

***Headline Finding**: Human exposure to global temperature rise was more than double global average temperature rise in 2016.*

Rising temperatures can exacerbate existing health problems among populations and also introduce new health threats. The extent to which human populations are exposed to this change and thus the health implications of temperature change depend on the detailed spatial-temporal trends of population and temperature over time.

Figure 1.1 calculates mean warming between 2000 and 2016, with the exposure-weighted line (blue) weighted by population, capturing human exposure to warming, which is significantly higher than area-weighted warming alone, 0.87K and 0.35K respectively. This is driven primarily by growing population densities in India (particularly in the Ganges Basin and the north east of India), parts of China and Sub-Saharan Africa. Accounting for population when assessing temperature change provides a vital insight into how human wellbeing is likely to be affected by temperature change. Although there has been evidence for years that global temperatures are increasing, the analysis here shows that temperature change where people are living is much higher. Populations are clearly much more exposed to higher changes in temperatures than figures on global warming alone have previously shown.

Further, areas where population density is increasing tend to be among the poorest and most vulnerable in the world, with high dependencies on the environment for basic needs such as water, food (subsistence farming) and energy (biomass). Thus, greater exposure to temperature change, which affects these environmental parameters, in these areas is of particular concern. Figure 1.2 overlays this on to a map of the globe, showing higher levels of warming around the Poles, Southern Africa, India, Europe, Western Australia and Western Canada.

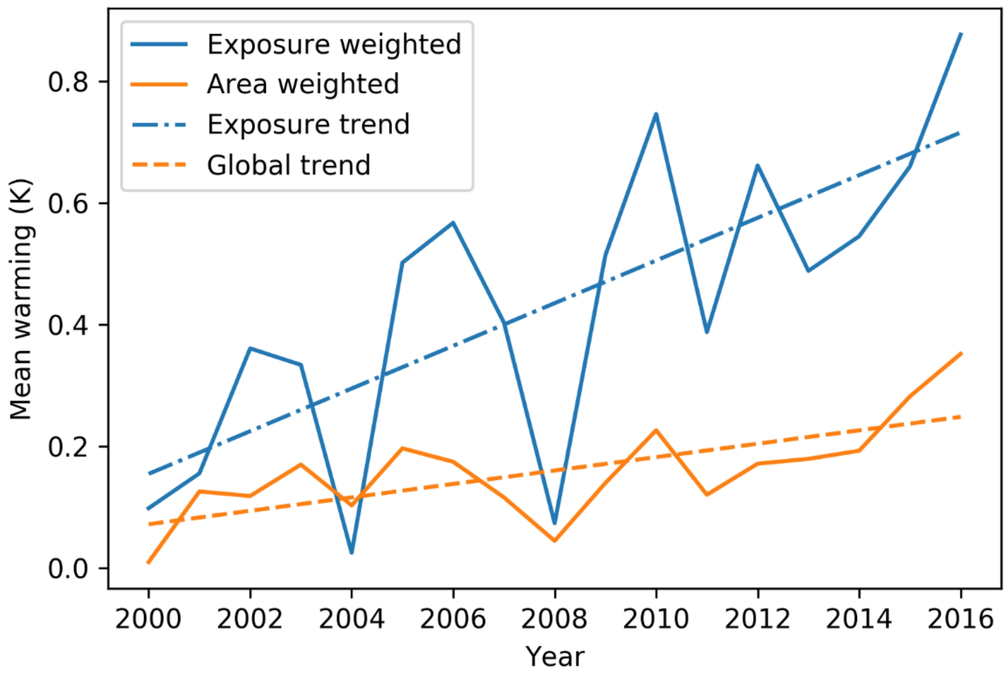


Figure 1.1. Mean warming from 2000 to 2016 area weighted and exposure weighted, relative to the 1986-2008 historical average.

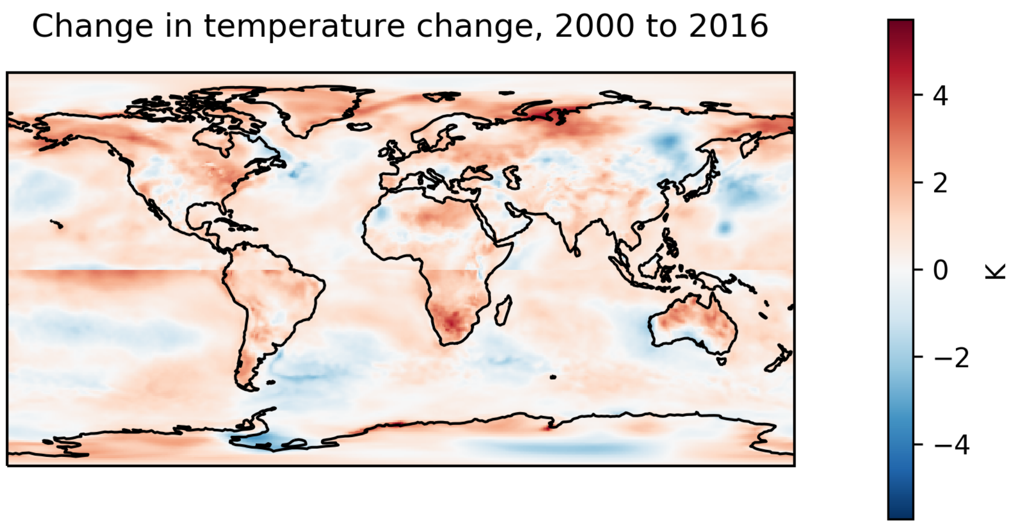


Figure 1.2. Map of global temperature change between 2000 and 2016.

Temperature data was calculated against the historical period 1986 to 2008, corresponding to the ERA climatology period. The time series shown in Figure 1.1 is a global mean of the gridded data, weighted by area (to avoid bias from measurements near the poles) and also weighted by population (to demonstrate population exposure); these are described as “area weighted” and “exposure weighted”, respectively. Changes in population were obtained per country and selected for 2005, as this was the approximate middle for the time-period studied, and the data was projected onto the gridded population.

How exposure to temperature change alters in future is dependent upon the responses of the climate system to greenhouse gas emissions, although climate models have increasing agreement on expected changes in temperature (especially in the short-term). Long-term, temperature changes will be lower or higher depending upon which emissions pathways the world takes; with higher greenhouse gas emissions, there will be greater temperature rise. The 2015 Lancet Commission modelled future exposure to temperature change up until 2100; these models show that temperatures will increase at relatively similar rates for all emission scenarios up until 2030. After this, emissions pathways become more important in determining future temperature change up to 2100. Therefore, despite the rate of greenhouse gas emissions in the next thirteen years, humans will nonetheless be exposed to a rise in temperatures of approximately 0.75°C between now and 2030.[7]

Indicator 1.2: Exposure to heatwaves

***Headline Finding**: In 2016, vulnerable populations were exposed to heatwaves that were on average, 1.5 days longer than the global average.*

The European Heatwave of 2003 resulted in an additional 70,000 deaths across Europe during the summer of that year, highlighting the importance of tracking global population exposure to heatwaves.[21] The health impacts of extremes of heat range from direct heat stress and heat stroke, through to exacerbations of pre-existing heart failure, and even an increased incidence of acute kidney injury resulting from dehydration in vulnerable populations. The elderly, children under the age of 12 months, and people chronic cardiovascular and renal disease are particularly sensitive to these changes.[17]

Figures 1.3 and 1.4 demonstrate the exposure weighted value of both the number of heatwaves and the length of heatwaves, indicating clearly that exposure to heatwaves is increasing more rapidly over time than area-weighted alone. Most significantly, the length of heatwaves is 5.2 days in exposed populations, as compared to 3.7 days when averaged globally (Figure 1.4), with the most heavily populated areas experiencing the most severe effects of heatwave since the turn of the century.

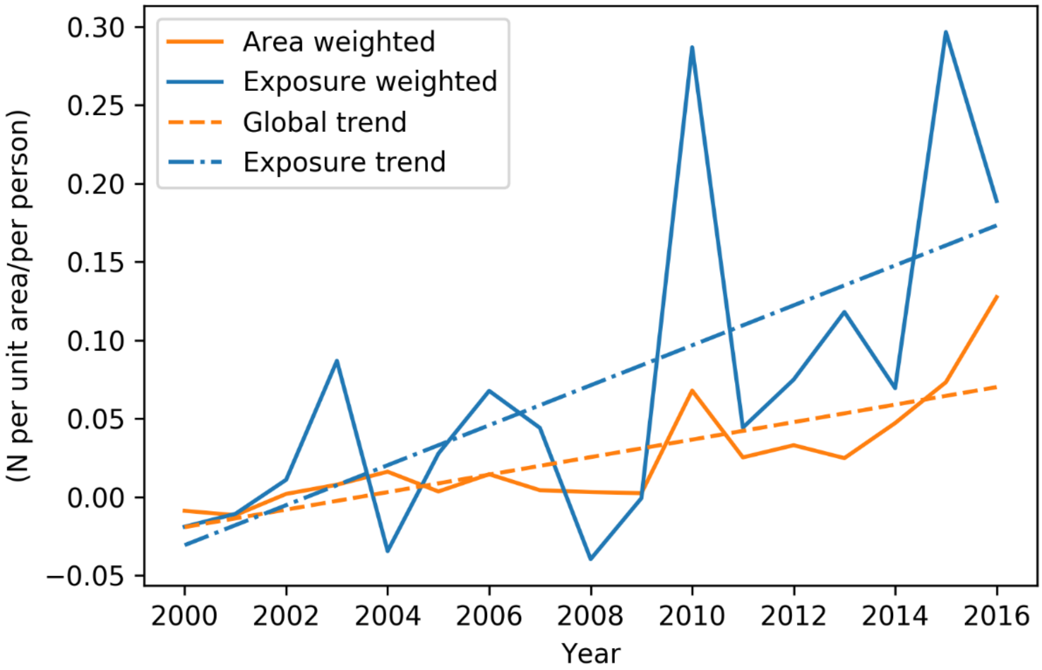


Figure 1.3. The area and exposure weighted change in the occurrence of heatwaves per unit area per person from 2000 to 2016.

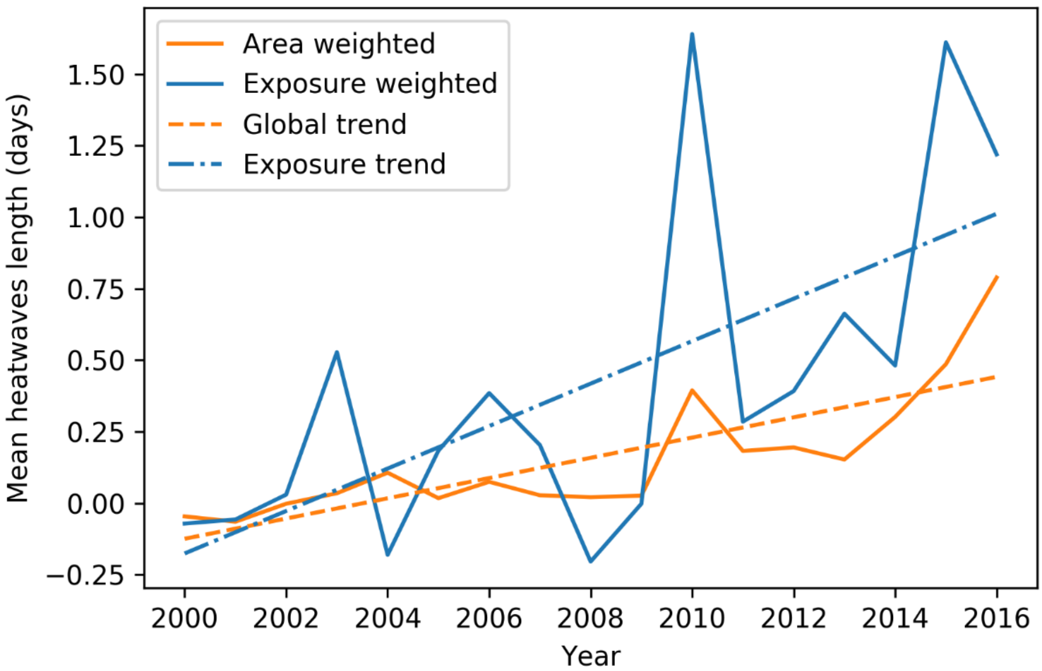


Figure 1.4. The area and exposure weighted change in the length of heatwaves (measured by the number of days over 3 days) globally from 2000 to 2016.

Heatwave data were calculated against the historical period 1986-2008, corresponding to the ERA climatology period. The time series shown in Figures 1.3 and 1.4 are a global mean of the gridded data, weighted by area (to avoid bias from measurements near the poles) and also weighted by population (to show population exposure); these are described as "area weighted" and "exposure weighted", respectively. Here, a heatwave is defined as a period of more than 3 days where the minimum temperature is greater than the 99th percentile of the historical minima (1986-2008 average). In addition, the length of the days a heatwave occurs for is summed, showing changes in the length of heatwaves since the year 2000. Thus, two measures of heatwave are shown: the number of heatwaves and the length of the heatwaves. The population is taken as the fraction of people aged over 65, as this age group is most vulnerable to the health impacts of heatwaves. Population data was obtained per country and selected for 2005, as this was the approximate middle for the time-period studied. The country data are projected onto the gridded population.

Over the next few decades, climate models agree that heat waves are likely to increase in duration, intensity and spatial extent. In the long-term up to 2100, heat waves are very likely to increase in intensity, frequency and duration.[22] Much as with temperature change, changes in the occurrence and duration of heatwaves up to 2030 is already committed to. Beyond 2030, mitigation will be vital to reduce the extent to which the intensity, frequency and duration of heatwaves changes. However, this does not account for human exposure, which the findings here show significantly affect changing exposure to heatwaves. Depending on future population growth and density trends, people may be even more exposed to more and longer heatwaves than the previously.

Indicator 1.3: Changes in labour Productivity

Headline Finding: *Labour capacity in populations exposed to temperature change has decreased by 5.3% from 2000 to 2016.*

Higher temperatures pose significant threats to occupational health and labour productivity, particularly for those undertaking manual labour outside in hot areas. This indicator shows the change in labour capacity (and thus productivity) globally and specifically for rural regions, weighted by population. Reductions in labour capacity have important implications for the livelihoods of individuals, families, and communities, with particular impact on those which rely on subsistence farming.

When population exposure is accounted for, labour capacity is estimated to have decreased by 5.3% between 2000 and 2016, with a dramatic decrease of over 2% in 2015 and 2016. Although there are some peaks of increased labour capacity (notably 2000, 2004 and 2008), the overwhelming trend is one of reduced capacity (Figure 1.6). As expected, these effects are most notable around the equator (Figure 1.7), where countries are generally poorer and more reliant on manual work for their livelihoods (often in the form of subsistence farming).

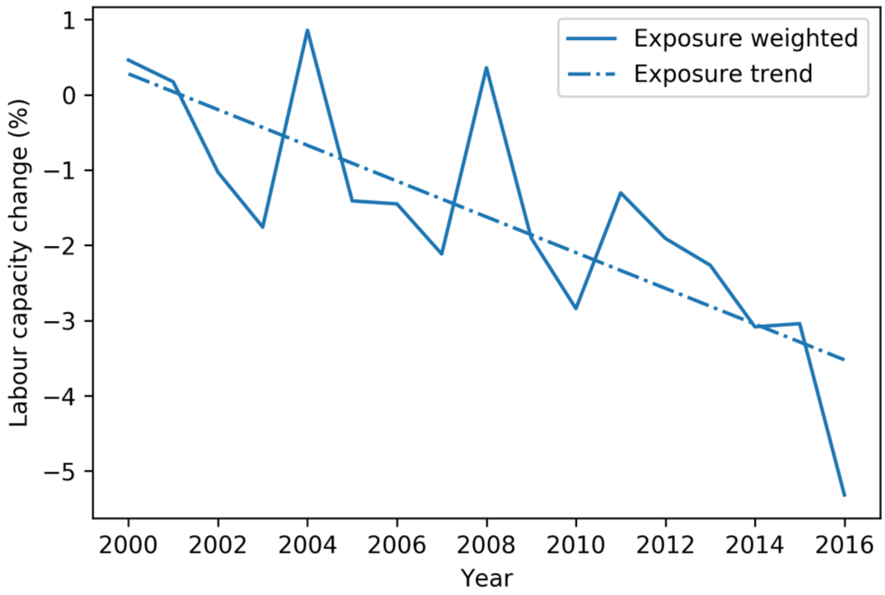


Figure 1.6. The exposure weighted labour capacity change (%) globally from 2000 to 2016.

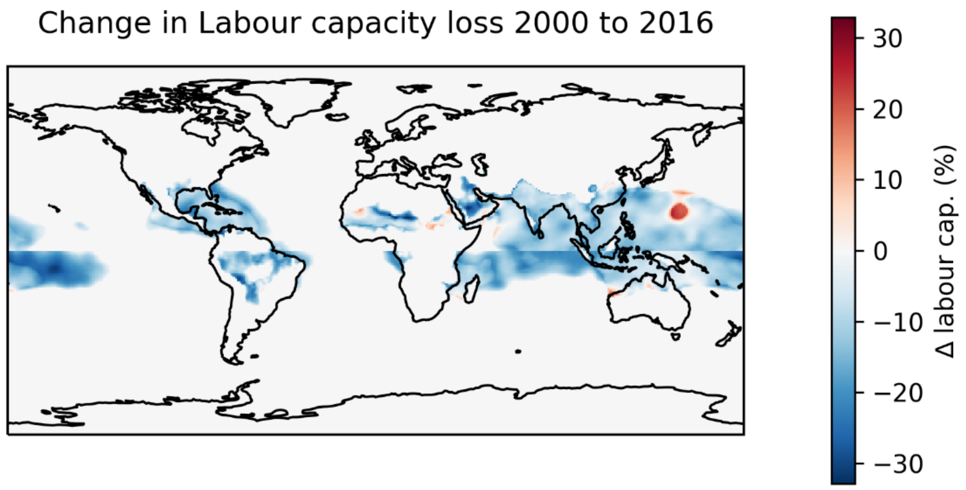


Figure 1.7. Map of the change in labour capacity loss globally from 2000 to 2015.

Wet bulb globe temperature data was calculated against the historical period 1986-2008, corresponding to the ERA climatology period. This period was taken as the historical average and capacity change was calculated from this. The time series shown in Figure 1.6 is a global mean of the gridded data, weighted by population (to demonstrate population exposure); described as "exposure weighted". Labour capacity was calculated from wet bulb globe temperatures. Labour capacity is here presented as a percentage, with 100% meaning no labour lost due to climatic conditions. The population was taken as the rural population (as outdoor labour is largely concentrated here for agriculture) and the data was obtained for every country for the year 2005, as this represented the approximate middle of the time-period studied. The country data was projected onto the gridded population data.

Labour capacity here is a direct result of temperature change, and so the changes in labour capacity again are likely to be committed to up to 2030. Given that over the past fifteen years there has already been a 5.3% decrease in labour capacity, a similar or bigger loss of productivity could occur between now and 2030. As with indicators 1.1 and 1.2, the findings here have shown the importance of accounting for population when measuring exposure to changes in labour productivity. Future expected population trends are therefore vitally important to consider when estimating future lost labour capacity.

Exposure to drought and flooding

The Lancet Countdown's 2016 report laid out a framework for two additional indicators relating to exposure to flood and to drought, which we unfortunately cannot report here.[8] This is partly due to resource constraints, however, it is also due to the fact that definitions of flood and drought are more complex than those relating to temperature change, heatwaves and changes in labour productivity. Drought has regional definitions, which are important to capture if exposure to drought, and significant changes in this exposure, is to be accurately reported on over time. Measuring flood risk is also complicated, and is driven by a variety of factors including precipitation and land use, manifesting as fluvial, pluvial, coastal and groundwater flooding. Modelling exposure to this would require a combined hydrological model and climate model, using observed data to model past flood exposure and weight this against population density. The Lancet Countdown will continue to work on the development of these two indicators for 2018.

Indicator 1.4: Exposure to climate-sensitive infectious diseases

***Headline Finding**: Relative vectorial capacity for the mosquito vector Aedes aeqypti has increased by 9.4% globally since the 1950s.*

Despite a declining overall trend, infectious diseases still account for around 20% of the global burden of disease and underpin more than 80% of international health hazards as classified by the WHO.[23,24] Climatic factors are routinely implicated in the epidemiology of infectious diseases, and they often interact with other factors, including behavioural, demographic, socio-economic, topographic and other environmental factors, to influence infectious disease emergence, distributions, incidence and burden.[5,25] Understanding the contribution of climate change to infectious disease risk is thus complex, but necessary for advancing both climate change mitigation and adaptation policies.[18]

Work for this indicator was broken in to two components: a systematic literature review of the links between climate change and infectious diseases, and a vector capacity model for the climate-sensitive vector, *aedes aegypti*. The strong link between climate and infectious diseases is reflected in the number of publications addressing climate change and infectious disease associations, which has dramatically increased since 2014 (Figure 1.8, black line in the top plot). The number of new publications in 2016 (n=89) was the highest yet reported, almost double the number published in 2015 (n=50) and more than triple the number published in 2014 (n=25). Figure 1.9 maps the focus country of publications on infectious disease and climate change in 2016. Here, China and North America are heavily over-represented, with South America and South East Asia underrepresented in 2016.

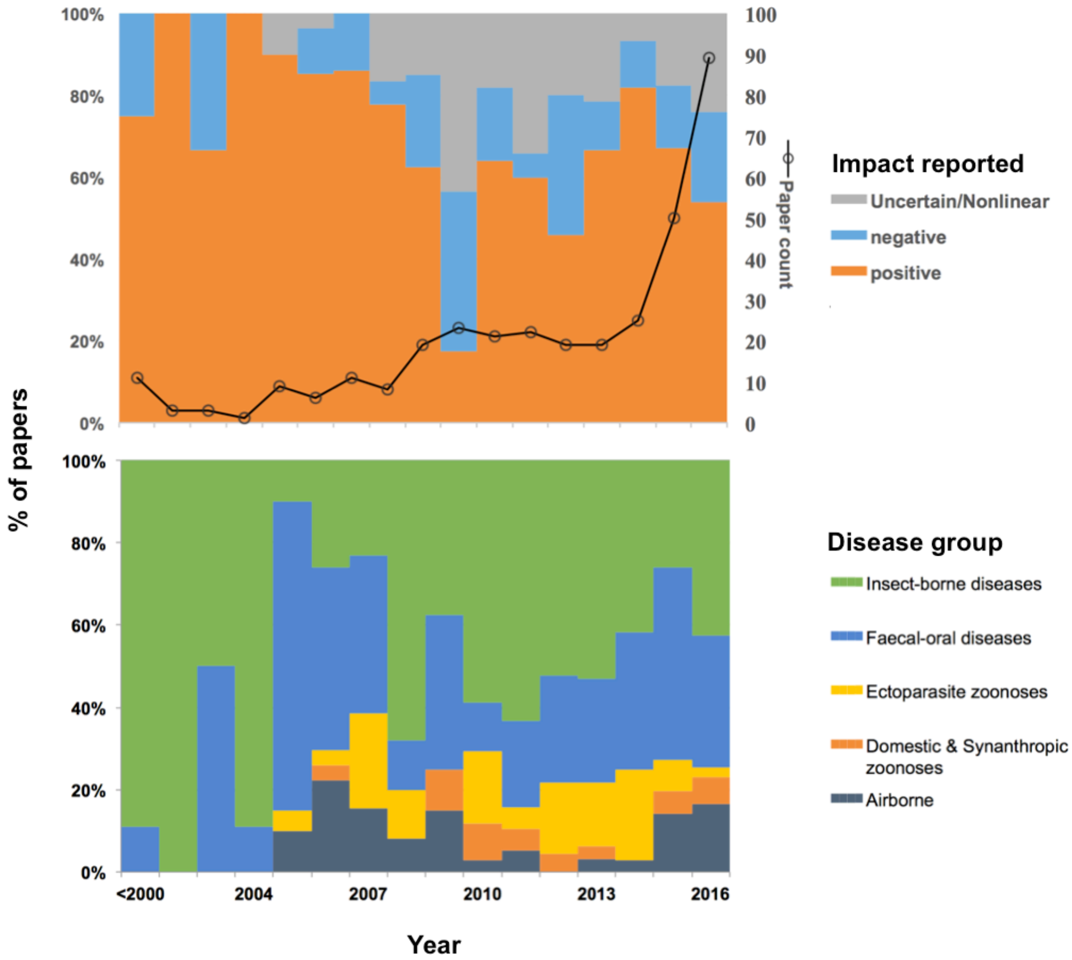


Figure 1.8. Academic publications reporting climate-sensitive infectious diseases by number and impact reported (top plot) and disease group (bottom plot).

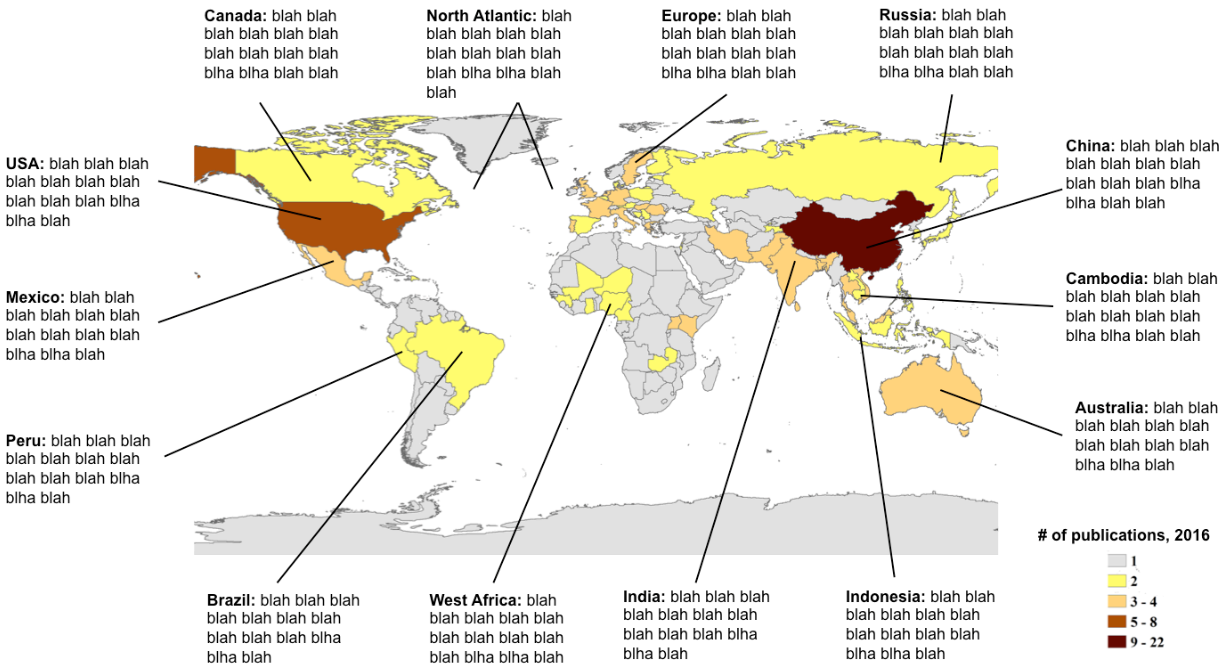


Figure 1.9. Number of infectious disease and climate change publications in 2016 by focus country.

The second component of this indicator examines trends in the global potential for dengue virus transmission (as represented by relative vectorial capacity, rVC, in the mosquito vector *Aedes aeqypti*). This reached its equal highest average level in 2015 (tied with 2010 and 1998) against a 1950 baseline (Figure 1.10, top panel). This consolidates a clear and significant increase (+8.7%) in rVC since the late-1970s. Nearly all countries in the analysis showed an increase in rVC since 1950, with only a few countries showing a decrease (Figure 1.10, bottom panel). Very similar results were obtained from a similarly parameterised model of rVC for dengue in *Aedes albopictus* (1950 v 2015 Δ rVC = +13.0%) (see Appendix 2 for details). Overall, 2015 exhibited the single highest globally averaged rVC for dengue in *A. albopictus* since 1950, with a 9.4% increase during this period.

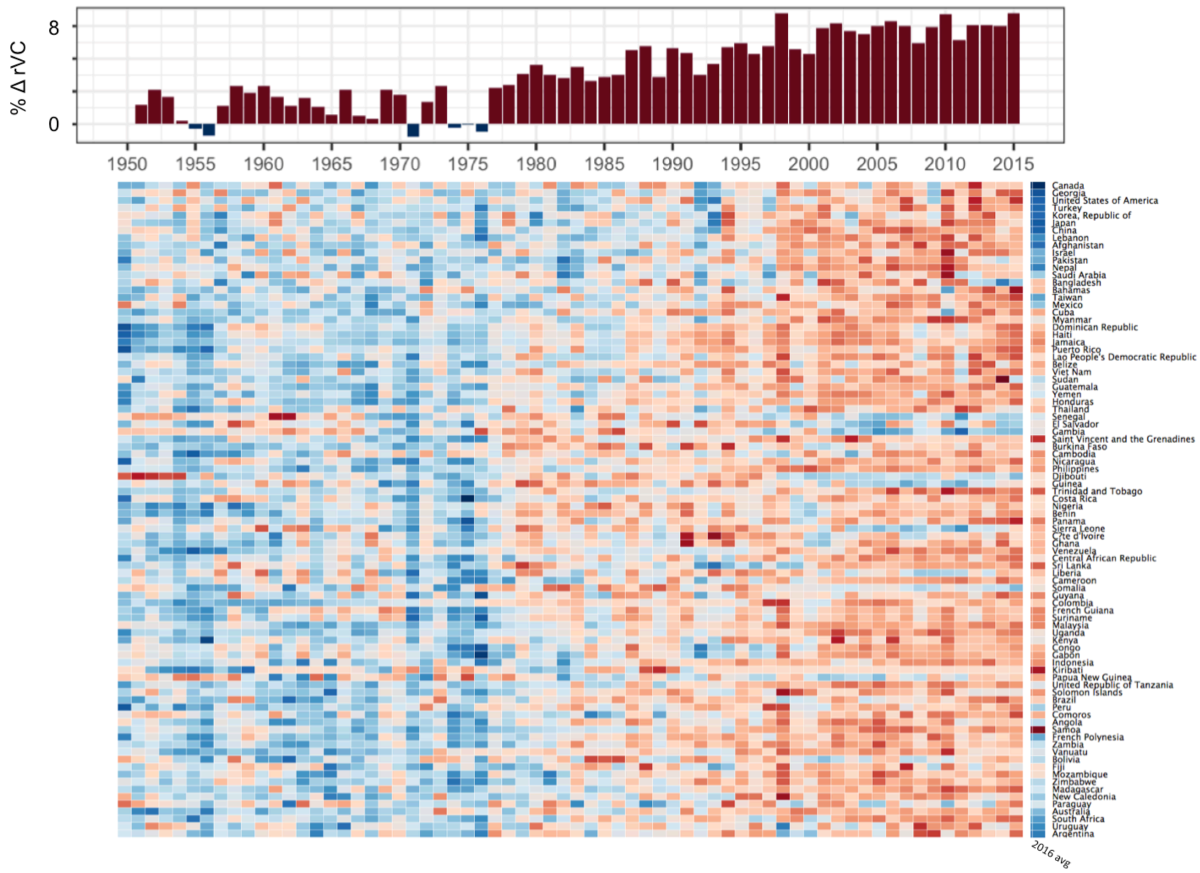


Figure 1.10. Average relative vectorial capacity (rVC) for dengue in Aedes aegypti calculated globally (top panel) (relative to 1950 baseline) and for selected countries (lower panel) (main matrix coloured relative to country mean 1950-2015; right most column coloured relative to global mean in 2015; red = relatively higher rVC, blue = relatively lower rVC). Countries in lower panel ordered by centroid latitude (north to south).

Two different approaches were used as a starting point for gauging the potential impacts that climate change may be having or will have on infectious diseases. Firstly, a systematic review of the climate-change infectious disease (CC-ID) literature, in which trends in the evolution of knowledge and direction (positive vs negative vs equivocal) of climate change disease risk associations were assessed (Figures 1.8 and 1.9). Secondly, a global, mechanistic investigation of changes in transmission potential for a model, high burden, climate-sensitive vector-borne disease, dengue fever (Figure 1.10). Cases of dengue have doubled every decade since 1990, with 58·4 million (23·6 million–121·9 million) apparent cases in 2013, accounting for over 10,000 deaths and 1·14 million (0·73 million–1·98 million) disability-adjusted life-years.[26] Climate change has been suggested as one potential contributor to this increase in burden.[27] *Aedes Aegypti, the principal vector* of dengue, also carries other important emerging or re-emerging arboviruses, including yellow fever, chikungunya and zika viruses, which are also similarly responsive to climate.

In the near term, an ongoing increase in the volume of publications exploring climate change infectious disease associations is expected, covering increasingly more dynamic and complex disease systems with increasing taxonomic and geographic representativeness. Climate change is not expected to be a universal driver of increased disease risk and many disease systems may exhibit overall declines in risk as changes in climatic factors could similarly drive components of disease transmission systems beyond environmental optima.[28] Understanding this broader range of responses is critical to tailor research and management efforts on disease systems and populations.

With respect to dengue virus transmission potential, there has been a clear and consistent increase in globally averaged VC since the late 1970s. For *Aedes aegypti*, VC was an average of 9.4% higher in 2015 relative to a 1950 baseline. Extrapolating the strong linear increase in VC for *Aedes aegypti* since 1950 (R^2 = 0.784) suggests that VC could increase by a further 1.6% by 2030 (i.e., ~11% overall increase relative to the 1950 baseline). This extrapolation is based only on the observed increase in VC to date and does not take into account actual projections of climate change from global circulation models.

Vulnerability of food systems and undernutrition

Links between climate, food insecurity, and undernutrition are well documented. Yet isolating the impact of climate change on health through the indirect impacts on food security is complicated, as policies, institutions, and the actions of individuals, organisations, and countries, strongly influence the extent to which food systems are resilient to climate hazards or can adapt to climate change, and whether individual households are able to access and afford sufficient nutritious food. For example, with respect to undernourishment, vulnerability has been shown to be more dependent on adaptive capacity (such as infrastructure and markets) and sensitivity (such as forest cover and rain-fed agriculture) than exposure (such as droughts, floods, storms).[29] Given the role of human systems in mediating the links between climate, food, and health, the chosen indicators focus on abiotic and biotic indicators and current population vulnerabilities, considering both terrestrial and marine ecosystems. The potential health implications are many and varied, with stunting as a result of malnutrition present throughout the rest of life, predisposing individuals to a broad range of communicable and non-communicable disease.

Indicator 1.5.1: Vulnerability to under-nutrition

Headline Finding:

The purpose of this indicator is to track the extent to which health in countries where dependence on domestic production of food is high and under-nourishment is already high, will be further compromised by climate change-induced changes in temperature and precipitation, manifested in falling yields.

Food markets are increasingly globalised, and food security – access to sufficient, affordable, and nutritious food – is increasingly driven by human systems. For example, poor wheat harvests in Australia in 2005-6, resulting from successive droughts, were a key trigger in the 2008 food crisis. Export restrictions, ‘panic buying’, ‘hording’, and speculation drove the extreme price spikes that increased food insecurity in many lower-income countries, whilst record harvests the following cycle eased the crisis. Yet equally importantly, many lower-income, food-insecure countries still depend primarily on growing a large proportion of the food that they consume, and localised crop losses will increase levels of under-nutrition.

Temperature and precipitation are highlighted as the key impacts of climate change on food production. Crop yields are sensitive to temperature increases, and globally the negative impacts outweigh the positive for most of the key staples. Rising temperatures have been shown to reduce global wheat production, which has been estimated to fall 6% for each degree Celsius of additional temperature increase. Rice yields are sensitive to higher night temperatures, with each 1°C increase in growing-season minimum temperature in the dry season resulting in a fall in rice grain yield of 10%. Higher temperatures have been demonstrated rigorously to have a negative impact on crop yields in lower-latitude countries.[30-32] Moreover, agriculture in lower-latitudes tends to be more marginal, and more people are food insecure. There is less confidence in the literature concerning the impact of precipitation on yields, in part due to measurement difficulties.[31]

In response to falling yields caused by temperature increases, governments, communities, and organisations can and will undertake adaptation activities that might variously include breeding programmes, area expansion, increased irrigation, or switching crops. However, the greater the loss of yield potential due to temperature increases, the more difficult adaptation becomes.

The indicator selected for this focuses on the vulnerability and exposure of populations to food insecurity, and is presented in Figure 1.11, below. The analysis selected a sample of countries with three key characteristics. Firstly, those with a low cereal import dependence ratio (and hence a high domestic production dependence) are selected, as these countries are most vulnerable to localised weather shocks (and indeed, may also be the most vulnerable to global food shocks). Secondly, countries in locations where temperature increases are clearly negatively affecting yields are selected. Thirdly, countries with 'moderately high' (18 countries), 'high' (15 countries) and 'very high' (5 countries) levels of under-nourishment as measured by the Food and Agricultural Organization, are selected.[33] Data for countries from the resulting five regions in Africa and Asia presented below is then analysed, with the percentage of the population under-nourished, multiplied by a country's dependence on domestic cereal production.[33] A detailed description of the reasoning and potential additional and future indicators available to complement this approach is described in Appendix 2.

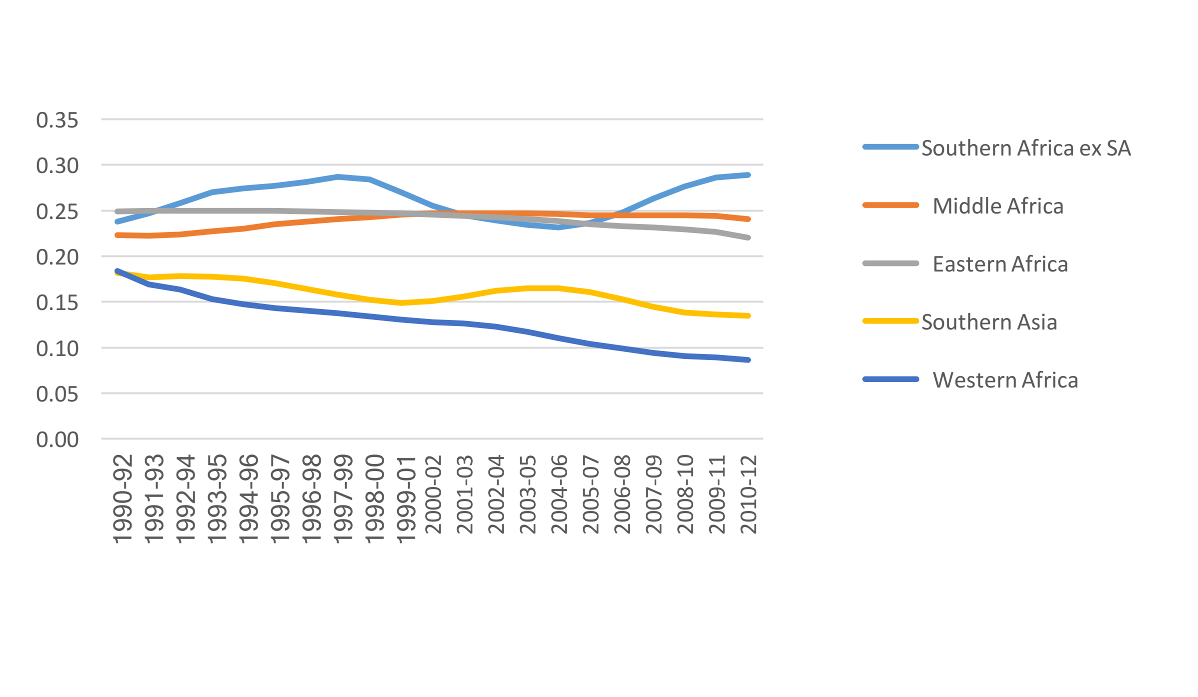


Figure 1.11: Vulnerability of regions to climate-driven yield losses.[33]

Three regions in Africa exhibit high and sustained vulnerability and exposure. These regions also coincide with areas where yield losses due to warming are predicted to be relatively high, thus increasing the vulnerability of these populations to the negative health consequences of under-nutrition. Southern Asia and Western Africa exhibit "high" levels of dependence on local cereal production, but low and falling levels of under-nutrition. Globally 38 countries are currently experiencing under-nutrition rates of over 15%, and 20 countries rates over 25%. Of these 38 countries, 29 depend on domestic production for at least half of their cereal consumption. High dependence on one crop increases the vulnerability of individual countries further. For example, Kenya has a domestic production dependency for cereals of almost 80%, is 69% dependent on maize, is experiencing high levels of under-nutrition, and is particularly vulnerable to climate-related yield losses. Going forward, this data will be refined through country-level exploration, incorporation of the predicted impact of warming on yield losses, and aggregated to determine the extent to which total population exposure and vulnerability is changing over time.

Maize, wheat, rice, and soybean account for around three quarters of human consumed calories,.[31] Though yields will be affected differentially depending on the particular crop and location, overall crop yields for staples (excluding rice for which no overall change is expected) are predicted to decline on average by 8% by the 2050s in South Asia (-16% maize, -11% sorghum) and Africa (-17% wheat, -5% maize, -15% sorghum, -10% millet), currently the most food insecure regions.[34] Considerable falls in total production are predicted by 2100 for maize and soybean that will affect vulnerable populations across the globe (30-46% under the slowest Hadley III warming scenario and 63–82% under the most rapid).[35]

Indicator 1.5.2: Marine primary productivity

Decline in fish consumption provides an indication of food insecurity, especially in local shoreline communities which are dependent on sea products for food, and are thus particularly vulnerable to any declines in marine primary productivity affecting fish stocks. This is particularly concerning for the 1 billion people around the world who rely on fish as their principal source of protein, and are hence at increased risk of stunting and malnutrition as a result of any decline in food security.[36] Low fish consumption is also associated with a diet low in seafood Omega-3 fatty acids which is a risk factor for cardiovascular diseases.[37]

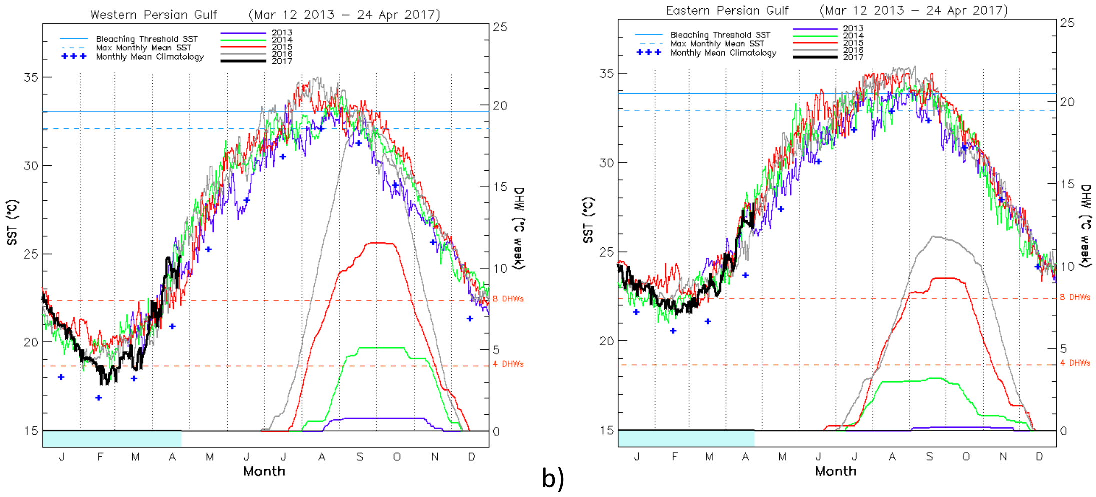
Marine primary productivity is determined by abiotic and biotic factors, and measuring these globally and identifying relevant marine basins is highly complex. Factors such as sea surface temperature (SST), sea surface salinity (SSS), coral bleaching and phytoplankton numbers are key determinants of marine primary productivity. These are often highly localised and other local determinants have particularly strong influences on marine primary productivity. For example, harmful algal blooms (HAB) occur as a result of uncontrolled algal growth producing deadly toxins. The consumption of seafood contaminated with the toxins of harmful algal blooms such as those produced by *Alexandrium tamarense*, is often very dangerous to human health, and potentially fatal.[38]

Changes in SST and SSS from 1985 to present, for twelve fishery locations essential for aquatic food security are presented here. Data was obtained from NASA's Earth Observatory Databank, and mapped across to the significant basins outlined in Appendix 2. From 1985 to 2016, a 1°C increase in SST (from an annual average of 22.74°C to 23.73°C) was recorded in these locations.[39] This indicator requires significant further work to draw out the attribution to climate change and the health outcomes that may result.

Box 1.1 provides a case study of the impacts of degrading marine primary productivity on commercial fish stocks in the Persian Gulf.

Box 1.1 Commercial fish stocks in the Persian Gulf

One basin in which fish stocks are an important source of food is the Persian Gulf. Fish stocks have been declining in the Persian Gulf since the 1970s, with food security concerns arising for the populations here dependent on fish for food.[40] Human activities are influencing fish stocks in the Persian Gulf, including industrial activity, dredging and land reclamation.[41] Furthermore, recent studies of fishing in the Persian Gulf show that actual fish catches in this region are up to six times higher than the reported quantities given to the UN.[42] These factors are compounding to increase the pressure on fish stocks and reduce marine populations, which many people in the area are dependent on as a primary source of food.



a) b)

Figure 1.12. Changes in the SST in the a) western and b) eastern regions of the Persian Gulf from 2014 to 2017 vs. the coral reefs bleaching threshold of 35°C.[43]

Beyond these direct human behaviours, anthropogenic climate change is also putting fish populations in the Persian Gulf at risk. Key proxies for the influence of climate change on fish stocks are SST and SSS. Changes to SST and SSS have been found to have been negatively impacting the coral reefs in the Persian Gulf, which fish populations are dependent upon for their survival; for example, there were mass coral bleaching events in the Persian Gulf in 1996 and 1998, which caused a decline in fish.[41] Figure 1.12 compares the variations in SST in the western and eastern regions of the Persian Gulf.[44] SST has risen since 2013, but also exceeds the coral bleaching threshold of 33°C in the summer months across both regions throughout the period 2013 to 2017. Rising SST and associated coral stress is likely to have contributed to lower fish populations and associated decreases in the total catch of major commercial fish species in the Iranian waters in the Persian Gulf, including tiger tooth croaker (Otolithes ruber), threadfin (Polynemus spp.), and silver pomfret (Pampus argenteus). Not only does this pose direct risks to human health through food insecurity, but retail prices have also spiked as a result of reduced availability, further contributing to reduced fish consumption in coastal provinces.[44] For instance, Bushehr Province, the main Iranian fish catching site, has experienced a decrease in the total catch of the major commercial fish species, leading to a sharp decline in annual fish consumption per capita, from 46.8 kg in 2009 to 24.7 kg in 2016 (Figure 1.13).[45] This decline is most likely a combination of human stresses, including climate change and overfishing, but nonetheless the consequences for human health are clear – reduced fish availability increases food insecurity and risks malnourishment in the region. If climate change is not mitigated, SST and SSS will increase further in future, placing coral reefs and dependent fish in the Persian Gulf at greater risk of depletion. Fishing activities should therefore also be mindful of the need for sustainable fish populations, as changes to commercial fish stock populations do not result from one sole factor, but rather a combination of stresses reducing fish populations that will be exacerbated by climate change.

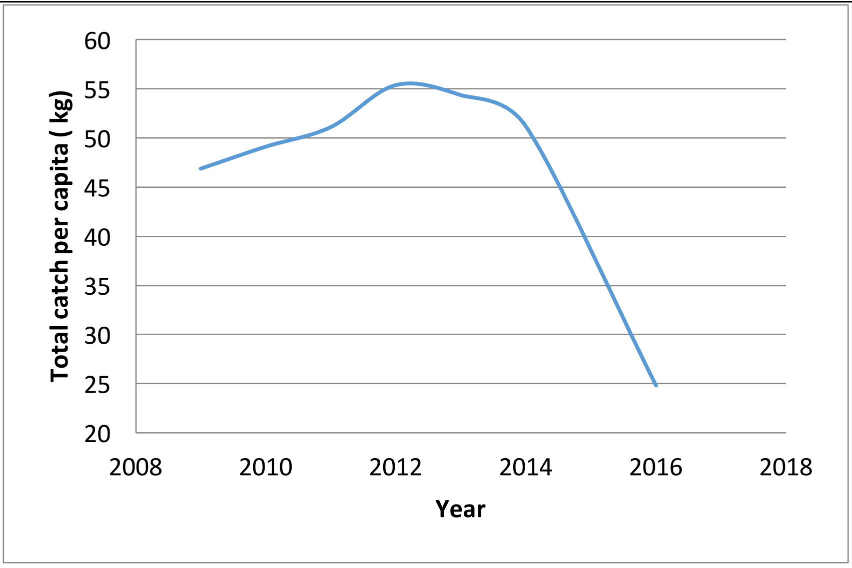


Figure 1.13. Annual fish consumption per capita in Bushehr Province (main Iranian fishing site) from 2009-2016.[45]

Indicator 1.6: Migration and climate change

***Headline Finding**: 4,400 people globally are already being forced to migrate due to sea-level rise caused by climate change.*

Many factors, including climate change, influence human migration, and these may interact. Further, climate change might drive such migration through diverse mechanisms that interact in complex and non-linear ways (loss of habitation due to extreme weather, loss of land due to sea level rise, degradation of agricultural land through flooding, drought, salt water ingress, or changes in resource availability or disease burden to name but a few). For these reasons, demonstrating a causal link between climate change and migration, and quantifying such an impact, is hard. Further, it can be hard to even define migration under such circumstances.

For example, the Pingelap atoll in the Federated States of Micronesia has a significant amount of land over 15 metres above sea level, all of which is within 300 metres of the coast. If its people move to different houses due to sea-level rise, a question is raised as to whether this would be counted as migration, given that the people are still living in effectively the same location. Consequently, this indicator is kept at a country level, identifying the countries which may not be able to remain as countries under thermal expansion, in addition to communities that are currently migrating due to climate change.

Currently, a minimum of 4,400 people across a minimum of fourteen communities are being forced to migrate due to climate change only, with many other communities and countries experiencing climate change as one of a number of factors driving migration. (Table 1.1). By 2050, a minimum of 584,000 people across a minimum of four countries will likely be forced to migrate due to climate change only (Table 1.2). All four countries are small island developing states (SIDS). Whilst all countries have been considered, these countries have limited inhabitable high ground. Ice sheet collapse scenarios lead to the possibility of more than one billion people (with wide sensitivity ranges) having to adapt to climate change or be forced to migrate as a result of it, from 2100 onwards.

Location	Population	Citation	Notes on causes
Carteret Islands, PNG	1,200	Connell (2016)[46] Strauss (2012)[47]	Migrating due to sea-level rise
Alaska (need to migrate as soon as possible)*		Bronen and Chapin III (2013)[48] Shearer (2012)[49]	Migrating due to changing ice conditions leading to coastal erosion and due to permafrost melt, destabilising infrastructure
Kivalina	398-400		
Newtok	353		
Shaktoolik	214		
Shismaref	609		
Alaska (need to migrate gradually)*		Bronen and Chapin III (2013)[48]	Migrating due to changing ice conditions leading to coastal erosion and due to permafrost melt, destabilising infrastructure
Allakaket	95		
Golovin	167		
Hughes	76		
Huslia	255		
Koyukuk	89		
Nulato	274		
Teller	256		
Unalakleet	724		
Isle de Jean Charles, Louisiana	25 homes		Coastal erosion, wetland loss, reduced accretion, barrier island erosion, subsidence, and saltwater intrusion were caused by dredging, dikes, levees, controlling the Mississippi River, and agricultural practices. Climate change is now bringing sea-level rise

Table 1.1 Locations migrating now due to only climate change. *The village names and populations are sourced from the US Government Accountability Office's report, "Alaska Native Villages: Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion".[46-49]

Location	Population	Notes
Kiribati	106,925	Has plenty of high ground above 10 m above sea level, but little is habitable or viable for large populations.
Maldives	392,960	Highest point is 2.4 m above sea level.
Marshall Islands	73,376	Highest point is 10 m above sea level.
Tuvalu	10,959	Highest point is 5 m above sea level.

Table 1.2. Locations possibly needing to migrate due to thermal expansion

These data are derived from peer-reviewed academic literature and books. The presumed link between climate change and migration is now firmly embedded in academic and public consciences. Yet critical voices continue to highlight both the lack of evidence linking climate change directly to migration through linear causality and the multitude of factors which influence any connections between the two. These criticisms do not deny interactions between climate change and migration, nor the possibility of future occurrences of large-scale migration linked to climate change. They simply point out the several truisms from migration research which are often bypassed. First, migration is and always has been part of humanity. Second, many factors, including climate, influence human migration. Third, where people are forced to migrate or not to migrate when they would prefer otherwise, this may in part be due to a lack of support mechanisms to deal with environmental changes.

Long-term, human exposure and vulnerability to ice sheet collapse is increasing, as the number of people living close to the coast and at elevations close to sea level are also increasing. In 1990, 450 million people lived within 20 km coast and less than 20 metres above sea level.[50] In 2000, 634,000 million (10% of the global population), of whom 360 million are urban, lived below 10 metres above sea level, (the highest vertical resolution investigated).[51] With 2000 as a baseline, the population living below 10 metres above sea level and connected to the ocean will rise from 638 million to, 1,005-1,091 million by 2050 and 830-1,184 million by 2100.[52] Given ice sheet collapse is not expected prior to 2100, this would suggest no additional people, being forced to migrate due to ice sheet collapse by 2100.[53] However, beyond 2100, without mitigation and adaptation interventions, over one billion people may need to migrate due to ice sheet collapse.

Conclusion

Climate change impacts health through diverse direct and indirect mechanisms. Potential positive impacts, particularly in higher latitudes (such as fewer winter deaths, longer agricultural growing seasons and higher yields due to CO_2 fertilisation) are likely substantially outweighed by the negative impacts, particularly in tropical and sub-tropical latitudes.

Adaptation pathways can negate help to minimise some of the negative health impacts of global warming, especially for lower predicted average temperature rises. Indeed, for each of the indicators tracked, the realised health impacts depend strongly on human systems and societal choices, suggesting the appropriate policy responses might be best driven by adaptation opportunities. However, there are powerful limits to adaptation, and this section has drawn attention to the non-linearity and the spatial distribution of the health impacts of climate change.

The indicators presented here demonstrate clearly that these impacts are being experienced across the world today, and provide a strong imperative for both adaptation and mitigation interventions to protect and promote public health.

2. Health Resilience and Adaptation

Introduction

The impact of climate change on human health will initially be disproportionately felt in developing countries, (due in part to weaker health infrastructures) and by vulnerable population groups, such as the young, elderly, women, and those with existing medical conditions.[54] As demonstrated in section one, human exposure to climate impacts is already much higher than previously estimated. Mitigation is therefore essential to reduce the burden on vulnerable populations, lessen the need for adaptation, and to improve the effectiveness of adaptation now.

As humans respond to the health threats of climate change, both adaptation and resilience are essential. Climate adaptation is defined by the IPCC as the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”.[55] With respect to health, adaptation consists of efforts to reduce injury, illness, disability, and suffering from climate-related causes. Resilience has been defined as “the capacity of individuals, communities and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it”. In the context of climate change and health, resilience is an attribute of individuals, communities, and health care systems; resilience at all levels can reduce adverse health outcomes of climate change.

Indicators of resilience and adaptation are challenging to identify. Many relevant efforts take place at the local level, however relevant data is most readily available at the national level. Actions that bring resilience and climate change adaptation are often embedded in broader initiatives such as public health system strengthening and disaster preparedness, and are therefore difficult to track independently. Health protection that flows from adaptation in other sectors, such as agriculture, housing, and energy, may not be identified as health adaptation. Indicators of health adaptation initiatives are generally process measures, not outcome measures, and are self-reported; measures of actual health improvement are more elusive. Accordingly, the indicators in this section are imperfect measures of health adaptation and resilience.

The indicators presented here are intended to track vulnerability and resilience, leadership and governance, implementation and adaptive capacity, and adaptation financing associated with health resilience and adaptation to climate change. These indicators are:

- Vulnerability to Climate Change:
    - 2.1 Deaths from climate- and weather-related disasters
    - 2.2 Trends in selected climate-sensitive diseases
- Leadership and Governance:
    - 2.3 Number of countries with a national adaptation plan for health
    - 2.4 Number of cities with climate change risk assessments
- Implementation and Adaptive Capacity: human resources, early warning systems, and infrastructure
    - 2.5 Implementation of IHR Core Capacity Requirements
    - 2.6 Proportion of national meteorological and hydrological agencies providing services tailored for the health sector
    - 2.7 Number of countries that have conducted a national assessment of vulnerability, impacts and adaptation for health
    - 2.8 Number of countries implementing activities to build health resilient infrastructure

- Adaptation Finance:
  - 2.9 Spending on adaptation for health and health-related activities
  - 2.10 Health adaptation funding from global climate financing mechanisms

Corresponding Appendix 3 provide more detailed discussion of the data and methods used.

Vulnerability to Climate Change

The indicators in this section track the vulnerability and resilience of populations and health systems, to climate risks. Understanding current vulnerability and resilience to climate change, and how this has changed over time provides essential guidance for adaptation planning and implementation.

Indicator 2.1: Deaths from climate- and weather-related disasters

Headline Finding: *Despite a 44% increase in annual climate-related disasters from 2000 to 2013, compared with the 1994-2000 average, there has been no accompanying increase in the number of deaths, nor in those affected by disasters, nor in the ratio of these two outcomes.*

Climate- and weather-related events have been associated with over 90% of all disasters worldwide over the last twenty years. The continent most affected by climate and weather related disasters is Asia, with some 2,495 events between 1995-2015 affecting 3.7 billion people and killing 332,000. On the whole, deaths from natural hazard-related disasters are largely concentrated in poorer countries.[56]

Disaster impact is a function of hazard and vulnerability, with vulnerability a function of exposure, sensitivity, and adaptive capacity. This indicator measures the ratio of the number of deaths, to the number of people affected by climate- and weather-related disasters: droughts, floods, extreme temperature events, storms and wildfires. This ratio is a proxy measure of disaster preparedness and response and adaptation in the health care sector. Data come from the Emergency Events Database (EM-DAT).[57,58] Here, a disaster is defined as either: 1) 10 or more people reported killed, 2) 100 or more people affected, 3) a declaration of a state of emergency, or 4) a call for international assistance.

Between 1994 and 2013 the frequency of climate-related events (mainly floods and storms) increased significantly. From 2000 to 2013 EM-DAT recorded an average of 341 climate-related disasters per annum, up 44% from the 1994-2000 average and well over twice the level in 1980-1989.[59] However this has not been accompanied by any discernible trend in number of deaths, nor in those affected by disasters, nor in the ratio of these two (Figure 2.1a). Separating out the disasters by the type of climate and weather hazard associated with the disaster (Figure 2.1b) shows there has been a statistically significant global decrease in the numbers affected by floods, equating to a decrease of 3 million people annually. Clearly, the bulk of the disasters affecting people are droughts, floods and storms. No significant trend is seen in the ratio of those killed to those affected for any of the different types of disasters, although there appears to be a slight upward trend since 2010 in this ratio for flood related disasters (Figures 2.1c and 2.1d).

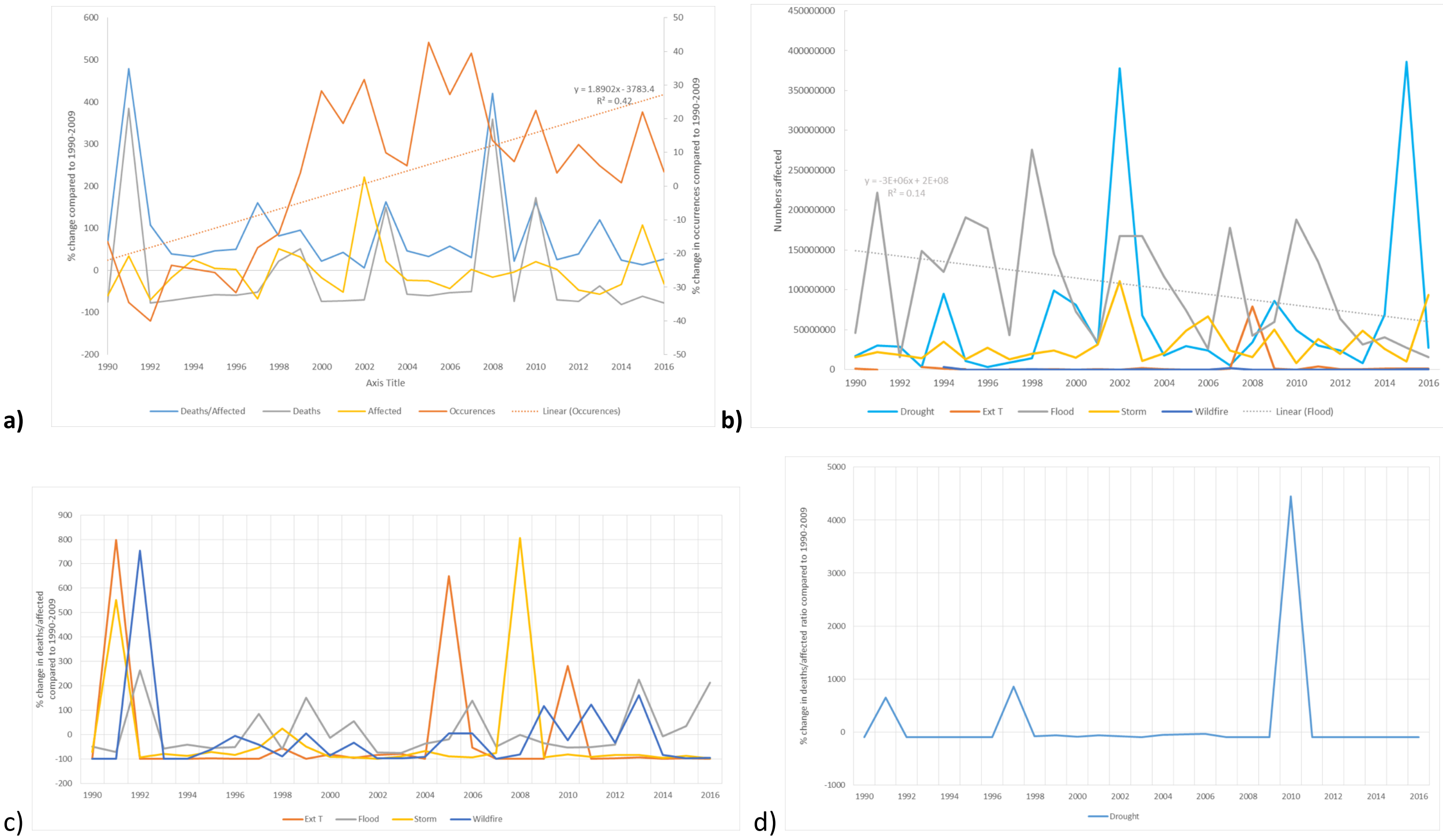
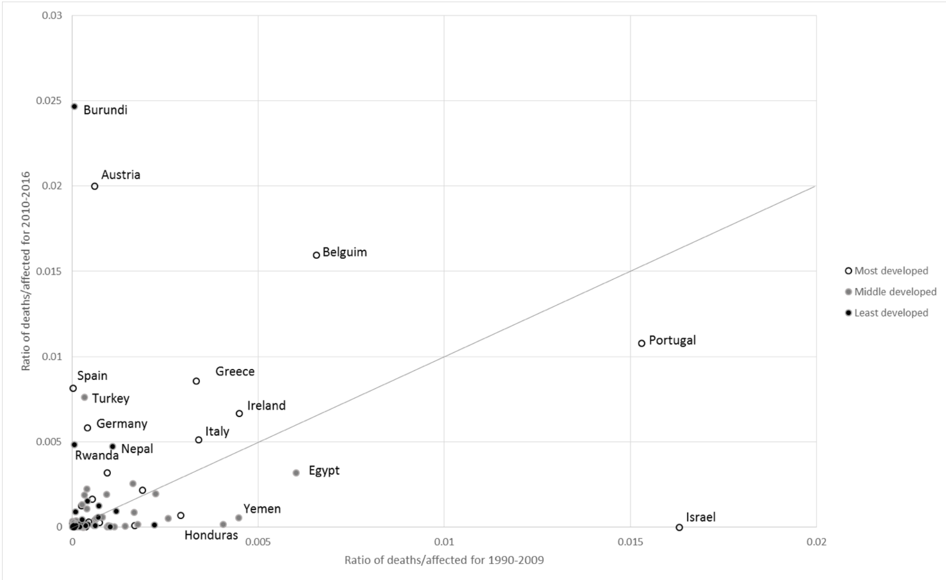


Figure 2.1. Deaths and people affected by climate- and weather- related disasters. 2.1a) Percentage change over time in the global number of deaths, the number of those affected, and the ratio of these. 2.1b) Change over time in the number of people affected globally by different climate- and weather-related disasters. 2.1c) Yearly change over time in the percentage of people killed, as a proportion of those affected globally by different climate- and weather-related disasters, as compared to the average for 1990-2010. 2.1d) Yearly change over time in the percentage of people killed as a proportion of those affected globally by drought related disasters, as compared to the average for 1990-2010.

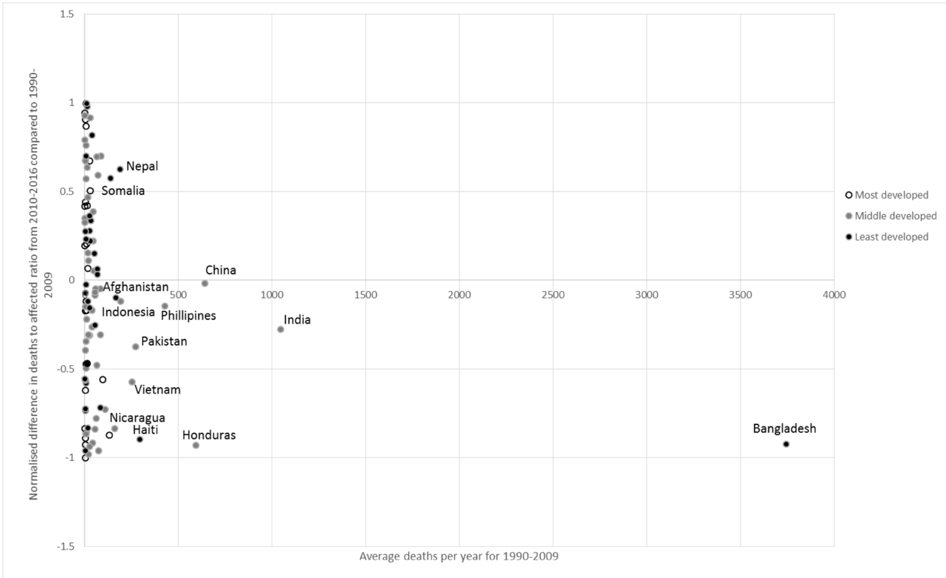
This indicates that countries are generally getting better at dealing with climatic hazards, with improved implementation and adaptive capacity and thus over time there has been a decrease in the number of people killed and affected by such events. However, although climatic hazards have increased in number over the past three to four decades, the data here does not capture the severity of such events – a factor directly relevant to a country's ability to adapt, and that is expected to increase as a result of climate change.[60]

Turning to national data, and comparing the periods 1990-2009 and 2010-2016 with the ratio of deaths to numbers affected in droughts, floods and storm-related disasters increased more in high-income countries, than in low- and middle-income countries (Figure 2.2a and b). This indicates a relative improvement in the adaptive capacity of low- and middle-income countries (LMIC) on the one hand, whilst the increasing number of deaths experienced in many high-income countries may reflect an increased number of extreme events, perhaps not previously experienced, in these countries over the past few decades. These findings might suggest a lack of preparedness to climate change even among wealthier nations, such as Germany and New Zealand. Evidently, more work is required in countries of all income groupings to reduce vulnerabilities to climate hazards and adapt to extreme weather events.

To date, there is no international consensus regarding best practices for collecting disaster impact data. However, EM-DAT represents one of the most widely used datasets in this area. The validity of the deaths: affected ratio as an indicator rests on the assumption that it reflects disaster management and health system capacity, which is debatable. A key part of this indicator is estimating those affected by a disaster and those exposed, and distinguishing the two; a difficult task in the context of disasters. An important caveat is that while the number of people affected in a disaster is often reported, the operational definition of who is "affected" varies across countries, as do the methods of estimation. Comparisons between countries should therefore be interpreted with caution.



a)



b)

Figure 2.2. 2.2a) Nationally disaggregated ratio of the average number of deaths: to numbers affected for drought, flood and storm related disasters for the period 2010-2016 compared to 1990-2009. 2.2b) The normalised difference in the ratio of the average deaths to numbers affected for 2010-2016 compared to 1990-2009 against the average number of deaths per climate and weather related disaster for 2009-2010. The normalised difference is comprised of the difference of the deaths: affected ratio between 2010-2016 and 1990-2009 normalised by the sum of these ratios. Positive values indicate and increase in the numbers of deaths per affected.

Indicator 2.2: Trends in selected climate-sensitive diseases

Headline Finding: *Global health initiatives have overwhelmingly decreased deaths associated with climate-sensitive diseases since 1990.*

Disease occurrence is determined by a complex composite of social and environmental conditions and health service provision, all of which vary geographically. Nonetheless, some diseases are particularly sensitive to variations in climate and weather, and may thus be expected to vary with both longer-term climate change and shorter-term extreme weather events.[17] This indicator draws from Global Burden of Disease (GBD) mortality estimates to show trends in deaths associated with eight climate-sensitive diseases since 1990 (Figure 2.3).[61]

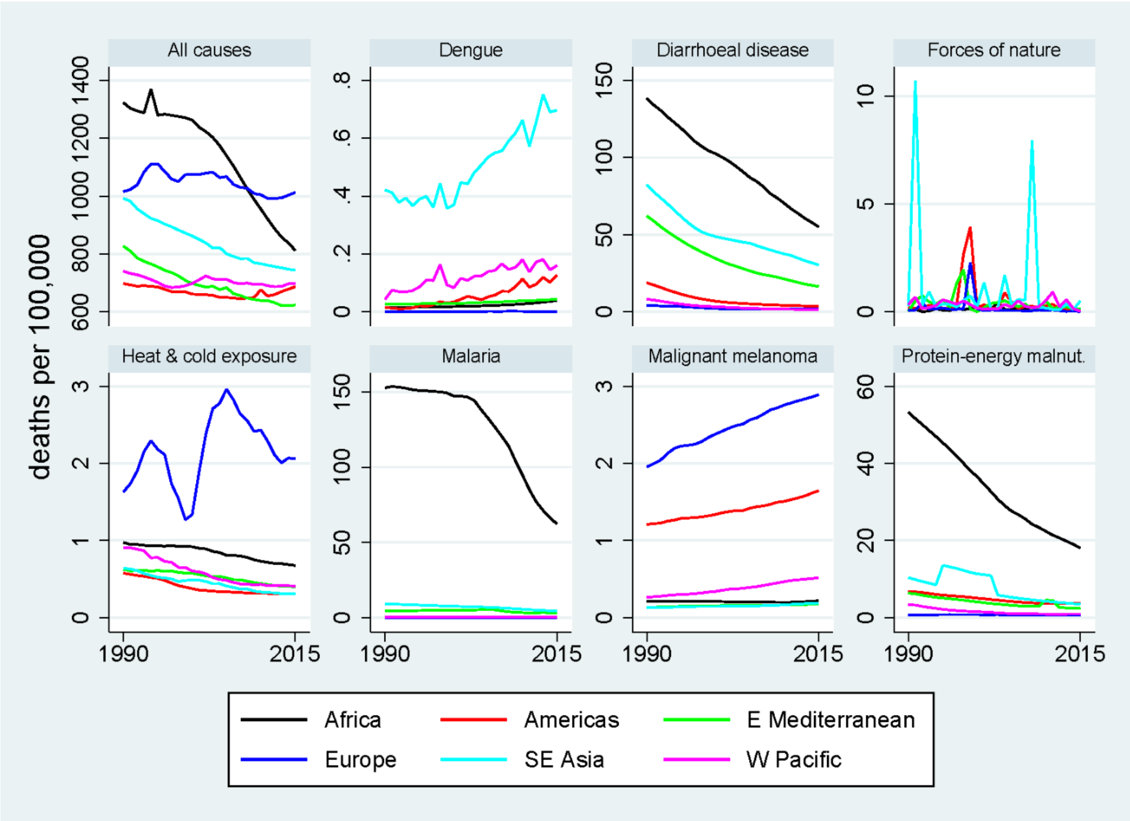


Figure 2.3: trends in mortality from selected causes as estimated by the Global Burden of Disease 2015, for the period 1990 to 2015, by WHO region.[61]

The disease trends reveal global increases in dengue mortality, particularly in the Asia/Pacific and Latin America/Caribbean regions, with some peak years (e.g. 1998) known to being associated with the El Niño conditions.[62] Beyond climate, likely drivers of dengue mortality include trade, urbanization, global and local mobility and climate variability; the association between increased dengue mortality and climate change is therefore hard to accurately discern.[63] However, the spread of dengue to new areas (for example, there was a large dengue outbreak in Madeira in 2012) demonstrates the risks of spreading infectious diseases and the need for health system resilience.[64] Malaria mortality is predominantly an African phenomenon, but has decreased strongly over the last 15 years, owing to continued investment in prevention. Despite this, possibilities of re-emergence exist, and could be weather-driven, particularly as population immunity declines with declining incidence. Malignant melanoma is a distinctive example of a non-communicable disease with a clear link to ultraviolet exposure, with mortality increasing steadily despite advances in surveillance and treatment. Heat and cold exposure is a potentially important aspect of climate-influenced mortality, although the underlying attribution of deaths to these causes in the estimates is uncertain.[65-70]

Overall, the findings here highlight the effectiveness and success of global health initiatives since 1990, in largely reducing deaths associated with these diseases. However, climate change threatens to undo this progress and outbreaks of climate-sensitive diseases in previously unexposed areas highlight the need for health system adaptation now, to prepare for potential future shocks.

Leadership and Governance

The following indicators monitor government commitments to health and climate adaptation measures, tracking the promulgation of a health national adaptation strategy (national level) and the presence of designated adaptation personnel at the city level.

Indicator 2.3: Number of countries with a national adaptation strategy for the health impacts of climate change

***Headline finding:** 30 out of 40 responding countries have an approved health component of their National Adaptation Plan .*

Effective national responses to climate risks require that the health sector identify strategic goals for building health resilience. A critical step in achieving these strategic goals is the development of a national health adaptation plan, outlining priority actions, resource requirements and a specific timeline and process for implementation. This indicator tracks the policy commitments of national governments for building health resilience to climate change. Data are drawn from the recent WHO-United Nations Framework Convention on Climate Change (UNFCCC) Climate and Health Country Profile Survey (Box 2.1).

Impressively, of the 40 countries responding to the survey, 30 reported having a national adaptation strategy for health, that has been approved by the Ministry of Health or relevant health authority (Figure 2.4). This number includes countries with a health component of their National Adaptation Plan (HNAPs). Although this is not representative of all countries, 75% of nations in the survey having an approved HNAP is a remarkable achievement and evidence of the recognition of the need to adapt to climate change. Countries with HNAPs are found across all regions and, perhaps most significantly, among some of the most vulnerable countries across Africa, South East Asia and South America.

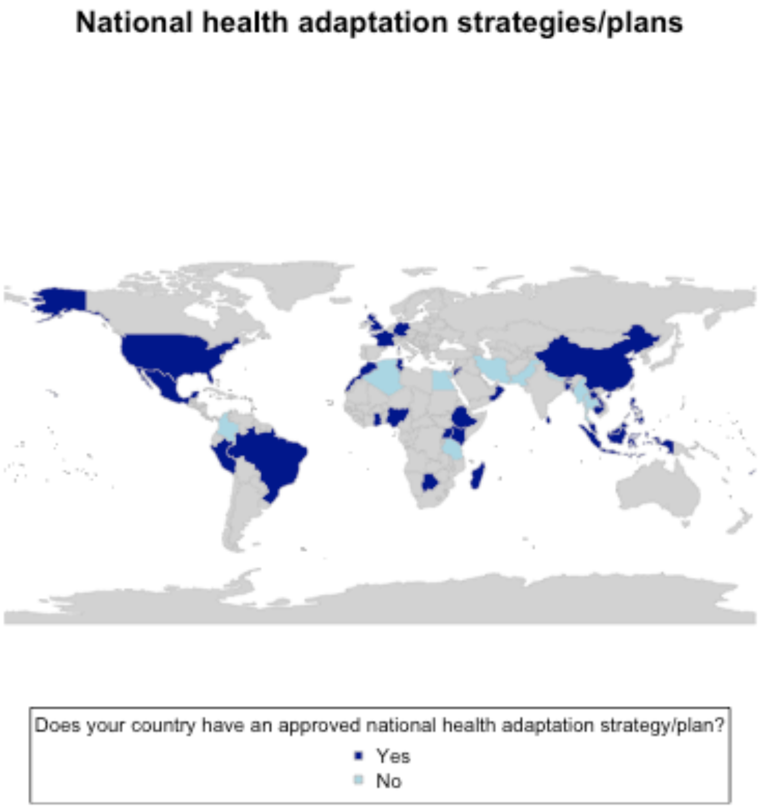


Figure 2.4: Countries with national heath climate adaptation strategies or plans. Source: WHO Climate and Health Country Profile Survey[71]

Box 2.1: WHO-UNFCCC Climate and Health Country Profiles

The WHO-UNFCCC Climate and Health Country Profile project is an ongoing effort to understand national-level information on climate-related health threats and responses. As part of this project, the WHO surveyed member states in 2015, with an emphasis on LMICs. The survey contained 23 questions on the following aspects of health and climate change: 1) governance and policy, 2) vulnerability, impact and adaptation (health) assessments, 3) health adaptation strategies and action plans, 4) preparedness, risk management and integrated risk monitoring, 5) awareness raising and capacity building, 6) research, and 7) financing. Forty nations responded, including countries from all WHO regions, all income categories (for instance, high income nations such as the USA, UK and France, emerging economies such as Brazil and China, as well as developing countries including Ethiopia, Nepal and Peru) and with varying levels of risks and vulnerabilities to the health impacts of climate change (for instance, Fiji as a small island state, Bangladesh with heavily populated coastal areas facing multiple climate threats and Morocco with diverse climatic regions each facing unique threats). The 2015 data were validated through a consultation process seeking input from key in-country stakeholders, including representatives of the Ministry of Health, Ministry of Environment, meteorological services and WHO country and regional technical officers. The Climate and Health

Country Profile Survey will be conducted biennially and will aim to gather data from all WHO member States.

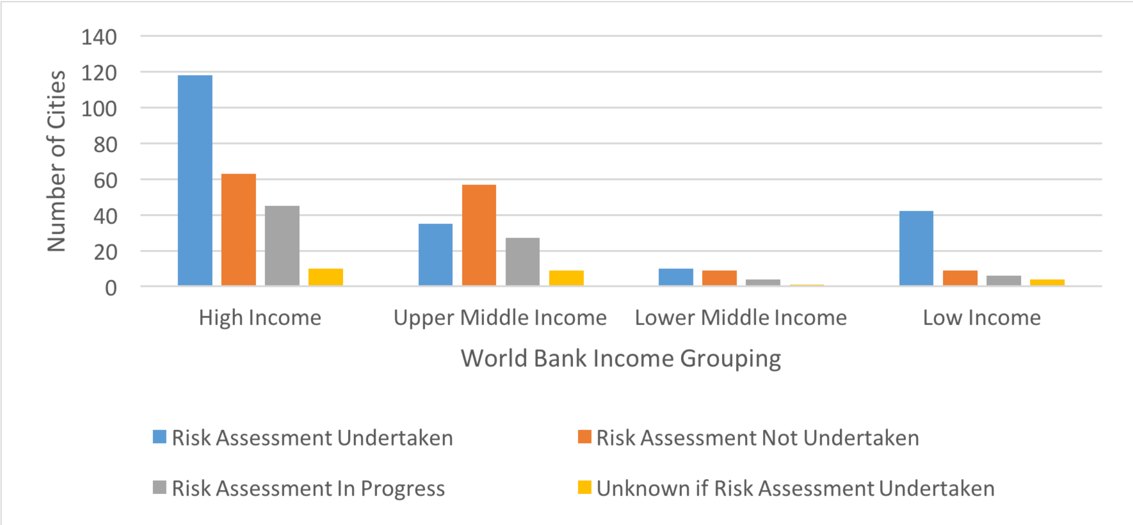
The degree to which this is representative of all (non-responding) countries is unclear. Indeed, participation in this survey was voluntary and the baseline sample tended to include countries with active climate and health projects. However, implementation of health adaptation plans may grow with time: the Paris Agreement states that the 'right to health' is central to national actions , whilst developing countries will likely have increasing access to adaptation funds through global mechanisms, and representation of health in strategic and planning processes will facilitate health sector access to them.[13] By 2030, this indicator should reflect the commitment of all or most nations to develop a national health adaptation strategy to climate change. Going forward, this indicator will be developed to allow better understanding of the practical implications of having national policies in place. Data will be gathered on the status of policy implementation, the main priorities for health adaptation, internal monitoring and review processes and the level of funding available to support policy implementation.

Indicator 2.4: Number of cities with climate change risk assessments

***Headline Finding**: Globally, 45% of cities have climate change risk assessments in place.*

Globally, 50% of the population live in cities where health infrastructure, such as emergency and acute hospital care, are predominately located in cities. Cities are increasingly at risk from climate change, with negative impacts predicted for human health and health services. These risks require city-level responses to complement National Adaptation Planning, in order to improve cities' resilience to climate change. The data presented in Figure 2.5 track the number of cities with climate change risk assessments using data from the Carbon Disclosure Project, an official reporting platform which collects and analyses a global survey of city-based and climate change data annually.[1] [Can we insert a paragraph on the kinds of actions cities can take to adapt to the health impacts of climate change?].

a)



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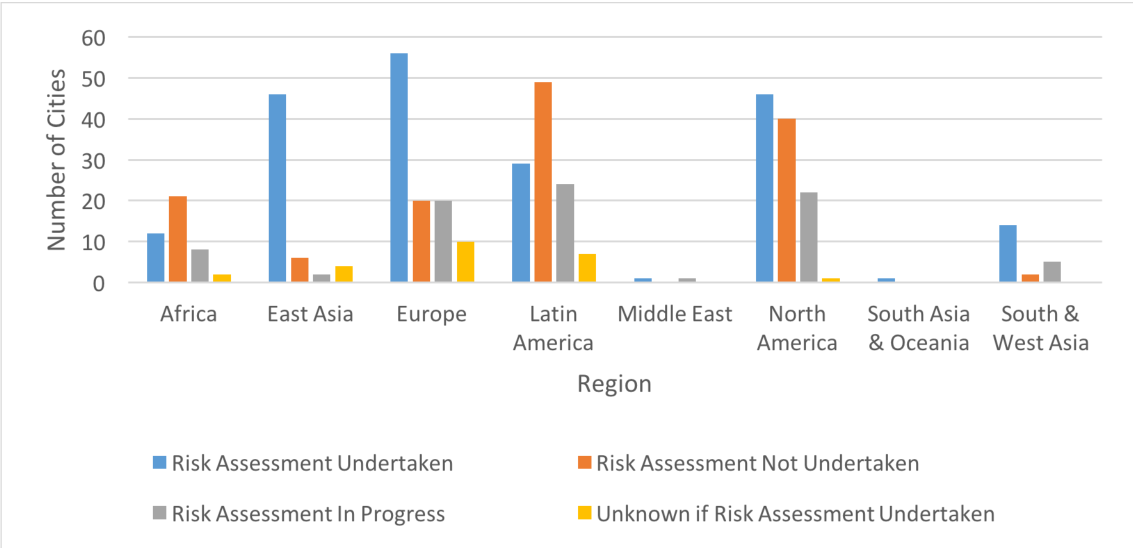


Figure 2.5. Number of global cities undertaking climate change risk assessments by a) income grouping, and b) WHO region.[1]

The highest number of cities with climate change risk assessments are in high-income countries (118 cities), with only 42 cities in low-income countries. This partly reflects the fact that more cities in high-income countries were surveyed, and partly the fact that these cities will have a greater capacity to develop such plans.

However, the regional breakdown of these cities highlights concerns. European cities have the highest number of climate change risk assessments (56 cities), representing 83% of European cities in the survey. Conversely, only 28% of African cities have climate change risk assessments.

Implementation and Adaptive Capacity: human resources, early warning systems, and infrastructure

Informed health adaptation requires climate information for evidence-based decision-making. This in turn depends upon having the human resources and established initiatives, services and infrastructure to prepare, respond, and adapt. Monitoring the implementation of these dimensions of adaptation provides an indication of health sector capacity to anticipate and prepare for climate risks, avoiding potentially maladaptive choices.

Indicator 2.5: Implementation of IHR Core Capacity Requirements

Headline Finding: *In 2016 61-87% of responding countries attained IHR Core Capacity Requirements in human resources, early detection and surveillance, and preparing and implementing multi-hazard public health emergency preparedness and response plans.*

The International Health Regulations (IHR) Core Capacity Requirements indicate the extent to which health systems are implementing systems to improve their resilience to climate change, and their adaptive capacity (Box 2.2). Three of the IHR Core Capacity Requirements are reported here: 'human resources to prepare, respond and adapt to climate-related health impacts'; 'surveillance for the early detection of a public health event'; and 'the number of countries reporting multi-hazard public health emergency preparedness and response plans'.[72] Full details of all three of these IHR Core Capacity Requirements can be found in Appendix 3.

Box 2.2: The International Health Regulations

The International Health Regulations support early detection and control of public health events that could have serious and international consequences. The current IHR (2005), which entered into force in 2007, is legally binding on 196 nations, including all WHO member states. It requires countries to identify, report, and appropriately manage public health events related to infectious diseases, food safety, and environmental, chemical and radiation exposures—and to build and maintain the capacity to perform these functions.[56] Examples of required core capacities include national legislation, policy and financing; public health surveillance; incident preparedness and response; risk communication; human resources; and laboratory services. An extensive monitoring and evaluation framework[73] includes an annual survey by WHO. The method of estimation calculates the proportion/percentage of attributes (a set of specific elements or functions that reflect the performance or achievement of a specific indicator) reported to be in place in a country. Since 2010, 195 nations have submitted self-reports at least once. Indicators 2.3, 2.4, and 2.5 are drawn from the results of the 2016 survey[74], to which, as of 2017, 120 of 196 nations had responded.

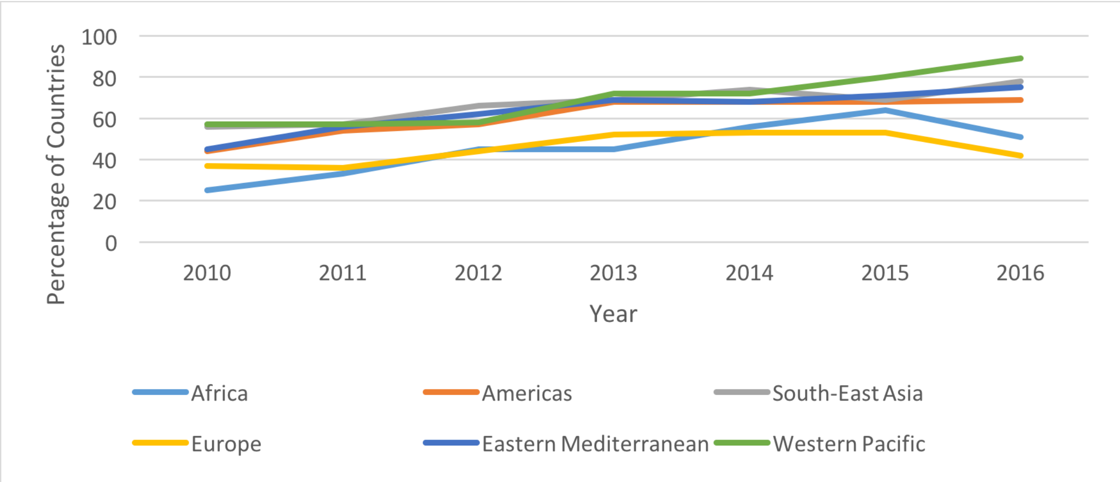
Figure 2.6 presents plots for these three sub-indicators drawn from the IHR. The first of these, the availability of adequate human resourcing to implement the rest of the core capacity requirements, is a useful proxy in lieu of an indicator which looks at specific capacity for health adaptation to climate change (Figure 2.6a). From a starting point of 44% in 2010, on average 67% of countries now report having met this capacity, which includes a foundational element (having a responsible unit identified for the development of human resource capacity); having conducted a needs assessment; and a set of key performance indicators to measure progress against.

Secondly, the IHR Core Capacity Requirement for the early detection and surveillance of public health events is used here as a proxy for a health system's ability to respond to outbreaks and changing patterns of climate-sensitive infectious diseases. The hazards measured by the indicator include: chemical events; radiation emergencies; zoonotic disease events; and food safety events. The latter two hazards are clearly relevant to climate change adaptation. Globally, 196 reporting countries achieved 87% of attributes required for surveillance for early detection of a public health event (Figure 2.6b). This proportion has increased steadily since 2010, indicating that health systems are increasingly implementing early warning systems to detect public health events.

Finally, the development and implementation of multi-hazard national public health emergency preparedness and response plans is tracked. These comprising the presence of a plan, the implementation of the plan, and the ability for this plan to operate under unexpected stress. Of responding countries, 75% reported achievement of IHR requirements for this (Figure 2.6c), with higher levels in Europe, South-East Asia and the Western Pacific, and lower levels in Africa.

[it would be good to have further breakdown and analysis of these three indicators from someone familiar with the IHR]

There are some very clear limitations to this indicator. Most importantly, IHR survey responses are self-reported, with relatively modest national-level verification conducted. Secondly, IHR Core Capacity Requirements are not specific to climate change, and hence whilst they provide a baseline, they do not directly measure a country's adaptive capacity. Thirdly, these findings capture potential capacity – not action. Finally, the quality of surveillance for early warning is not shown and neither is the impact of that surveillance on public health. Nonetheless, this indicator provides a useful starting measure of potential adaptive capacity of health systems globally.



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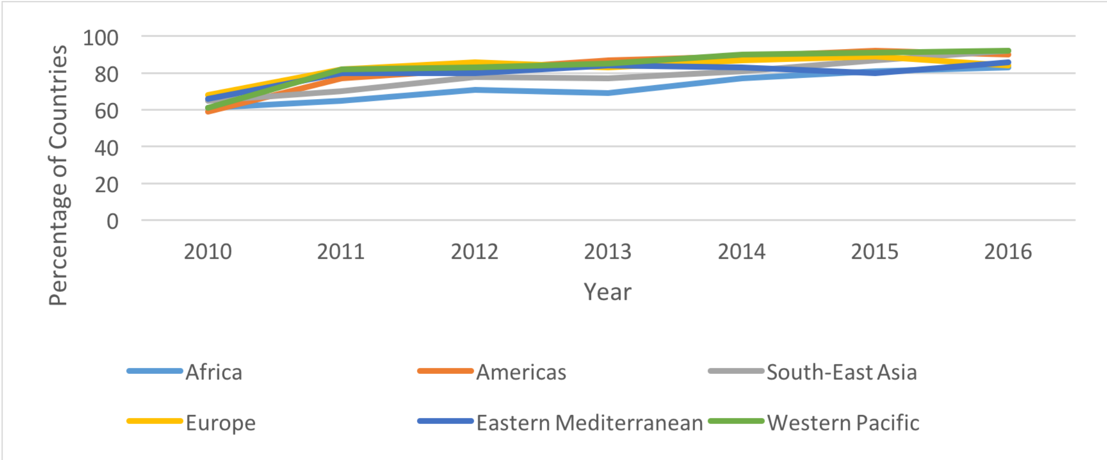

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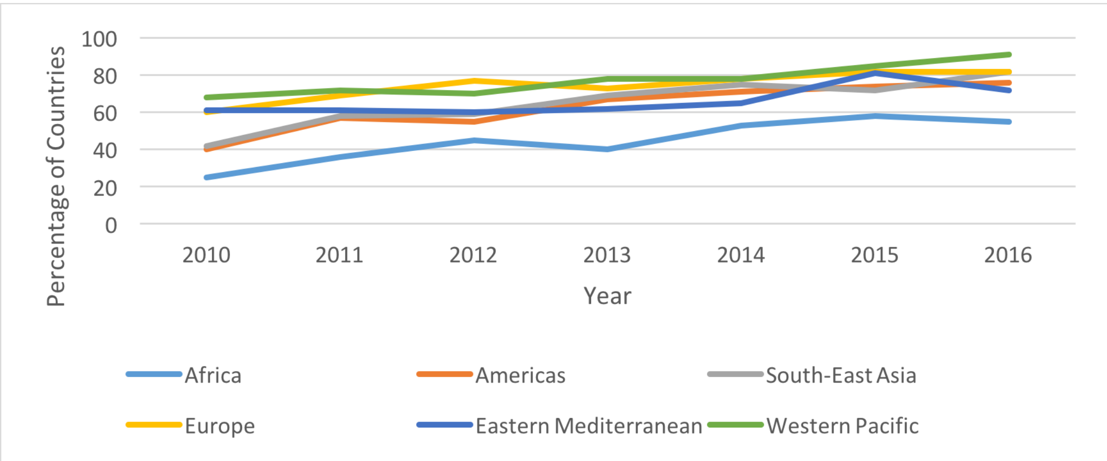

c)

Figure 2.6: 2.6a) Percentage attainment of human resources available to implement the International Health Regulations Core Capacity Requirements, by WHO Region[2]. 2.6b) Percentage of countries reporting indicator-based surveillance for early detection of a public health event under the International Health Regulations Source:[3] 2.6c) Achievement of IHR preparedness core capacity (proportion of required attributes achieved) for multi-hazard public health emergency preparedness and response plans.

Indicator 2.6: Proportion of national meteorological and hydrological agencies providing services tailored for the health sector

Headline Finding: *Of 104 responding countries, 75% report providing tailored climate information to the public health sector.*

The availability of climate information tailored to the health sector is reported by member states to the World Meteorological Organization (WMO).[75] In 2015, the most recent year for which data are available, 104 Members (54%) responded to the survey. Response rates were 53% for Africa, 44% for Asia, 75% for South America, 68% for North America, Central America and the Caribbean, 29% for the South-West Pacific, and 63% for Europe. This indicator measures the proportion of countries that report providing tailored climate information, products and services to their public health sector.

Of respondents, 75% report providing tailored climate information to the public health sector. Although this is fewer than the provision of climate information to other sectors, notably the general public and agriculture/food security, this is still an overwhelming majority of health services that have access to climate information among those surveyed (Figure 2.7).

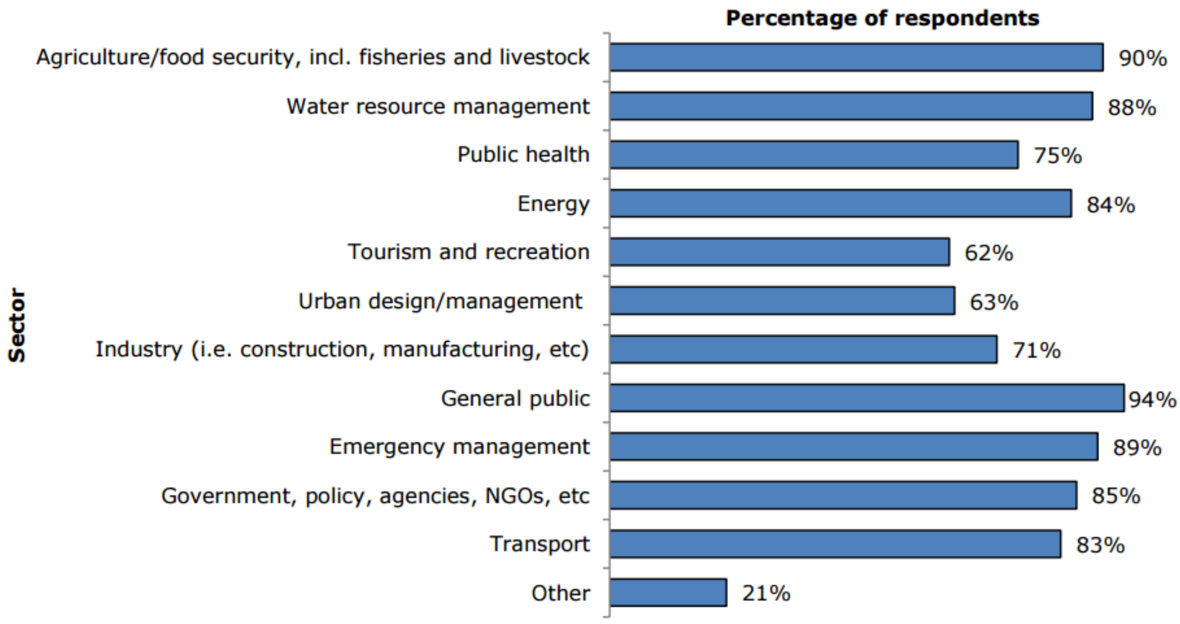

Figure 2.7: Sectors to which National Meteorological and Hydrological Services (NHMSs) provide targeted/tailored climate information, products and services.[76]

However, it is important to note that this sample is not representative or all countries and these are self-reported results. Crucially, this indicator does not capture the quality of the data provided, the ways in which the health sector makes use of this data (if at all), and whether the data is presented in a format and timely fashion relevant to public health. Corresponding information from 40 national

Ministries of Health on the use of climate information for integrated disease surveillance systems can be found in Appendix 3.

Indicator 2.7: Number of countries that have conducted a national assessment of vulnerability, impacts and adaptation for health

Headline Finding: Over two thirds of responding countries report having conducted a national assessment of vulnerability, impacts and adaptation for health.

National assessments of vulnerability, impacts and adaptation for health allow governments to understand more accurately the extent and magnitude of potential threats to health from climate change, the effectiveness of current adaptation and mitigation policies and the range of needs for future policies and programmes. Although national assessments may vary in scope between countries, the number of countries that have conducted a national assessment of vulnerability, impacts and adaptation for health is a key indicator to monitor the global availability of information required for adequate management of health services, infrastructure and capacities to address climate change. This indicator tracks the number of countries that have conducted national assessments, based on responses to the WHO Climate and Health Country Profile Survey (Box 2.1).

Over two-thirds of countries sampled (27 out of 40) reported having conducted a national assessment of vulnerability, impacts and adaptation for health (Figure 2.8). These countries cover all regions and include countries that are particularly vulnerable; for instance, seven countries in Africa have national assessments of vulnerability, impacts and adaptation for health.

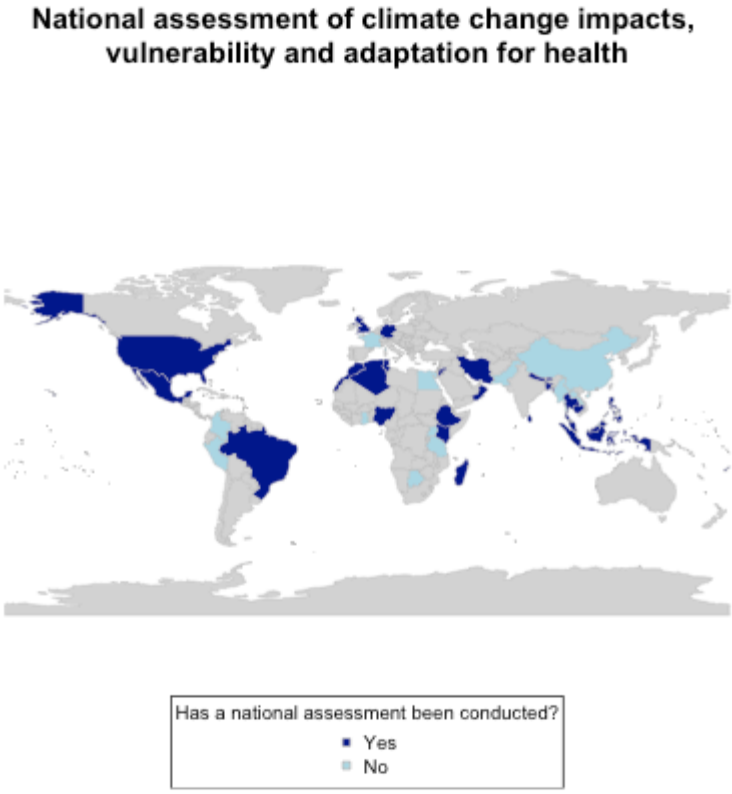

Figure 2.8: Countries with national assessment of climate change impacts, vulnerability and adaptation for health.[71]

Again, these results are not representative of all countries and could over-estimate the proportion of countries with these national assessments, as participation in this survey was voluntary and the sample tended to include countries that had active climate and health projects and thus were more likely to have conducted an assessment.

Indicator 2.8. Number of countries implementing activities to build health resilient infrastructure

Headline Finding: *One in three responding countries reported ongoing efforts to increase the climate resilience of their health infrastructure.*

Functioning health infrastructure is essential during emergencies. Climate-related events, such as severe storms and flooding, may compromise electrical and water supplies, interrupt supply chains, and disable transportation links, contributing to reduced capacity to provide medical care. This indicator measures efforts by countries to increase the climate resilience of health infrastructure. Data is drawn from the WHO Climate and Health Country Profile Survey (Box 2.1). Approximately one in three (14 out of 40) countries reported having ongoing efforts to increase the climate resilience of their health infrastructure (Figure 2.9). These results suggest widespread vulnerability of health system infrastructure to climate change, with no countries in South America reporting efforts to improve the climate resiliency of health infrastructure.

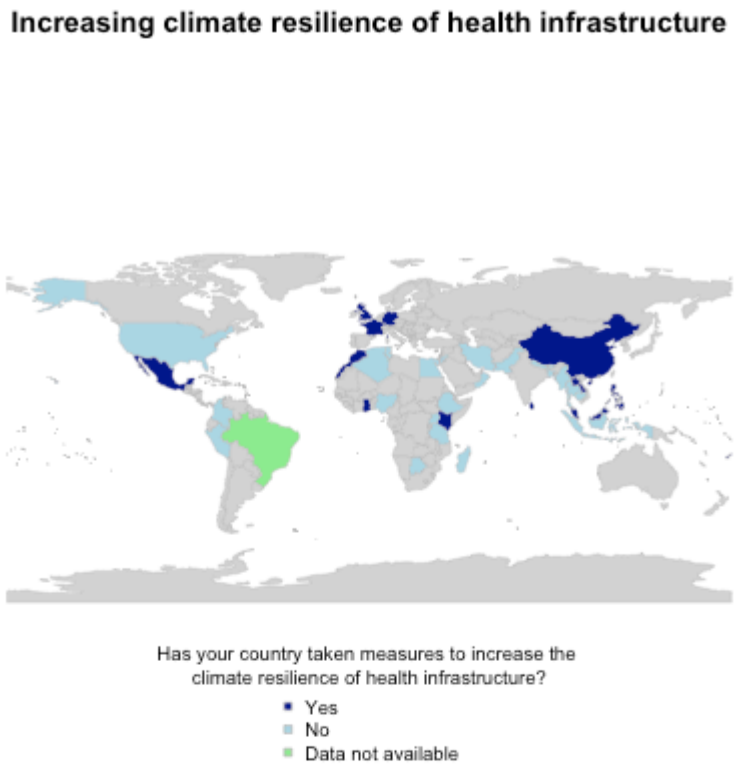

Figure 2.9: Countries taking measures to increase climate resilience of health infrastructure.[71]

In addition to previously mentioned limitations of the data from the WHO Climate and Health Country Profile Survey, this indicator does not capture the quality or effectiveness of efforts to build resilient health system infrastructure. Nonetheless, it highlights the importance of ensuring that countries working to implement climate resilient health infrastructure, as these findings suggest such infrastructure is generally lacking, most especially in low-income countries.

Adaptation Finance

The indicators presented thus far have examined both vulnerability to climate change, and efforts to reduce this vulnerability through governance and the improvement of adaptive capacity. The extent to which these measures are successfully implemented is in large-part dependent on the funding available. These last two indicators track health adaptation spend and funding. This in turn, reflects national priorities, indicating the relative importance of health within adaptation spending, and within the broader economy. Spending therefore reveals regional and national wealth-related disparities in the ability to deliver adaptation activities.

Indicator 2.9: Spending on adaptation for health and health-related activities

Headline finding: *Spending on health and health-related adaptation is just 4.63% (16.46 billion USD) and 13.3% (47.29 billion USD) of the global total.*

This indicator reports estimates of spending on health-related climate change adaptation and resilience. While many kinds of adaptation spending may protect health indirectly, this indicator reflects only spending within the health sector and in two domains closely related to health: disaster preparedness and agriculture.

This indicator draws data from the health sector, agriculture and forestry (due to the centrality of food and nutrition to health) and disaster preparedness (due to of the direct public health benefits of these efforts). The level of spending on adaptation and resilience in general, including on the three sectors most relevant to health, was derived from analyses by kMatrix, using a data triangulation method which aggregates transactional and operational business data that leave digital footprints, to estimate economic values in areas where government statistics and standard industry classifications are unavailable.[77] Here, 180 countries are reported on. This method aggregates transactional and operational business data to measure economic activities where they leave a "footprint", to estimate economic values in areas where government statistics and standard industry classifications are not available. Examples of data sources and databases accessed include financial and transactional data, company data, industry and trade association data and data from market/economic research organisations

Global health adaptation spending for the financial year 2015-2016 studied totalled 16.46 billion USD, representing 4.63% of the global aggregate. Health-related adaptation spending (which included the health and agricultural sectors, and disaster preparedness) totalled 47.29 billion USD, or 13.3% of the global total adaptation spend. While the importance of health-related spend is clear in contributing to health adaptation, that only 4.64% of adaptation spending is on health adaptation specifically is concerning.

Health-related adaptation and resilience spending, both national totals and per capita levels, are extremely low in low-income countries, and increase across the continuum towards high-income countries (Figures 2.10 and 2.12). Interestingly, health and health-related adaptation spending as a proportion of total adaptation spending is relatively constant across income groups. The proportion of the national GDP represented by health-related adaptation spending is substantially higher in low-income countries, suggesting that the highest burden of the cost of adaptation or borne by those experiencing the greatest risk, with the least capacity to respond.

Regional analysis (Figure 2.11) reveals that absolute and per capita spending on health and health-related adaptation is highest in Europe, the Americas and Western Pacific; although health and health-related adaptation spending as a proportion of total adaptation is relatively consistent across regions.

The income and regional groupings hide significant country-to-country variation. For example, spending on health and health-related adaptation as a proportion of total adaptation spending varies between 0.0071% (Timor-Leste) and 0.2617% (Ukraine), and per capita spending on health and health-related adaptation ranges from 0.17 USD (Timor-Leste) to 42.72 USD (Luxembourg). Future research at the country-level will therefore be highly useful in understanding the geography of and the disparities in spending health-related adaptation to climate.

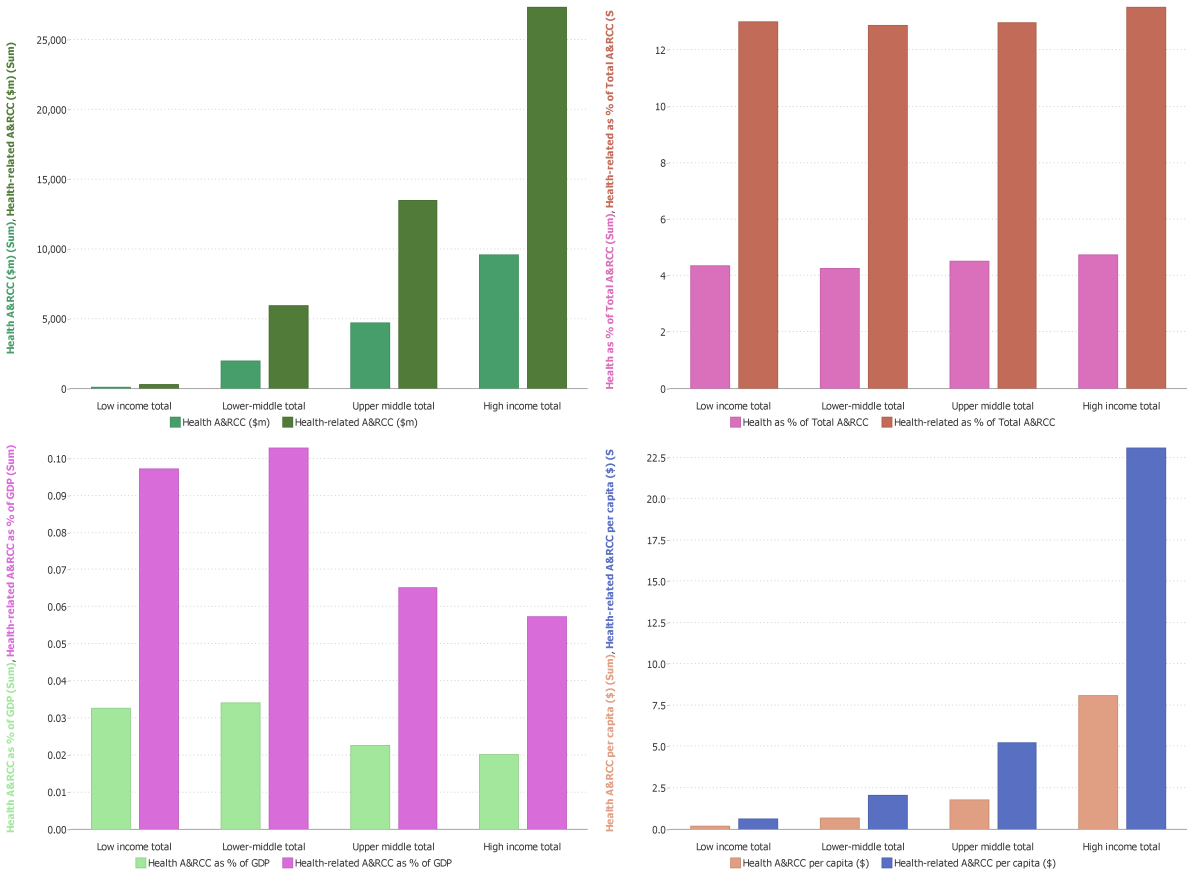

Figure 2.10. For the financial year 2015-2016. From left to right top and left to right bottom: total health and health-related A&RCC, percentage of health and health-related A&RCC as a proportion of total spend, health and health-related A&RCC as a proportion of GDP, and health and health-related A&RCC per capita. All plots are disaggregated by World Bank Income Grouping.[77]

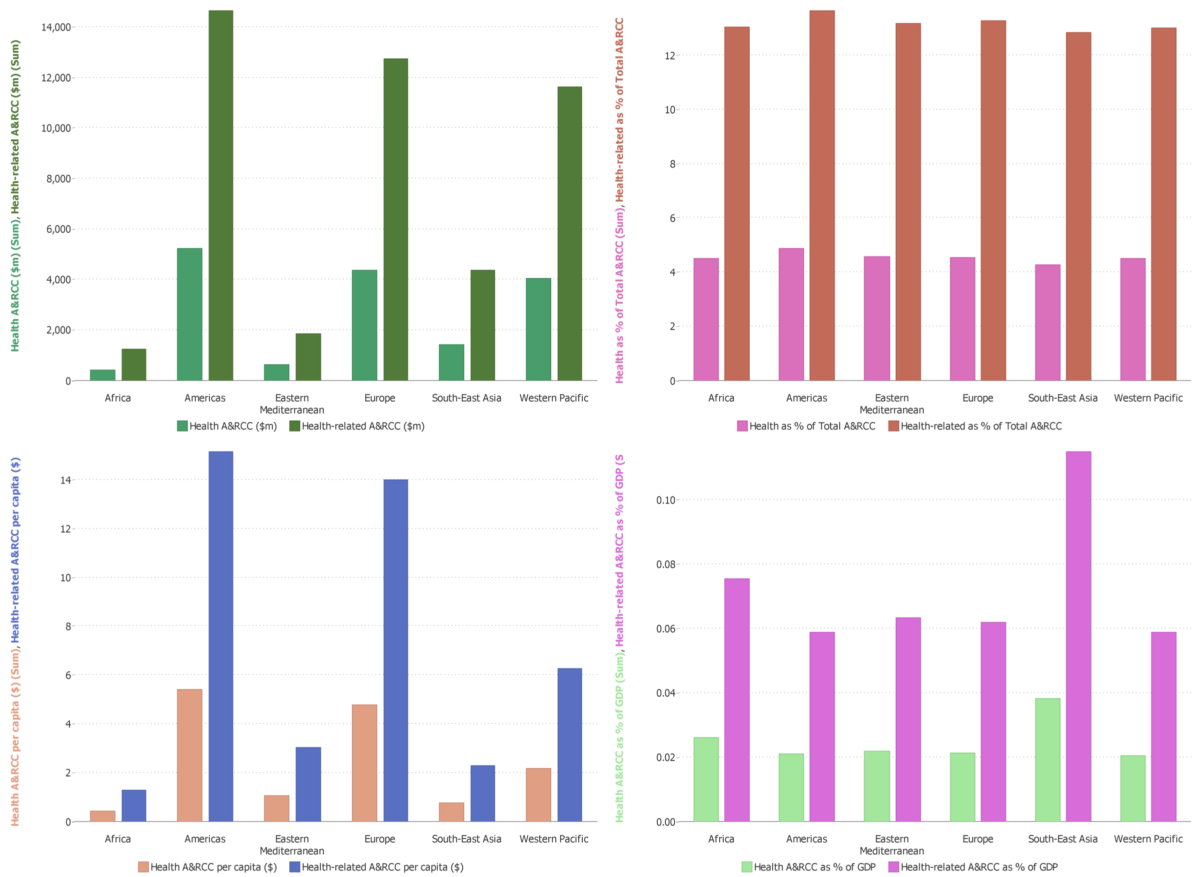

Figure 2.11: For the financial year 2015-2016. From left to right top and left to right bottom: total health and health-related A&RCC, percentage of health and health-related A&RCC as a proportion of total spend, health and health-related A&RCC per capita, and health and health-related A&RCC as a proportion of GDP. All plots are disaggregated by WHO region.[77]

An important caveat is that the method of tabulating expenditures is innovative and will benefit from further validation and refinement over time. Second, while health adaptation spending unambiguously belongs in this indicator, the definition of which other forms of adaptation spending should be included is debatable; agriculture and disaster preparedness were included here, but other forms of adaptation spending also have health implications. Third, only the financial year 2015-2016 of economic data was available, precluding time trend analysis. Fourth, since public sector transactions may not leave a sufficient ‘digital footprint’, adaptation spending data here may exclude some public-sector spending.

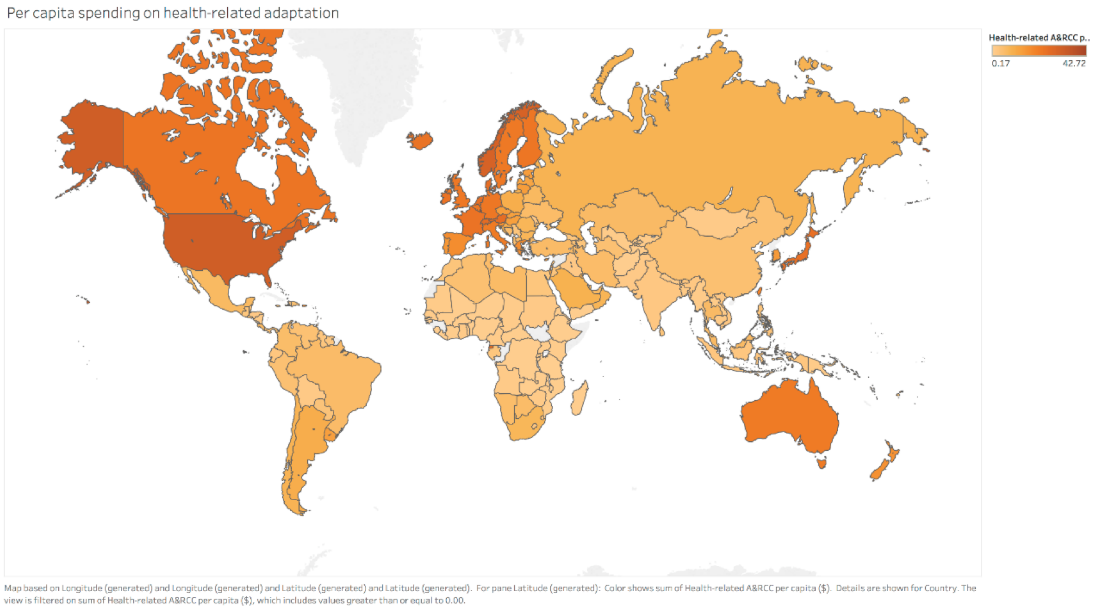

Figure 2.12 Per capita spending on health-related adaptation.

Indicator 2.10: Health adaptation funding from global climate financing mechanisms

Headline Finding: In 2017, an all time high of 0.96% of total adaptation funding for development flowing through global climate change financing mechanisms, was dedicated to health adaptation.

The final indicator in this section is designed in parallel with the one above, and aims to capture development funds available, as distinct from private-sector spending described in indicator 2.9. It reports on global financial flows dedicated to health adaptation to climate change, moving through established global climate financing mechanisms. Data was drawn from the Climate Funds Update (CFU), an independent source which aggregates funding data from multilateral and bilateral development agencies since 2003.[23,78] CFU data is presented in four categories (pledged, deposited, approved, and disbursed); this indicator uses data designated as "approved".

Between 2003 and 2017, only 0.96% of approved adaptation funding was allocated to health adaptation, corresponding with a cumulative total of $39.55 million USD (Figure 2.13). Total global adaptation funding peaked in 2013 at $910.36 million USD and declined thereafter. However, health-related adaptation funding reached its highest level in early 2017.

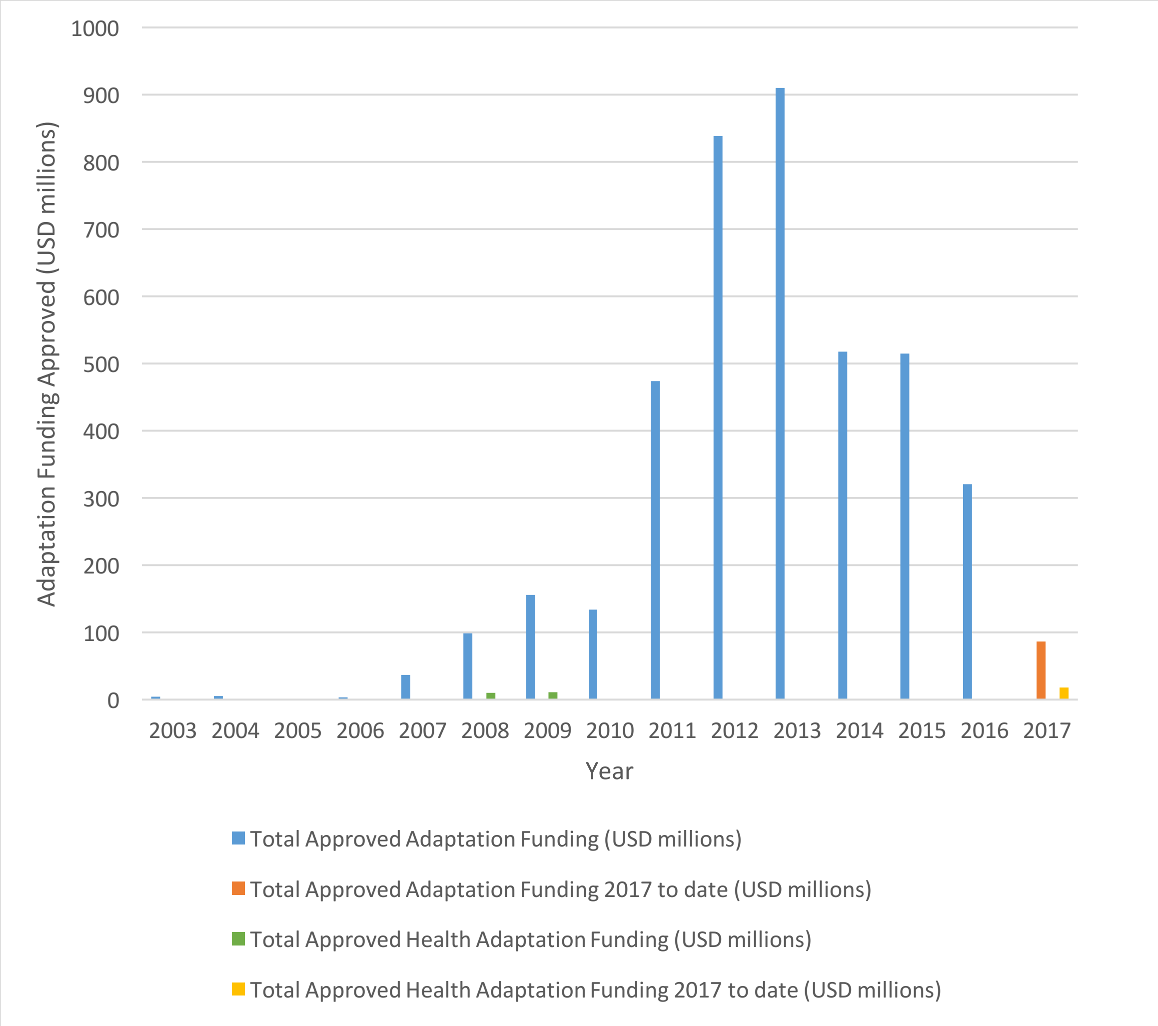

Figure 2.13: Year on year multilateral and bilateral funding for all adaptation projects and health adaptation projects (2003 through May 2017).[78]

The data presented does not include funding from a number of important donors, including the US, Japan, and Denmark, and does not include co-financing arrangements from either the public or private sector in recipient countries. Only global flows labelled as explicitly targeting public health were included in the analysis, meaning that it likely underestimates health-related adaptation spend.

Conclusion

This section has presented indicators across four domains, each of which informs the next: vulnerability and resilience; leadership and governance; implementation and adaptive capacity; and adaptation financing. Taking these as a whole, it is clear that the public, and the health systems they depend upon, are ill-prepared to manage the health impacts of climate change.

Future work on developing and improving these indicators will begin immediately. In many cases, the data and methods available provide only a starting-point for an eventual suite of which better captures health adaptation specific to climate change, and moves from process-based indicators to outcome-based indicators. New indicators will also be required to better capture important indicators of resilience.

This section is the first of three looking at the policy responses to climate change. When it comes to adaptation, human systems can and do mediate the impacts of climate-induced health hazards. Indeed, there is broad scope for impact reduction through adaptation, particularly for under-nutrition, heat, and food and water-borne infections, even for global mean temperature increases of 4°C above pre-industrial levels.[17] Yet poorer individuals, communities, and countries are typically the least able to adapt, generating equity and justice considerations.[79,80] Further, the greater the extent of climate change, the harder and more costly it will be for individuals, communities, and governments to adapt. Systemic crises, such as the 2010 Arab Spring, reflecting an inability of systems to dampen through adaptive capacity a shock precipitated by a climate hazard, will become increasingly more common.[81]

Whereas adaptation activities tend to have nationally-localised benefits (adaptation activities in one region or country will likely have little impact elsewhere), the mitigation of climate change has many characteristics of a global public good (many countries benefit from another country's mitigation efforts).[82] Interventions to mitigate climate change, and the health co-benefits available from such a transition are the topic of section three of this report.

3. Health and Co-Benefits of Mitigation

Introduction

Sections one and two of the Lancet Countdown have covered the health impacts of climate change, the adaptation available and currently being implemented, and the limits to this adaptation. This third section presents a series of indicators relevant to the short-term health co-benefits of climate mitigation policies. Accounting for this enables a more complete consideration of the total cost and benefits of such policies, and is essential in maximising the cumulative health benefit of climate change mitigation.

The health co-benefits of meeting commitments under the Paris Agreement are immense, reducing the burden of disease for many of the greatest global health challenges faced today and in the future. The indicators presented in this section tell two stories. Primarily, they describe a clear and urgent need to increase the scope of mitigation ambition if the world is to keep global average temperatures "well below 2°C".[13]

And yet, across the world, countries are accelerating their response to climate change, with Finland, the UK, and even China making strong commitments to phase-out or dramatically reduce their dependence on coal. [83-85] By the end of 2017, electric vehicles are poised to be cost-competitive with their petroleum equivalents, a phenomena that wasn't predicted to occur until 2030. Globally, more renewable energy capacity is being built every year than all other sources, combined.[86]

Tracking the health co-benefits of climate change mitigation

Meeting the Paris Agreement will require global GHG emissions to peak within the next few years and undergo rapid reduction thereafter, implying near-term actions and medium- and long-term cuts through country level activities.[14] Carbon emissions were at 36.3 $GtCO_2$ in 2015 (60% higher than in 1990), with 41% of the total emissions estimated as coming from coal, 34% from oil, 19% from gas, and 6% from cement.[87] Current global annual emissions of methane (CH_4) are estimated to be 558 (540-568) Tg – responsible for some 20% of global warming produced by all well-mixed gases.[88] They have recently begun to increase again after a somewhat stable period between 1999 and 2006.

The actions needed to embark on rapid decarbonisation include avoiding the 'lock-in' of carbon intensive infrastructure and energy systems, reducing the cost of 'scaling-up' low-carbon systems, minimising reliance on unproven technologies, and realising opportunities of near-term co-benefits for health, security, and the environment.[14] These actions will need to also be cost-effective and supported by non-state actors and industry.

Indicators in this section are considered within the framework of Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA). The DPSEEA framework is recognized as one of the most suitable frameworks for the development of environmental health indicators, and identification of entry points for policy intervention.[89] Our adaptation of the framework for examination of the health co-benefits of climate change mitigation is explained in Appendix 4.

Here, health co-benefit indicators are captured for four selected sectors: 1) energy, 2) transport, 3) food, and 4) healthcare. Where possible, a baseline of 1990 has been used, with further historical data provided as context. Corresponding Appendix 4 provides more detailed discussion of the data and methods used.

Future work will look to capture other relevant sectors such as the building sector and manufacturing; to more fully identify the health outcomes associated with mitigation actions; and to identify a complete set of indicators, for every level of the DPSEEA framework. This will require development of an integrated data collection and analysis platform and the development of consistent but context-relevant data collection and processing methodology.

Energy Supply and Demand Sectors

Fossil fuels comprise the largest single source of greenhouse gas (GHG) emissions globally, producing an estimated 72% of all GHG emissions resulting from human activities.[90,91] The majority (66%) of these emissions arise in the energy sector from the production of thermal and electric power for consumption across a range of sectors including industry, commercial, residential and transport.

To meet the climate change mitigation ambitions of the Paris Agreement, it is widely accepted that the energy system will need to transition towards near zero-carbon emissions by, or soon after, 2050.[92] Recent analysis has framed the necessary action as a halving of CO_2 emissions every decade.[93] Such a rate of reduction is unprecedented and therefore requires strong policies to be put in place to drive the necessary change. Figure 3.1 provides an illustration of the type of actions needed to meet this ambitious goal. Under this pathway there is a heavy reliance on energy efficiency improvements, fuel switching, and low- and zero-carbon fuels.

The potential health benefits of such strategies are unprecedented, with significant improvements from a reduction in indoor and outdoor air pollution; more equitable access to reliable energy for health facilities and communities; and lower costs of basic energy services for heating, cooking, and lighting.

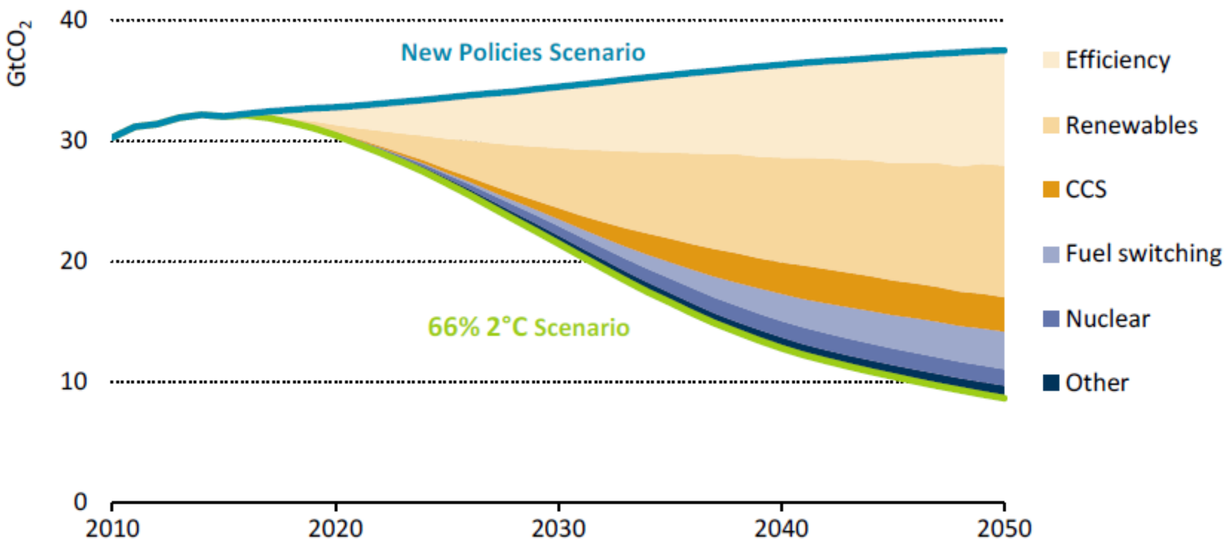

Figure 3.1. Measures needed to surpass current NDCs to achieve a 2°C trajectory, through 2050. The "New Policies Scenario" takes into account countries' pledges under the Paris Agreement.[94]

The DPSEEA diagram in Figure 3.2 illustrates the process in the energy sector that contributes to climate change and needs to be regulated by policies for climate change mitigation. In this process macro-factors such as growth in population and economic activity (driving forces), stimulate continuous increase in the energy consumption and production levels, these in turn, produce emissions of GHGs and other pollutants (pressures), leading to increased GHG concentration in the atmosphere and air pollution levels (state), which subsequently lead to human exposure to pollutants that have negative impact on human health, resulting in the a health burden attributable to the same processes that lead to GHG emissions from energy production.

Of particular importance to climate change mitigation in the energy sector are factors determining the extent to which increase in the energy production translates into the emissions of greenhouse gases and other pollutants. Indicators 3.1-3.4 are tracking some of the key factors that determine this extent. Indicator 3.5 is tracking the state of air pollution in cities, where exposure levels tend to be highest and affecting largest fractions of the population. The overall ambient air pollution in cities is most relevant to human health and is most operational, as it is most comprehensively monitored by urban authorities. However, ambient air pollution has multiple sources beyond energy production, e.g., dust, tyre wear, trash and agricultural waste burning, smoking. Therefore, the sub-indicator 3.5.1 illustrates air pollution attributed specifically to the energy production sector. The indicator 3.6 tracks progress in terms of the air pollution attributed health impact, thus, quantifying changes in the health co-benefit of cleaner energy production.

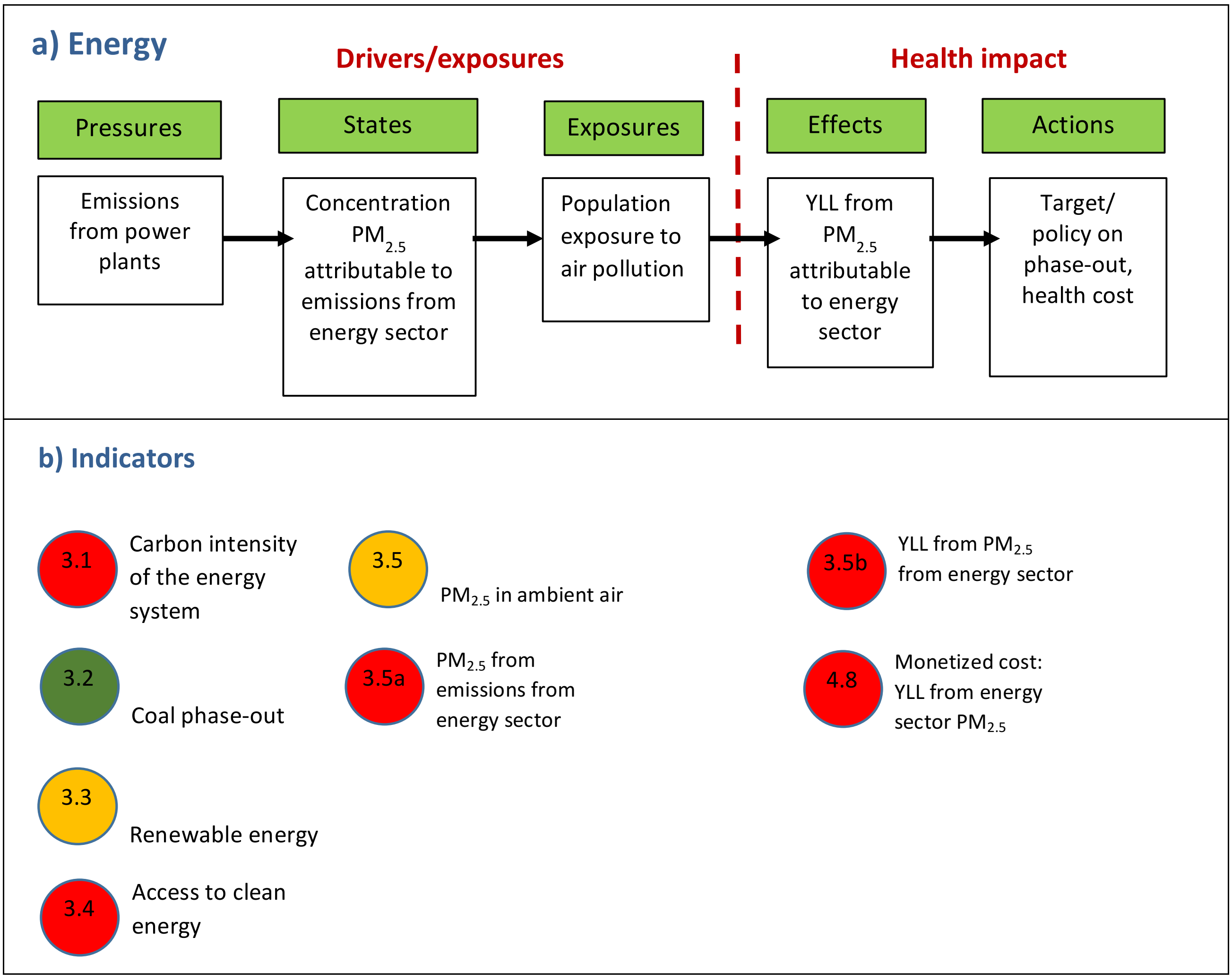

Figure 2.2. 3.2a) DPSEEA Framework applied to Energy Sector. 3.2b) Energy sector indicators within the DPSEEA framework. A simple traffic-light system has been used to provide a qualitative indication of global progress to-date, on each of the indicators.

Indicator 3.1: Carbon intensity of the energy system

Headline Finding: *Globally, the TPES has remained stable since 1990, between 55-56 tCO2/Tj. This has occurred because countries, which have achieved a reduction in carbon intensity (USA, UK, Germany), have been offset by those which have rapidly increased the carbon intensity of their energy supply (India and China).*

To achieve the 2 °C target (at a 66% probability), the global energy sector must reduce GHG emissions more than 70% below current levels (Figure 3.1). This means a large reduction in the carbon intensity of the global energy system, which can be measured as the tonnes of CO_2 for each unit of total primary energy supplied (tCO_2/TJ). Total Primary Energy Supply (TPES) reflects the total amount of primary energy used in a specific country, accounting for the flow of energy imports and exports.[95] Commitments under the Paris Agreement should begin to lower the carbon intensity of TPES.

At the global level, since the 1990s, the carbon intensity of energy supply has remained between 55-56 tCO_2/TJ. However, a 53% growth in energy demand over the period has meant that global CO_2 emissions have grown significantly. Rapidly developing countries have seen an increase in carbon intensity since the 1970s, driven by increased coal use (Figure 3.3). For example, India's TPES has almost tripled since 1980, with the share of coal in the mix doubling (from 22% to 44%). Over the same period, China's TPES has quadrupled, with the coal share increasing from 52% to 68%.

Other developed countries have seen carbon intensity fall since the 1970s (for example, the USA, Germany and the UK in Figure 3.3). This decrease has resulted from a move away from coal use in the power generation sector, reduced heavy industrial output, and increased use of lower carbon fuels, notably moving from coal to natural gas in the power sector and the use of renewable energy. Other developing countries have remained at relatively low carbon intensities, such as those with large dependence on bioenergy, as shown by the example of Kenya, typical of many countries in sub-Saharan Africa.

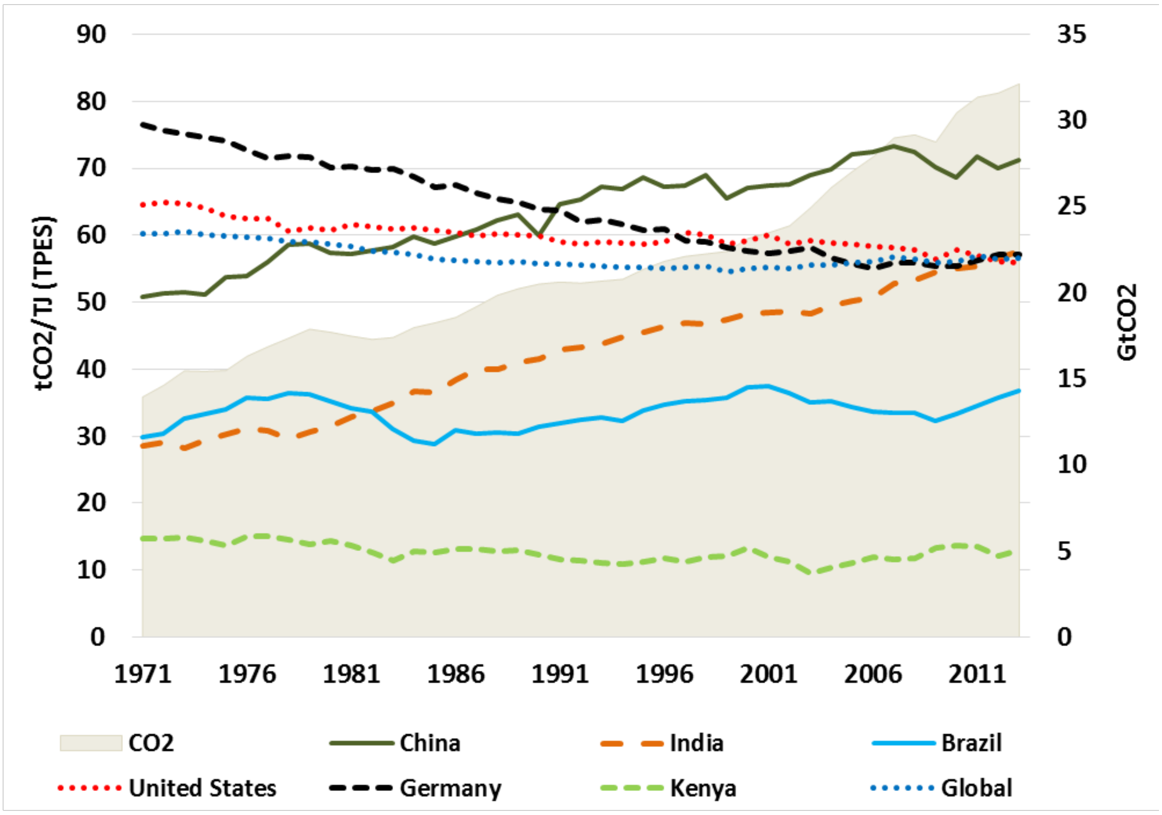

Figure 3.3. Carbon intensity of Total Primary Energy Supply (TPES) for selected countries, and total CO_2 emissions, 1971-2013 (Adapted from IEA data). Per unit of primary energy, coal has the highest CO2 emissions of any of the fossil fuels therefore if coal is used to displace other sources of energy or adds a greater proportion of coal to the mix then carbon intensity rises.

Indicator 3.2: Coal phase-out

Headline Finding: *Globally, total primary coal supply has increased from 356 EJ in 1990, to 531 EJ in 2015. This production level in 2015 is a reduction from a high of 548 EJ in 2013.*

The primary means of reducing carbon intensity of the energy system will be the phase out of coal. Worldwide, coal supplies 30% of energy use and 44% of global CO_2 emissions. The dirtiest coal produces almost twice the carbon per unit of primary energy than the cleanest fossil fuel, natural gas. Globally, 63% of electricity supply comes from coal (40%) and gas (23%) power plants. These plants also produce more than 40% of global CO_2 emissions (13.5 Gt) from the energy sector, and are a worrying source of air pollution.

The primary indicator of coal phase-out used here is the total primary coal supply (EJ) in the energy system. (Figure 3.4) A secondary indicator provides additional information on the share of electricity (%) produced by coal plants. (Figure 3.5) The analysis and graphs for these indicators make use of recent data from the International Energy Agency's (IEA).

Globally, coal use as a share of total primary energy supply increased markedly from 24% to 30% between 2000 and 2013. This growth was largely driven by China's increasing use of coal in industry and for electricity production (see East Asia trend in Figure 3.4). Crucially, this coal use has levelled off in recent years, in large part due to a recognition of the health effects of air pollution, slower growth and structural changes in China's economy, and a slowing in energy sector expansion.[96] India has also seen significant growth in coal use, with a doubling of the share of coal in TPES since 2000.

The other large coal consuming regions are the USA and Europe. The USA has had a stable level of consumption since the 1990s, but experienced a recent fall in use, particularly in the power generation sector, due to the cost-competitiveness of shale gas. Europe has seen a steady decline in coal use since the 1990s, again through a move to gas in economies such as the UK, although this overall downward trend has transitioned to a plateau in recent years.

Given that the majority of coal is used in power generation, it is also worth considering an indicator reflecting the share of electricity that is generated by coal (Figure 3.3.5). Today, China and India both have similar shares, at around 75% of total generation, a share that has steadily grown since 1990. Whilst this trend is plateauing in China, the rapidly-emerging economies of Indonesia, Vietnam, Malaysia, and the Philippines are cause for particular concern. The latter two countries have seen their shares increase from around 10% in 1990, to 40% today. Indonesia has also seen strong growth over this period, from 30% to 50%.

Meeting the IEA's 2°C pathway and the Paris Agreement requires that no new coal-fired plants be built (beyond those with construction currently underway), with a complete phase-out of unabated plants occurs by 2040. Crucially, such a transition appears to be underway, with the amount of coal power capacity in pre-construction planning at 570 gigawatts (GW) in January 2017, compared to 1,090 GW in January 2016.[97] There are a range of reasons for this reduction, including a historically optimistic capacity expansion planning, a desire to tackle air pollution, and active efforts to expand renewable investment.

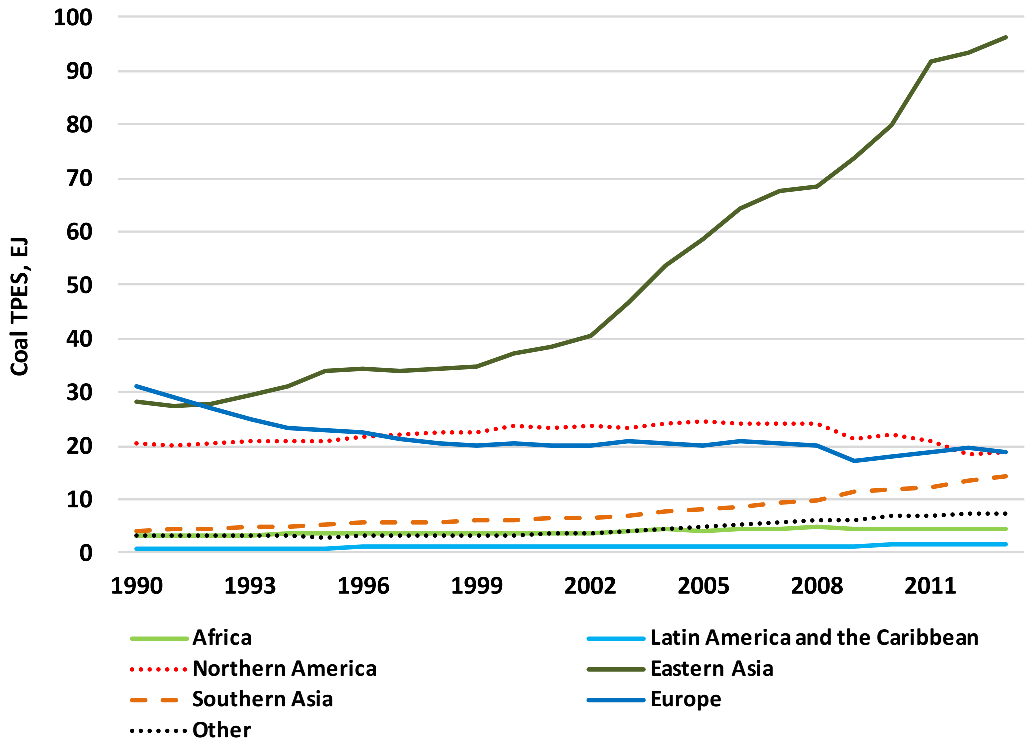

Figure 3.4. Total primary coal supply by region, 1990-2013 (Source IEA) [Steve to update]

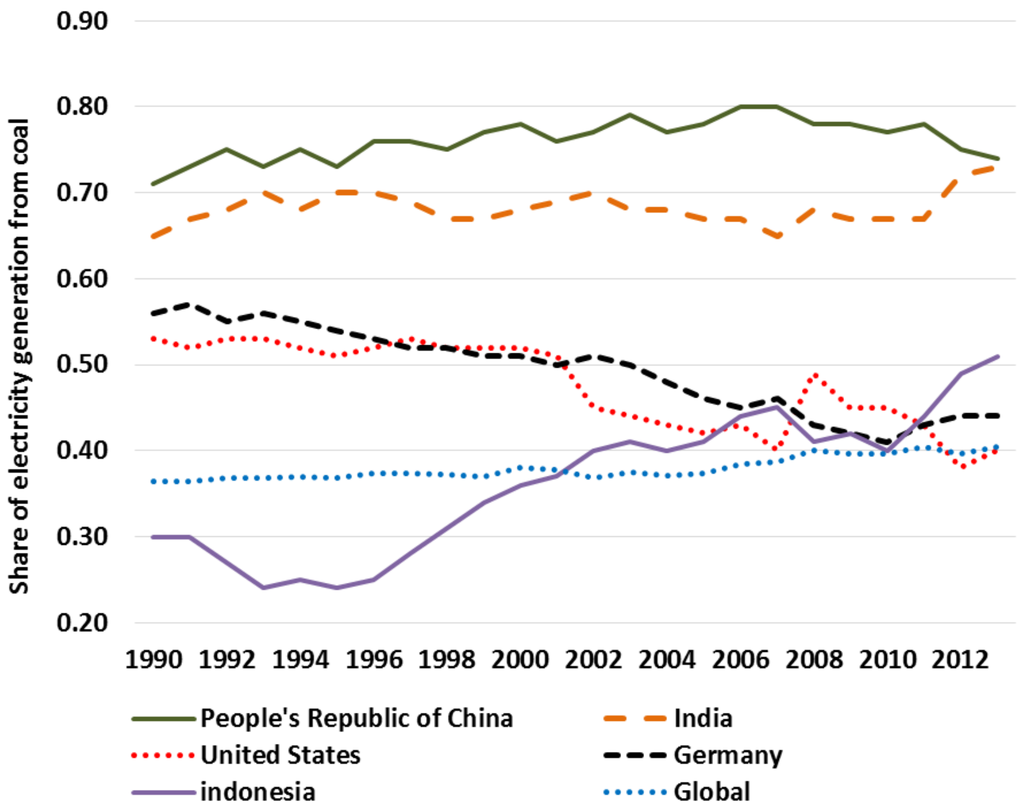

Figure 3.5. Percentage of electricity generated from coal, 1990-2013 (Source IEA) [Steve to update]

Indicator 3.3: Zero-carbon emission electricity

Headline Finding: *Globally, renewable energy as a share of total generation has increased by over 20% from 1990 to 2013. In 2015, renewable energy capacity added exceeded that of new fossil fuel capacity, with 80% of global renewable energy capacity currently located in China. To the extent that this transition displaces fossil fuels, it represents the beginning of unprecedented reductions in morbidity and mortality from air pollution, and a potentially remarkable victory for global health.*

As coal is phased out of the energy system, in particular the power generation sector, the rapid scaling up of zero-carbon power generation will be crucial, in particular for electricity generation. To remain on a 2°C pathway, renewables-based capacity additions will need to be sustained over the next 35 years, reaching 400 GW by 2050, which is four times the current level. Critical renewable technologies for achieving this will be solar, wind and hydroelectric. Nuclear generation may also continue to play a role in those countries where it has traction and the capacity to maintain, such as Russia, China, India and South Korea.

Indicator 3.3 considers both renewable and zero-carbon electricity. Renewable energy, as defined by the International Renewable Energy Agency (IRENA), refers to "*all forms of energy produced from renewable sources in a sustainable manner, which include: bioenergy, geothermal, hydropower, ocean energy (tidal, wave, thermal), solar energy and wind energy*". By comparison, zero-carbon energy means no GHG emissions (i.e. zero-carbon and carbon equivalent) at the point of power generation, which therefore also includes nuclear-powered electricity, but excludes biomass.

As both displace the use of fossil fuels, improving air pollution and GHG emissions, both are important indicators for climate change and for health. One caveat is that the combustion of solid biomass fuels such as wood, sometimes promoted for climate change mitigation purposes, may increase fine particulate air pollution exposure.

As a share of total generation, renewable energy has increased by over 20% from 1990 to 2013. Renewable energy continues to grow rapidly, mainly from increasing wind and solar PV investment, most notably in the USA, China and Europe (Figure 3.6). In 2015, more renewable energy capacity (150GW) was added than fossil fuel plant capacity globally. Overall, there is now more renewable energy capacity installed globally (almost 2000 GW) than coal, with about 80% of this capacity located in China. The total investment in renewables of $288 billion in renewables in 2015 meant it accounted for 70% of total electricity generation investment in that year. [98]

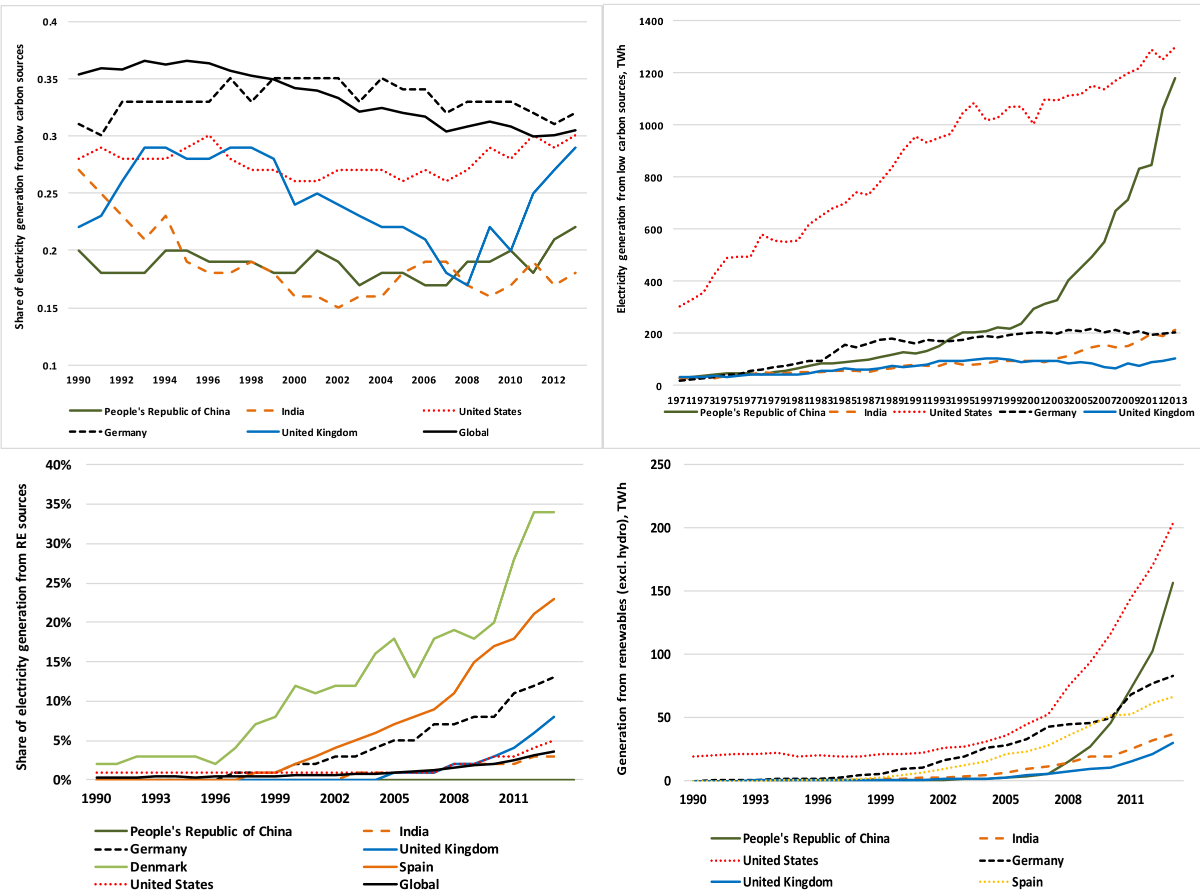

Figure 3.6.- Renewable and zero-carbon emission energy sources

Indicator 3.4: Access to clean energy

Headline Finding: *In 2016, it was reported that 1.2 billion people did not have access to electricity, with 2.7 billion people relying on the burning of unsafe, unsustainable, and inefficient solid fuels.*

Increased access to clean fuels and clean energy technologies will have the dual benefit of reducing indoor air pollution exposure, and reducing GHG emissions by displacing fossil fuels.[99] The use of clean energy for heating, cooling, cooking and lighting plays an important role in improving global health and wellbeing, economic productivity, and reducing the risk of harm from living in energy poverty.[100] While access to any form of secure and cheap energy will have health benefits, access to *clean* energy will have additional health benefits through the reduction of poor air quality.

It is estimated that 1.2 billion people do not currently have access to electricity and 2.7 billion people rely on burning unsustainable and inefficient solid fuels, which contributes to poor indoor air quality, estimated to result in 4.3 million premature deaths related to pneumonia, stroke, lung cancer, heart disease, and chronic obstructive pulmonary disease (COPD) each year.[101,102] Access to electricity, an energy source that emits no direct airborne particles (though particles ma be emitted indirectly through the fuel used to generate the electrical power), is currently at 85.3% but varies widely among countries and urban and rural settings. This indicator draws on and aligns with the proposed SDG indicator 7.1.2, defining 'clean energy' as the emission rate targets and specific fuel recommendations (i.e. against unprocessed coal and kerosene) included in the normative guidance, *WHO guidelines for indoor air quality: household fuel combustion.* This same indicator estimates the proportion of the population with primary reliance on clean fuels and technologies for cooking, heating and lighting compared to all people accessing those services. The data used for this indicator comes from estimates of fuel use from WHO household survey data from roughly 800 nationally representative surveys and censuses, and is modelled to estimate the proportion of their reliance on clean fuels.[103]

Furthermore, access to electricity is an important comparator to access to clean energy, and so is also tracked here. Globally, 85% of the population has access to electricity, but this differs substantially between urban and rural areas and by country. For urban households, global access to electricity is estimated to be 96%, however Sub-Saharan Africa has an urban electrification rate of just 60%.[95] Many of the least-developed countries (LDC) have very low levels of urban access to electricity, and whilst the average for African LDCs is 48%, estimates range as low as 4% in South Sudan, Liberia, and the Central African Republic. It is estimated that 80% of the 1.06 billion people without access to electricity live in only 20 countries, most in Sub-Saharan Africa.

Moving towards 2030, progress towards universal access to clean fuels and technologies for heating, lighting and cooking must increase beyond the current global average rate of 1-2% per year.[100] This challenge will be particularly pressing in urban areas that continue to come under population growth pressures and where energy infrastructure is already stressed.

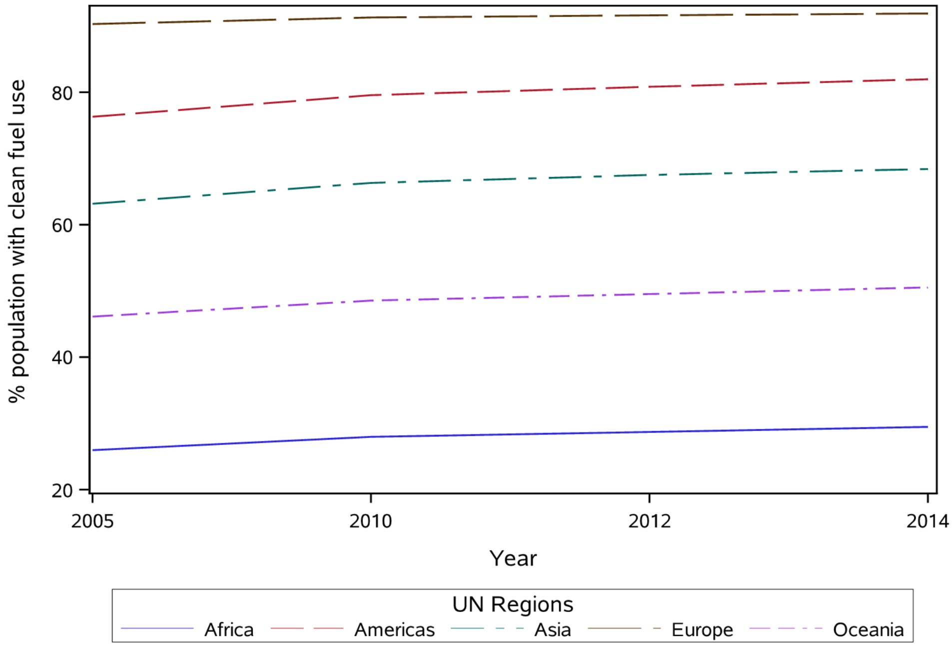

Figure 3.7. Proportion of population with primary reliance on clean fuels and technology

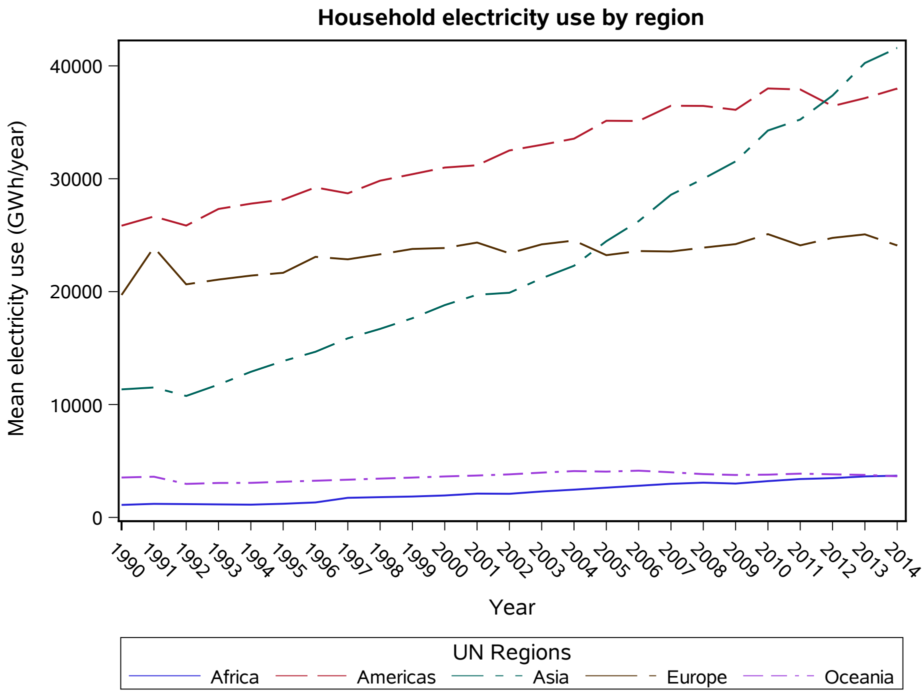

Figure 3.8. Mean residential electricity use (MWh/year).

Indicator 3.5: Exposure to ambient air pollution

***Headline Finding:** 83.5% of the 121 cities in the SHUE database do not satisfy WHO annual particulate matter exposure recommendations; global population-weighted $PM_{2.5}$ exposure has increased by 11.2% since 1990.*[104]

Air pollutants harmful to health are emitted by combustion processes that also contribute to emissions of GHGs. As such, properly designed actions to reduce GHG emissions will lead to improvements in ambient air quality, with associated benefits for human wellbeing.[105] We divide this indicator into two parts: total exposure to air pollution in cities and contributions to exposures from specific sectors. To represent levels of exposure to air pollution, this indicator collects information on annual average urban background concentrations of fine particulate matter (PM2.5) in urban settings across the world.

3.5.1 Exposure to air pollution in cities

The data for this indicator makes use of the WHO's Urban Ambient Air Pollution Database, which compiles information form a range of public sources, including national and subnational reports and websites, regional networks, intergovernmental agencies, and academic publications.[106] The air pollution measurements are taken from monitoring stations located in urban background, residential, commercial, and mixed areas. The annual average density of emission sources in urban areas and the proximity of populations to those sources led the Lancet Countdown to focus on exposure in cities. Average air pollution levels in cities are driven by a wide range of factors, with the degree of socio-economic development being of particular importance with lower air pollution levels generally found in cities with higher per capita GDP on average (Figure 3.9).

For this indicator of ambient air pollution exposure, the Lancet Countdown has combined the WHO database with the Sustainable Health Urban Environments (SHUE) database, presenting data on 143 randomly sampled cities across the world.[107]

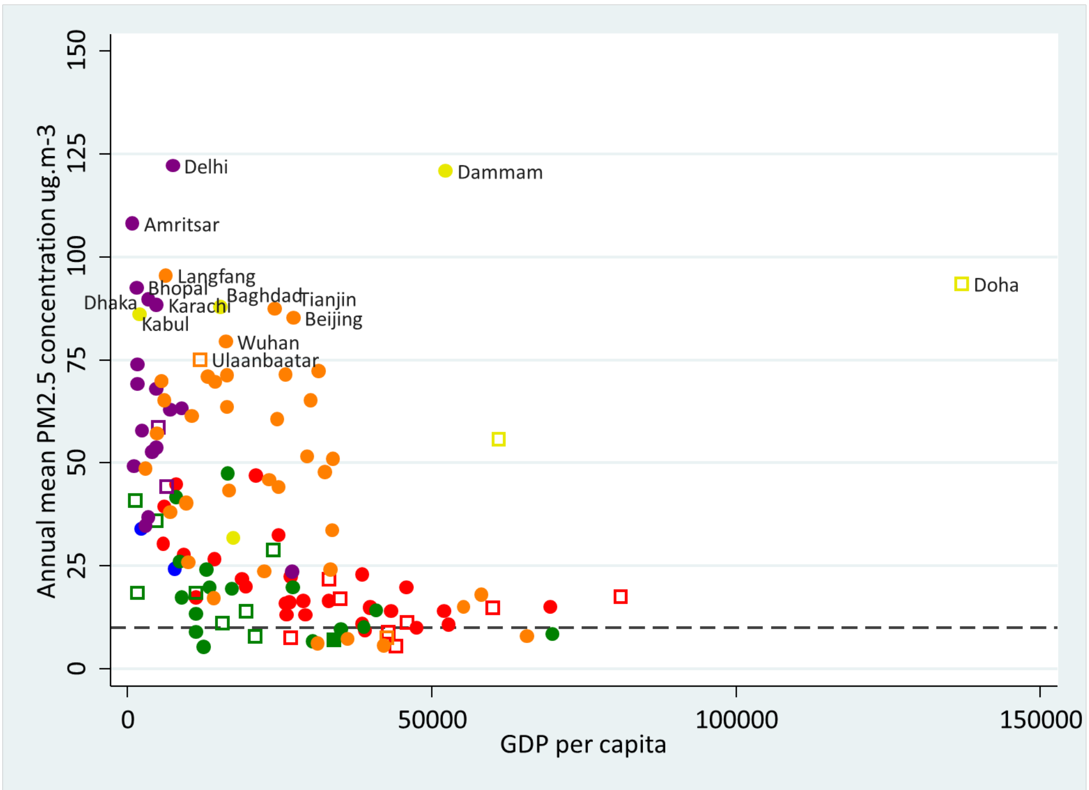

Figure 3.9. Annual mean PM2.5 concentration vs per capita GDP for 143 cities in the SHUE database. Colours indicate WHO regions: blue – Africa; red – Europe; green – the Americas; Lime – Eastern Mediterranean; orange – Western Pacific; purple – South East Asia.[106,107]

$PM_{2.5}$ levels in the majority of global cities are currently well above the WHO's annual guideline level of 10 μg.m^{-3}, with particularly high levels in cities in central, South and East Asia. There is relatively little data on recent trends in air pollution exposures and this indicator represents only an estimate of the current situation. The data suggest that air pollution levels have generally decreased in high income settings over recent decades, whilst they have marginally increased, globally.[108] Correspondingly, estimates from the Global Burden of Disease (GBD) study suggest a modest increase in the health burden due to air pollution, from 3.5 million deaths worldwide in 1990 to 4.2 million in 2015, though this is in part due to factors such as population growth and aging. Future work will look to build on these preliminary efforts by tracking air pollution over a more regular and frequent time period, and establishing attribution between changes in air pollution and interventions to mitigate climate change. This will necessitate the development of new modelling techniques and improved source apportionment data to better identify key targets for policy action (see Box 3.1 below).

Furthermore, tracking exposure to household air pollution could also help to quantify important health co-benefits of climate change mitigation strategies due to exposure to short-lived climate pollutants, most notably black carbon.[109] While currently there is no systematically collected data that is comparable at a national level, a future indicator could draw on existing studies to monitor personal exposure to indoor carbon monoxide (indicating exposure to combustion products) in a number of different settings.[110]

Box 3.1 Source apportionment of air pollution in Delhi

Recent work led by the International Institute for Applied Systems Analysis (IIASA) has attempted to identify the primary sources of $PM_{2.5}$ in Delhi and their relative contributions to concentrations and attributable health impacts in the city. Using the GAINs model, the work demonstrates the large contribution (60%) to air pollution in Delhi from outside the city, emphasising the need for cities to work in collaboration with neighbouring areas to reduce air pollution. A large proportion of Delhi's air pollution is also due to secondary $PM_{2.5}$ from agriculture, suggesting that current strategies focused predominantly on vehicle sources will have a limited impact.

Based on scenario modelling, the most effective policy responses involved extending clean air strategies to neighbouring states. By 2030, such strategies would reduce the number of premature deaths due to air pollution each year in Delhi (from about 14,000 under business-as-usual to about 11,000), reduce GHG emissions, and provide additional benefits including accelerated infrastructure development and job creation.

3.5.2 Sectoral contributions to air pollution exposures

[Melissa]

Transport Sector

Transportation systems—including road vehicles, rail, shipping, and aviation—are a key source of GHG emissions, contributing 14% of global emissions in 2010. [95,111] In order to meet the 2°C target (at a 66% probability), the global transport sector must reduce its total GHG emissions by more than 20% below current levels, by 2050.[98] The DPSEEA diagram in Figure 3.10 illustrates the process in the transport sector that contributes to climate change and needs to be regulated by policies for climate change mitigation.

The transport sector is also a major source of air pollutants, including particulate matter, nitrogen oxides, sulphur dioxide, carbon monoxide, volatile organic compounds, and indirectly, ozone. Furthermore, exposure to air pollution from road transport is particularly challenging in cities where vehicles emit street-level air pollution in close proximity to where people live, walk and breathe. In turn, significant opportunities for health exist through the reduction of GHG emissions from transport systems, both in the near-term through cleaner air and increased physical activity, and the long-term through the mitigation of climate change.

Today, the transport sector is heavily dependent on motorized transport powered by the combustion of petrol and diesel fuels. This dependence contributes both to the emission of GHGs and also to poor air quality (especially particulate matter and NO_2). Overdependence on motorized transport rather than active travel (walking and cycling) is a significant contributing factor to low levels of physical activity, high rates of obesity, and the associated health risks of chronic disease, including diabetes, ischaemic heat disease, and selected cancers. It is therefore appropriate to reflect trends in vehicle usage, the deployment of low-emission vehicles, levels of active travel, and exposure to fine particle air pollution, as well as the associated health outcomes attributable to transport-related pollution.

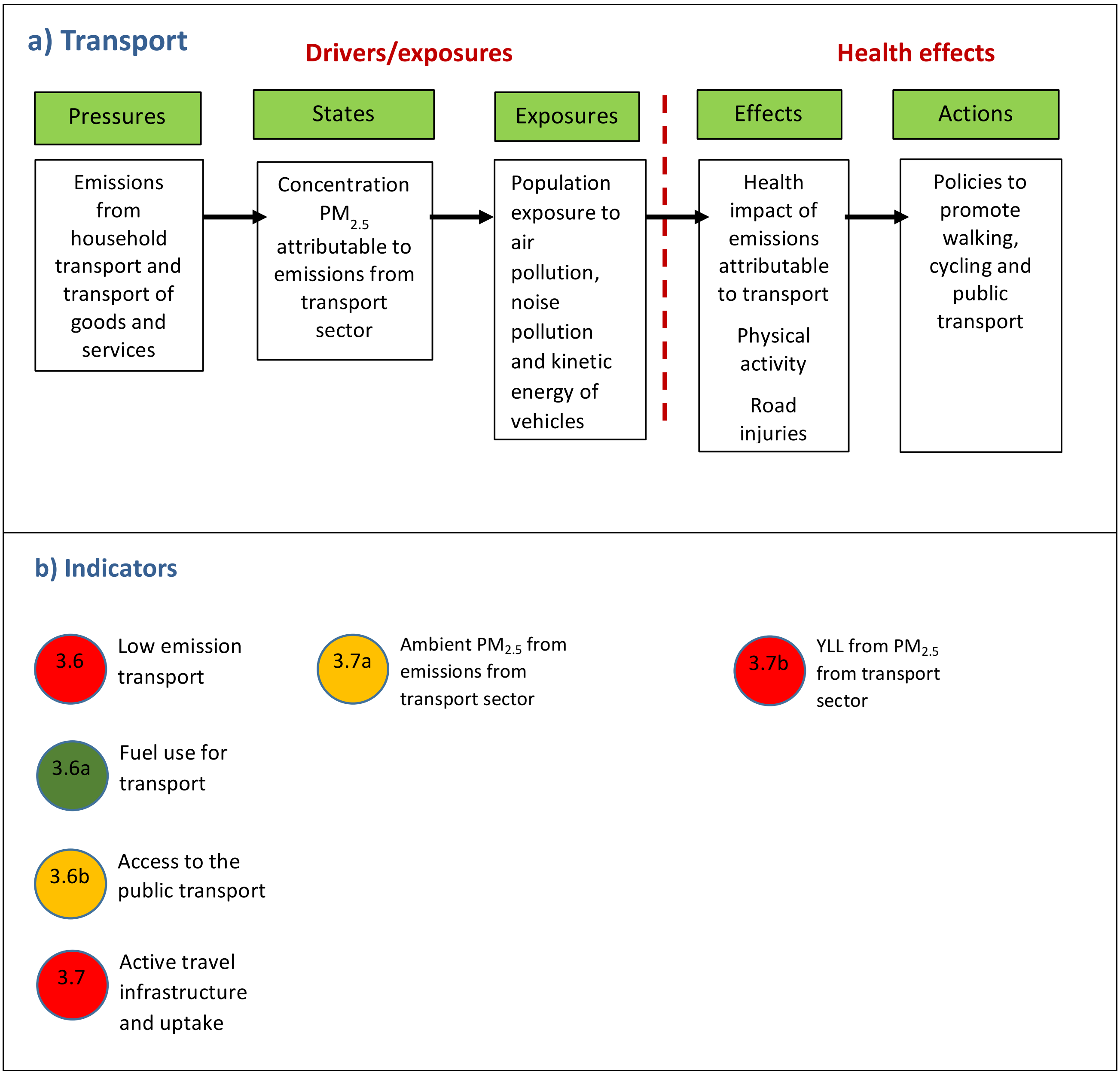

Figure 3.10. 3.10a) DPSEEA Framework applied to Transport Sector. 3.10b) Transport sector indicators within the DPSEEA framework. A simple traffic-light system has been used to provide a qualitative indication of global progress to-date, on each of the indicators.

Indicator 3.6: Fuel use for transport

***Headline Finding:** Global transport fuel use (TJ) has increased by almost 24% since 1990 on a per capita basis. While petrol and diesel continue to dominate, non-conventional fuels have been rapidly expanding, with more than 1.2 million electric vehicles being sold between 2010-2015.*

The International Energy Agency's (IEA) 2016 report "Energy and Air Pollution" makes clear that fuels used for transport currently produce more than half the nitrogen oxides emitted globally.[95,111] Switching to low-emission transport systems is an important component of climate change mitigation and will help to reduce concentrations of most ambient air pollutants. However, the transport sector's extremely high reliance on petroleum-based fuels makes this transition particularly challenging.

This indicator focuses on monitoring global trends in levels of fuel efficiency, and on the transition away from the most polluting and carbon intensive transport fuels. More specifically, this indicator follows the metric of fuel use for transport on a per capita basis (TJ/person) by type of fuel. To develop this indicator, the Lancet Countdown draws on transport fuel data from the IEA and population data from the World Bank. This indicator is particularly relevant to three sustainable development goals (3.9, 11.6, and 13), which are focused on reductions in morbidity and mortality from pollution, reductions in the environmental impact of cities, and enhanced action on climate change.[112]

While some transition away from carbon-intensive fuel use, towards increasing levels of fuel efficiency has occurred in select countries (e.g. the USA), transport is still heavily dominated by gasoline and diesel (Figure 3.11). Global transport fuel use has increased by almost 65% since 1970 on a per capita basis. However, as seen on the right in Figure 3.4, non-conventional fuels (e.g. electricity, biofuels, and natural gas) have been rapidly gaining traction since the 2000s, with more than one million electric vehicles have been sold around the globe since 2010, mostly in the United States, China, Japan and some European countries (

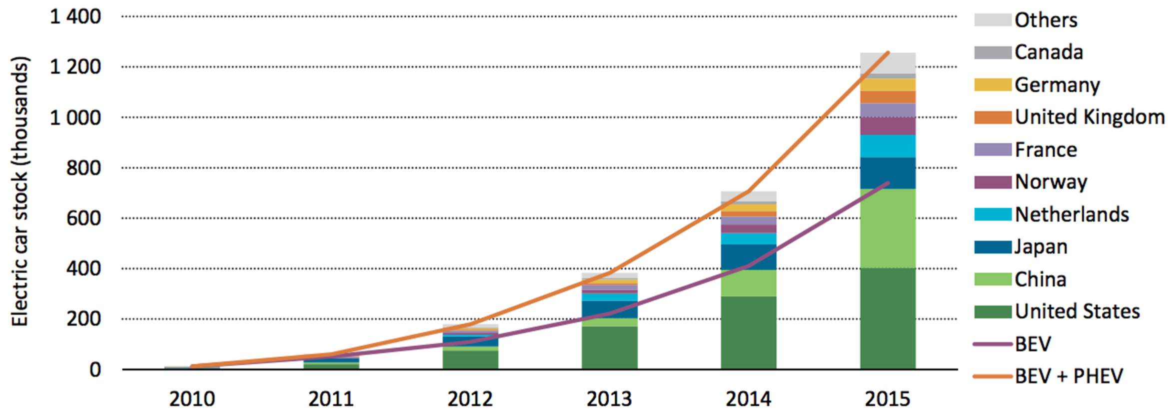

Figure 3.5).[113] These figures remain modest when compared to the overall number of cars sold per year, 77 million in 2017, and the total global fleet of 1.2 billion cars.

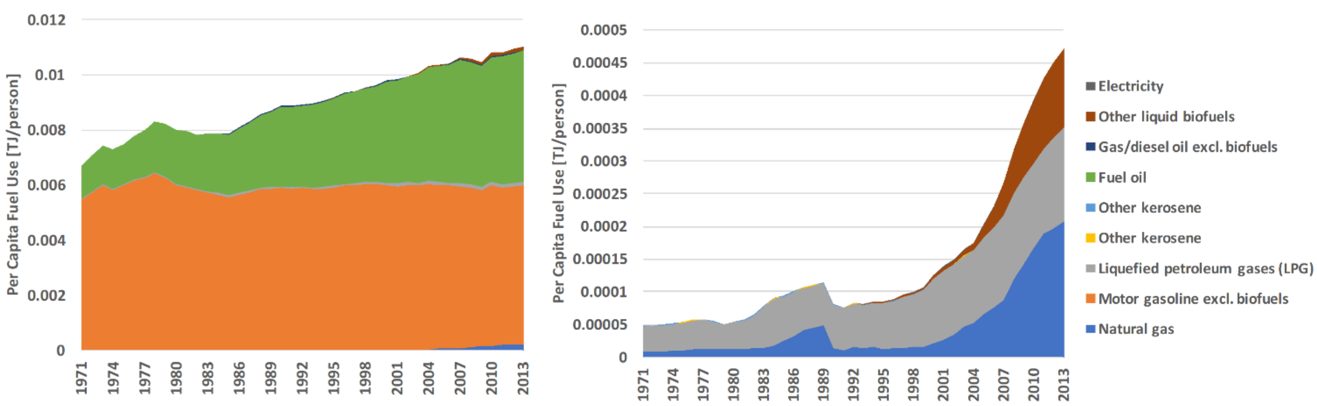

Figure 3.4. Per capita fuel use by type (TJ/person) for transport sector with all fuels (left) and for less-conventional fuels only (right).[114,115].

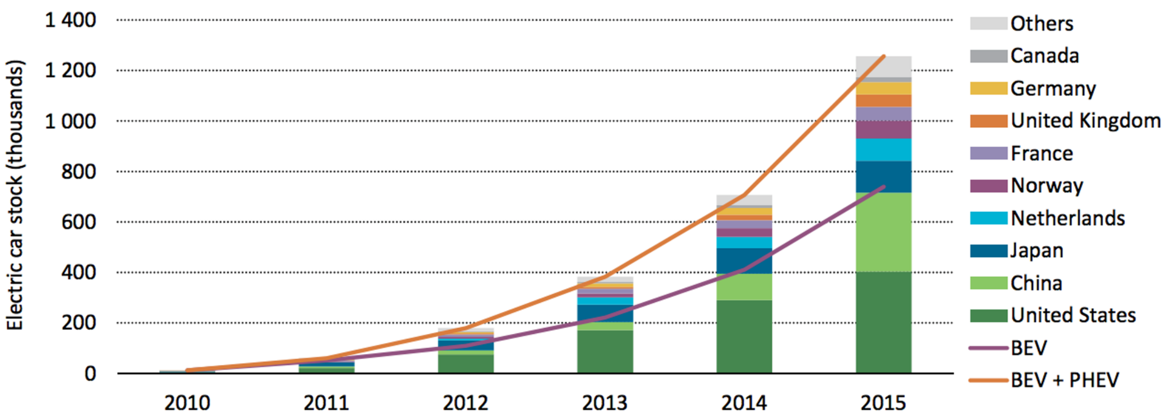

Figure 3.5. Cumulative Global Electric Vehicle Sales.[116]

Indicator 3.7: Active travel infrastructure and uptake

Promoting active travel (walking and cycling) for short journeys not only reduces GHG emissions from vehicles but also leads to appreciable improvements physical activity at the population level, reducing the risk of conditions related to sedentary lifestyle (e.g. ischaemic heart disease, stroke, diabetes, some types of cancer), such benefits generally exceeding any increased risk through road injury.[117,118]

Whilst this indicator would ideally track the proportion and distance of journeys undertaken on foot and bicycle, data availability for national- and city-level modes of travel is particularly scarce. As such, the Lancet Countdown will instead present data for selected locations, across a limited time-scale, in place of an indicator. Figure 3.13 presents data from [please insert brief description of data source, references, and of the kind of cities represented here. A full description to be included in the appendices]. At the national level, Figure 3.14 collates data from published proportions of travel surveys and census data, although even wider data gaps exist for Asia and South America.[119]

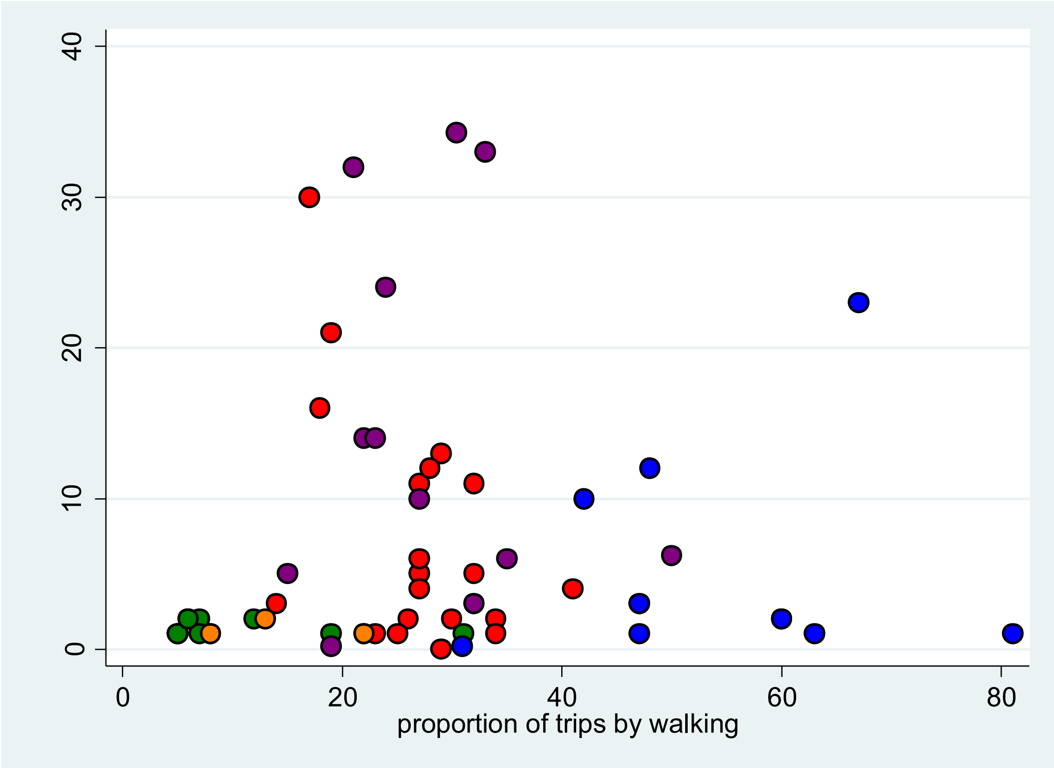

Figure 3.13. Proportion of all journeys made by walking and cycling, selected world cities. Importantly, this does not capture the distance travelled for each journey. Colours indicate regions as follows: blue – Africa; red – Europe; green – Americas; orange – Oceania; purple – Asia.[107,120-124]

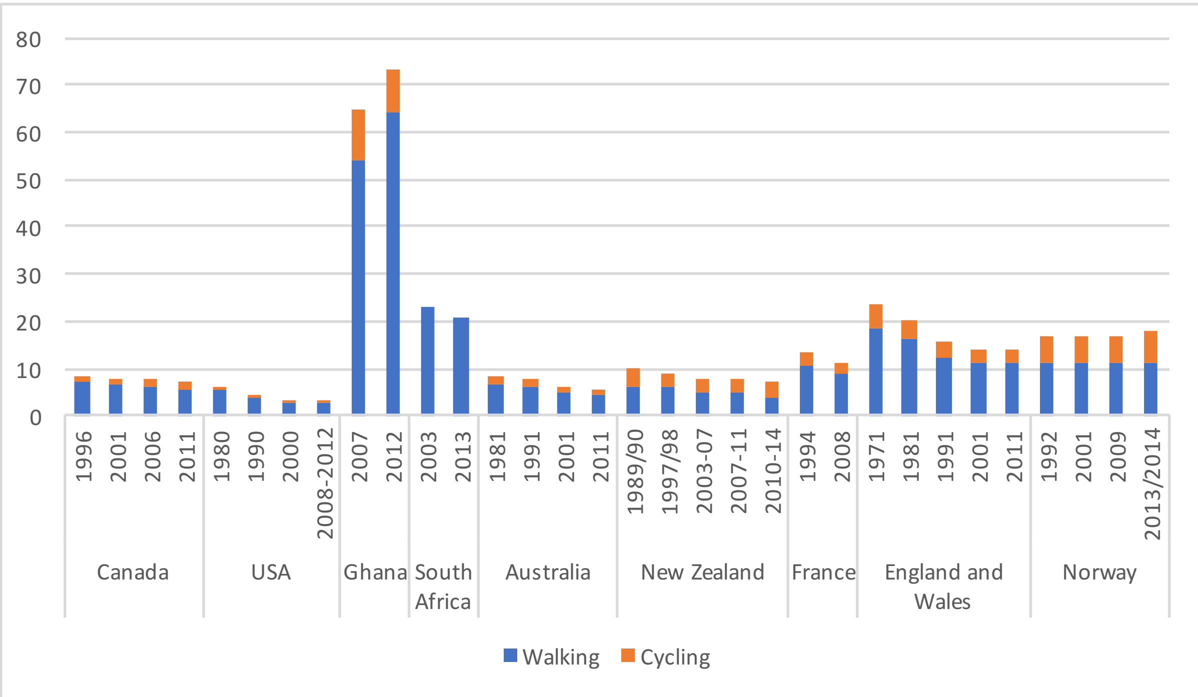

Figure 3.14. Proportion of commuters by usual mode of transport to work (South Africa did not report on journeys to work by cycling).[125-133]

Travel patterns depend on a variety of factors including transport infrastructure, urbanization, mobility needs, availability of motor vehicles and personal preferences, with levels of active travel vary widely across cities. As indicated in the figure, cities in Africa tend to have higher levels of walking, while cities in the Americas and Europe have relatively low levels of both walking and cycling. Across Europe and Asia, more than 20% of trips are made by foot in most cities, while the proportion of cycling journeys ranges from 1-35%.

Globally, trends of increasing urbanization, suburbanization and motorization are likely to continue the global direction of the previous century, leading to further declines in active travel in the future.[134] Organization for Economic Cooperation and Development (OECD) countries are beginning to modestly increase their reliance on active travel with obvious European examples found in Germany, the Netherlands, and Denmark. However current indications of any potential modal shift suggest it is likely to be insufficient to meet global commitments under the Paris Agreement. Choice of transport mode has explicit links to poverty, with the more disadvantaged often unable to afford private or even public modes of transport.

To this end, a rapid decline in the proportion of journeys by foot and cycle is expected in emerging economies as countries develop. As this transition occurs, ensuring the mistakes made in OECD countries are not repeated, will be vital. Recent United Nations (UN) guidance recommends devoting 20% of transport budgets to fund non-motorized transport at national and local levels in low- and middle-income countries.[135]

Food sector

The availability of food (in sufficient quantity and of appropriate type and quality) is central to human health. Its production, however, is also a major contributor climate change, with the agricultural sector alone contributing 29% of anthropogenic GHG emissions.[16]

Dietary choices determine food energy and nutrient intake, which are essential for human health, with inadequate and unhealthy diets clearly associated with health outcomes ranging from malnutrition, diabetes, cardiovascular diseases, and cancer. Globally, dietary factors were estimated to account for over 10% of all Disability Adjusted Life Years (DALYs) in 2013.[136] A transition to healthier diets, with reduced red meat consumption, and high in locally and seasonally produced fruit and vegetable consumption, could provide significant emissions savings. This may in-turn reduce the health impact of excessive and unregulated pesticide application, which is in and of itself, GHG emission intensive.[137-141]

Various dietary options have been examined in terms of their health impact and carbon footprint, with one in the UK indicating as much as a 36% reduction in GHG emissions, under reasonable constraints on food group diversity.[142-144] Despite this, further research is clearly required to identify what constitutes sustainable diets, which must be culturally acceptable, accessible, economically fair affordable, nutritionally adequate, safe and healthy, and protective of biodiversity and ecosystems in those settings.[142,143]

Figure 3.15 makes use of DPSEEA to outline the key pressures exerted on the food sector, and subsequent implications for health and climate change. GHG emissions in the food sector can be altered both through a reduction in the production of food types with the highest life-cycle carbon intensity, and through specific adjustments to production and supply processes.[145]

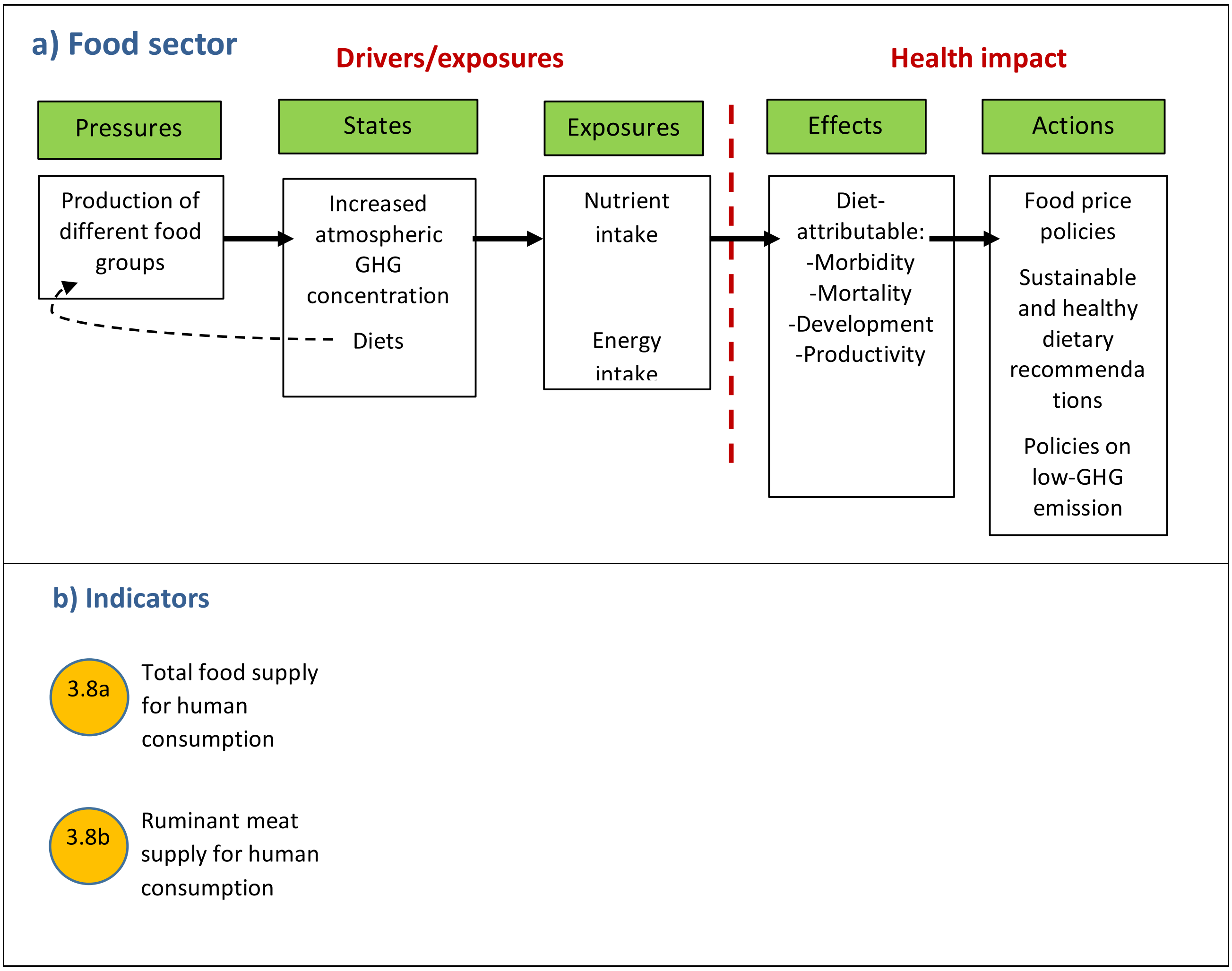

Figure 3.15. 3.15a) DPSEEA Framework applied to Food Sector. 3.15b) Food sector indicators within the DPSEEA framework. A simple traffic-light system has been used to provide a qualitative indication of global progress to-date, on each of the indicators.

Tracking progress towards more sustainable diets requires consistent and continuous data on food consumption, and relatged GHG emissions throughout food product life cycles. On the consumption side, this would require annual nationally representative dietary survey data reflecting food consumption at the individual level. However, due to the complexity and cost of such data collection, dietary surveys are available for a limited number of countries and years only.[146] Although efforts of compiling and ensuring comparability of these data are under way, their current format is not suitable for global monitoring of progress towards optimal dietary patterns in terms of health benefits of climate change mitigation.[147,148] The SDG indicator 2.4.1 is designed to track the proportion of agricultural area under productive and sustainable agriculture.[112] With some limitations, progress here can also be estimated from aggregate data on commodity production.

Both indicators 3.8a and 3.8b, below, were constructed using data from the Food and Agriculture Organization of the United Nations (FAO) food balance sheets, which comprises of national supply and utilization accounts of primary foods and processed commodities.[149]

Indicator 3.8.1: Total food supply for human consumption

Headline Finding: *Globally, total food supply has increased by 10%, from 2621 kcal/capita/day in 1990, to 2884 kcal/capita/day in 2013.*

Total food supply for human consumption (kcal/capita/day) indicates trends in food production, defining pressure on GHG emission intensity, and approximates trends in food energy availability, for human consumption.

[Please insert a brief (2-3 sentence) description of the data used for this indicator and the reference]

Overall food supply for human consumption has been increasing in most parts of the world, with notably flatter trends in Oceania and Europe, since the 1960s. (Figure 3.16) Average levels have been lower in Africa and Asia, and higher in the Americas, Europe, Oceania. Current levels are still below recommended levels of food energy intake in Africa and Asia, and in excess in the Americas, Europe, and Oceania, reflecting persistent inequality. This corresponds to inequality-related health outcomes across these regions, with the highest levels of child undernutrition in Africa and Asia, and higher prevalence of obesity in the Americas, Europe, and Oceania.[150-152] However, there are regional disparities and the prevalence of overweight and obesity is increasing globally: two thirds of the worlds' obese people now live in developing countries.

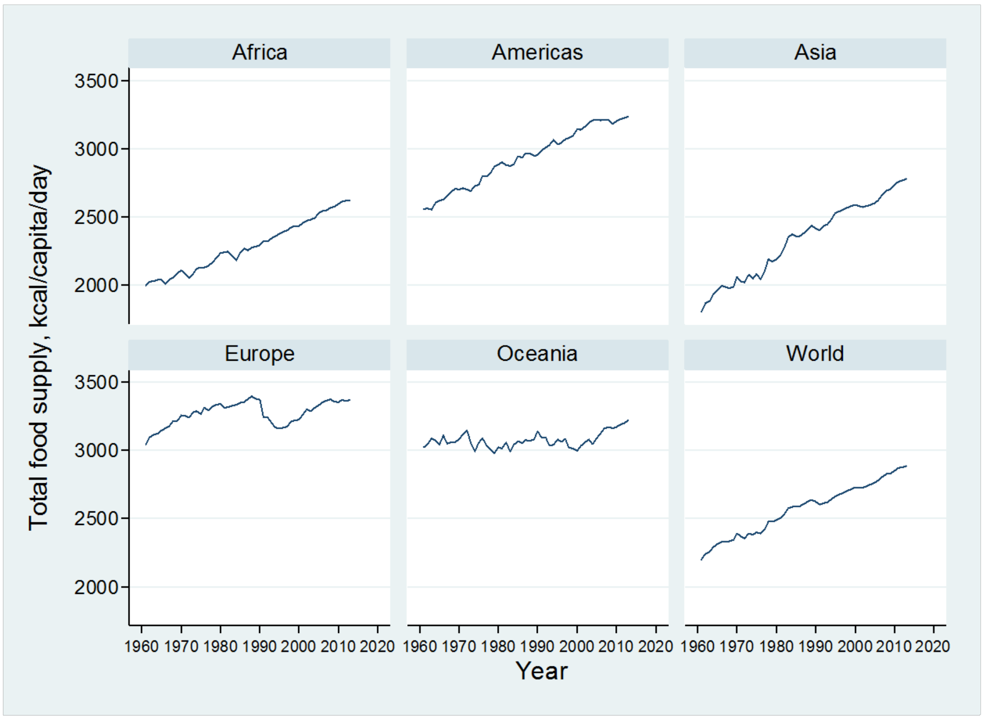

Figure 3.16 - Total food supply for human consumption (kcal/capita/d) by UN-defined regions.[150]

Indicator 3.8.2: Supply of ruminant meat for human consumption

Headline Finding: *Globally, ruminant meat consumption has been stagnant since 1960.*

Annual change in ruminant meat supply reflects trends in the production of the most impactful food group in terms of its GHG emissions[153-155] (Figure 3.17). Assuming correlation between ruminant meat supply and its consumption, the indicator will also inform on the health aspect of variations in diet (i.e. risk of colorectal cancer, or heart disease).[156,157] However, this should be viewed in relation to the context of any setting where this trend is examined, as in some populations, meat consumption is the only core food energy and provides essential micronutrients as well as livelihoods for pastoralist communities.

Ruminant meat supply for human consumption has been notably higher in Oceania than other regions since the 1960s, although the trend has been decreasing over time. By contrast, the trend has been increasing in Asia, possibly reflecting the increasing trend in beef consumption in China at a rate of 16% per annum.[152] In Europe, the trend has been increasing until 1995 and decreasing thereafter.

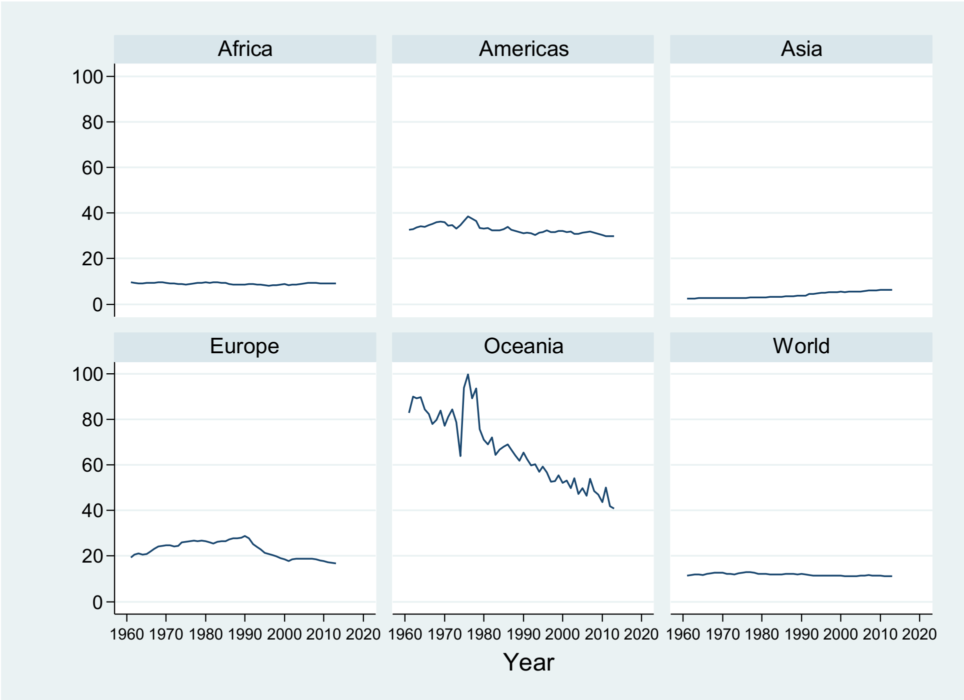

Figure 3.17. Ruminant meat supply for human consumption (kg/capita/year) by UN-defined regions.[150]

Future indicator development requires better quality data and closer examination of actual consumption patterns, identifying potential setting-specific shifts in diets towards more sustainable patterns as well as sophisticated analyses of GHG emissions along the food product life cycle.

Healthcare sector

The healthcare sector is a considerable contributor to GHG emissions, and has both a responsibility and an appreciable opportunity to lead by example in reducing its carbon footprint. In 2013 the estimated US health care sector emissions were 655 MtCo2e, which exceeded emissions of the entire UK.[158] GHG emissions in the health care sector illustrate an obvious externality which contributes to climate change, which contradicts the sector's aim of improving population health.

The World Bank estimates that a 25% reduction from existing healthcare emissions in Argentina, Brazil, China, India, Nepal, Philippines, and South Africa would equate to 116-194 million metric tons of CO2e emission reduction, in other terms equal to decommissioning of 34-56 coal fired power plants or removing 24-41 million passenger vehicles from the road.[158]

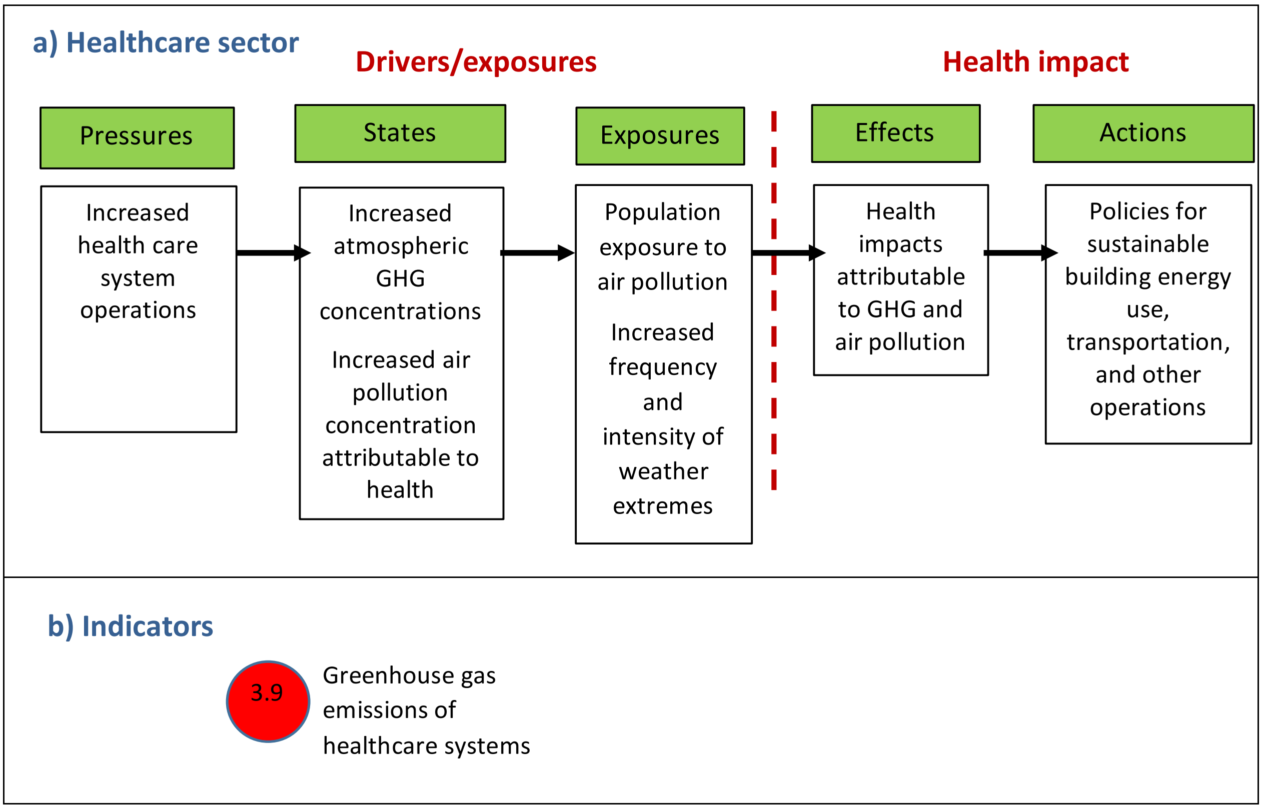

Figure 3.18. *3.18a) DPSEEA Framework applied to* Health *Sector. 3.18b)* Health *sector indicator within the DPSEEA framework. A simple traffic-light system has been used to provide a qualitative indication of global progress to-date, on each of the indicators.*

Indicator 3.9: Healthcare sector emissions

Several health sector emission reduction targets can be highlighted as positive examples. The National Health Service (NHS) in the UK set an ambitious target of 34% health-system wide GHG emission reduction by 2020; the Western Cape Government health system in South Africa committed to 10% emission reduction by 2020 and 30% by 2050 in government hospitals; and Albert Einstein Hospital in Sao Paulo, Brazil, is aiming to reduce its annual emissions by 41%.[158]

Monitoring healthcare system emissions is an essential step towards accounting for the externality of health sector emissions. Comprehensive national GHG emissions reporting by the healthcare systems is currently only routinely performed in the UK. Elsewhere, select healthcare organisations, facilities, and companies provide self-reported estimates of emissions, however this is rarely standardized across sites.

In the UK, comprehensive GHG emission reporting was facilitated by the centralized structure of the NHS. Sustainable Development Unit (SDU) of the NHS has been monitoring greenhouse gas emissions from a 1992 baseline. Due in large part to their work and many others, NHS emissions reduced by 11% from 2007 to 2015, despite an 18% increase in activity.[159] In 2015, GHG emission of the health care system represented 39% of public sector emissions in England.[160]

A future set of indicators would need to reflect country-wide GHG emissions of health care systems with denominators of the system size and volume of health care service provision. Indicators should be available at each level of policy and managerial decision-making to inform choices and facilitate the selection of policies and organizational operations with lowest GHG emission levels. Understanding the emissions-intensity of healthcare activities under varying contexts would potentially allow for 'top-down' national-level estimates, with countries grouped by region or income.

Conclusion

The indicators and analysis presented in this section have provided an overview of the current and historical mitigation ambitions relevant to public health for the energy, transport, food and healthcare sectors. They have been selected for their relevance to both climate change and to human health and wellbeing. The Lancet Countdown will work to develop these indicators for future reports, drawing closer attribution to both climate change mitigation, and to the health outcomes that results from these interventions.

The first section covered the negative health impacts of climate change, providing a strong imperative for accelerated action. To this end, a number of areas show remarkable promise – each of which are already yielding impressive benefits for human health. Globally, there is now more renewable energy generation capacity installed than there is for coal-related capacity, and the total power capacity of 'pre-construction' coal has halved from 2016 to 2017, reflecting potentially seismic shifts in global energy investment patterns. The transport sector, which has been historically slow to respond, is approaching a threshold. In late-2017/early-2018, electric vehicles are expected to reach cost-parity with their non-electric counterparts – a phenomena that wasn't expected to occur until 2030.

However, these positive examples must not distract from the enormity of the task at hand. The indicators presented in this section serve as a reminder of the scale and scope of increased ambition required to meet commitments under the Paris Agreement. They demonstrate a world which is only just beginning to respond to climate change, and hence only just unlocking the opportunities available for better health.

4. Finance & Economics

Introduction

Interventions to protect human health from climate change impacts have now been presented. , This section focuses on the economic and financial mechanisms necessary for them to be implemented. A number of the indicators here do not have an explicit link to human health, and yet, for example, investment in renewable energy and a declining investment in coal capacity is essential in displacing fossil fuels and reducing their two principal externalities – the social cost of carbon and the health costs from air pollution. Other indicators – those looking at valuing the health benefits of mitigation interventions, or economic and social losses from extreme weather events – have more explicit links to human wellbeing.

The landmark 2006 Stern Review on the Economics of Climate Change estimated that the impacts of climate change would cost the equivalent reducing annual global Gross World Product (GWP) – the sum of total global economic output – by "5-20% now, and forever", compared to a world without climate change.[161] The IPCC's AR5 estimates an aggregate loss of up to 2% GWP even if the rise in global mean temperatures is limited to 2.5°C above pre-industrial levels.[60] However, such estimates depend on a range of assumptions, such as the rate at which future costs and benefits are discounted, and derive from economic models built upon physical models that cannot fully characterise all the dynamic physical processes of importance.[162] Indeed, Weitzman concluded that due to the 'fat tails' of the climate-risk, and the uncertainty surrounding the potentially systemic effects of such high-risk phenomena (e.g. regional societal collapse, famine or widespread conflict), existing analytical approaches poorly suited to capture estimates of the economic impact, potentially drastically underestimating its effect.[163]

In the presence of such uncertainty, with potentially catastrophic outcomes, prevention will always be better that cure. The prescription is investment in a long-term course of low-emission infrastructure and activities, administered through enabling policy action. The nature of the side effects on the economy and social welfare this course of action produces will depend on the form of the low-emission infrastructure and activities adopted, and how these investments are made.

The indicators in this section, which seek to track flows of finance and impacts on the economy and social welfare resulting from (in)action on climate change, fall into three broad themes:

a) Investing in a Low-Carbon Economy

Significant investment in energy systems over time is required simply to maintain existing services (as infrastructures age and needs to be replaced), and to meet growing demand with access to modern energy services (in the case of emerging economies). An increasing proportion of this investment must be directed towards low-carbon energy, and energy-efficiency interventions, whilst investment in carbon-intensive sources must be minimized, to prevent high-carbon 'lock-in' and the risk of 'stranded assets' (see Box 4.1, below). The first two indicators under this theme track investment in renewable energy and energy efficiency, and investment in new coal-fired electricity generation capacity. The third and final indicator tracks the value of funds divested from fossil fuel assets, including by health institutions.

b) Economic Benefits of Tackling Climate Change

Action to tackle climate change may produce a wide range of economic benefits. These will be direct, such as reducing the risk of increasing human and economic loss from extremes of weather. The first indicator under this theme tracks the economic losses due to climate-related events. Benefits of action on climate change may also be indirect. This includes health-related co-benefits of mitigation action, such as a reduction in local pollution levels associated with the combustion of fossil fuels. The second indicator under this theme tracks the economic value of health-related co-benefits of mitigation action. Another indirect benefit is the emergence of new low-carbon industries and employment opportunities, and the decline of carbon intensive industries that may have negative impacts on human health. The third and final indicator under this theme tracks global employment levels in high- and low-carbon industries.

c) Pricing the GHG Emissions from Fossil Fuels

The Stern Review refers to the market externality of GHG emissions 'the greatest and widest-ranging market failure ever seen'.[Error! Bookmark not defined.] An economist's principal approach to tackling this is through GHG (or carbon) pricing. In addition, environmentally harmful subsidies to fossil fuels must be removed. The first two indicators under this theme track the global value of fossil fuel subsidies, and the global coverage of carbon pricing instruments including the weighted average global carbon price produced. The third and final indicator under this theme tracks the total revenue generated by carbon pricing instruments around the world, and how this revenue is used.

Corresponding Appendix 5 provide more detailed discussion of the data and methods used.

Indicator 4.1: Change in annual investments in renewable energy and energy efficiency

To be completed when 2016 data for this indicator will be available, during the first week of July (made available in advance of its scheduled publication date, for the Lancet Countdown), at which point, this will be added to the draft publication.

The combustion of fossil fuels for the production of energy is the principal source of anthropogenic CO_2 emissions (and other emissions with harmful consequences for human health) that lead to climate change. Transitioning to a low-carbon energy system through the rapid deployment of renewable energy and energy efficiency is therefore central to tackling climate change. This indicator tracks the level of global investment in renewable energy and energy efficiency in absolute terms, and as a proportion of total energy system investment. Figure 4.6 illustrates the data for 2015 and 2016.

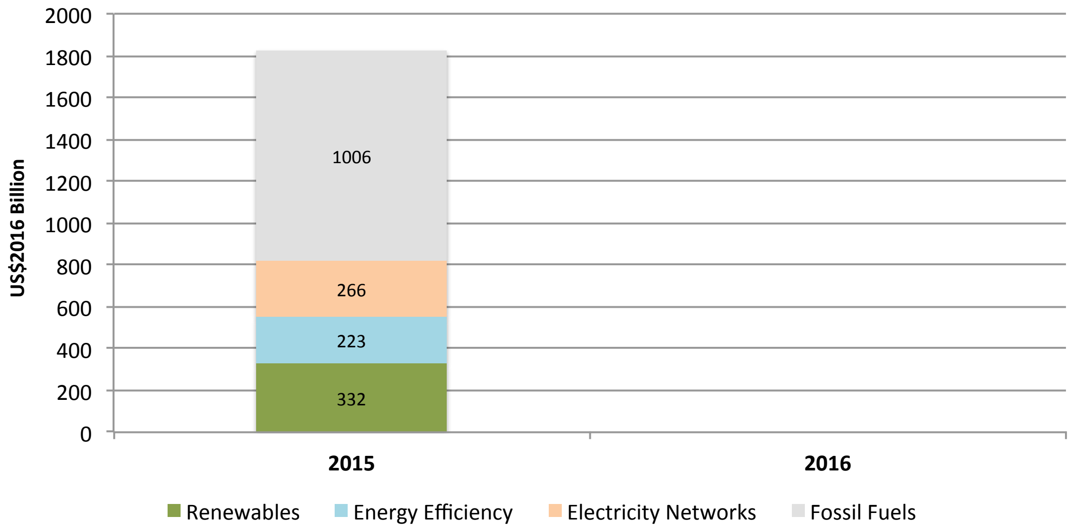

Figure 4.6. Annual Investment in the Global Energy System.[164].

Indicator 4.2: Change in annual investment in coal capacity

To be completed when 2016 data for this indicator will be available, during the first week of July (made available in advance of its scheduled publication date, for the Lancet Countdown), at which point, this will be added to the draft publication.

The combustion of coal is the most CO_2-intesive process for the generation of electricity, with coal-fired power stations responsible for a third of global CO_2 emissions in 2015.[165] In addition, air pollution from coal plants led to over 18,200 premature deaths, 8,500 new cases of chronic bronchitis and over 4 million lost working days in Europe in 2012 alone, producing an annual economic cost of up to €43 billion.[166] These numbers would increase dramatically if expanded to the global scale. A reduction in the use of coal for electricity generation should therefore be a priority for the low-carbon transition. This indicator tracks annual investment in new coal-fired power capacity in absolute terms, and as a proportion of total energy system investment.

Indicator 4.3: Value of funds divested from fossil fuels

Headline Finding: *Global Value of Funds Committing to Divestment in 2016was $1.24 trillion, of which Health Institutions represent $2.58 million; this represents a cumulative sum of $5.45 trillion (with health accounting for $859 billion)*

The fossil fuel divestment movement seeks to encourage institutions and investors to divest themselves of assets (including equity, stocks, bonds and other income-generating investments) involved in the extraction of fossil fuels. Proponents cite divestment as embodying both a moral purpose (e.g. reducing the fossil fuel industry's 'social licence to operate'), and an economic risk reduction strategy (e.g. through reducing the investor's exposure to the risk of 'stranded assets' – see Box 4.1). However, others believe active engagement between investors and fossil fuel businesses is a more appropriate course of action (e.g. the encouragement of diversification into less carbon-intensive assets, through stakeholder resolutions).[167]

Box 4.1. **The Low-Carbon Transition and Stranded Assets**

'Stranded assets' are assets which, at some point before the end of their economic life (as assumed when the initial investment was made), are no longer able to make an economic return as a result of changes in the market or regulatory environment.

If climate change is to be limited to 2°C, analysis by McGlade and Ekins suggests that a third of global oil reserves, half of natural gas and 80% of coal reserves must remain unused by 2050.[168] Such reserves would thus cease to hold any economic value. The IEA & IRENA estimate the cost incurred to 'prove up' these unburnable reserves (i.e. exploration costs) to be $520 billion for oil and gas alone.[94] In addition, Muttitt estimates that an additional $10.6 trillion in capital expenditure between 2014 and 2035 on developing oil and gas fields and coal mines may be at risk of stranding, with a further $3.9 trillion in transportation infrastructure (e.g. pipelines).[169] 'Downstream' fossil fuel assets are also at risk of stranding. For example, IEA & IRENA also project stranded assets of $320 billion by 2050 resulting from the closure of fossil fuel power stations before they are able to recover their capital investment.[Error! Bookmark not defined.]

This indicator tracks the global total value of funds committing to divestment in 2016, and the value of funds committed to divestment by health institutions in 2016, which was $1.24 trillion, and $2.58 million respectively.

The values presented above are calculated from data collected and provided by 350.org. They represent the total assets (or assets under management, AUM) for institutions that have committed to divest in 2016, and thus do not directly represent the sums divested from fossil fuel companies. 'Divestment' is defined relatively broadly, ranging from an organisation that has made a binding commitment to divest from coal companies only, to those who have fully divested themselves of any investments in fossil fuel companies and have committed to avoiding such investments in future. It also includes only those institutions for which such information is publicly available (or provided by the institution itself), with non-US$ values converted using the market exchange rate when the commitment was made. See Appendix 5 for more information.

Asset data is available for 93 of the 124 organisations, and for 1 of the 3 healthcare institutions (Chicago Medical Society) that committed to divestment in 2016. By the end of 2016, a total of 695 organisations with cumulative assets worth at least $5.45 trillion, including 11 health organisations with assets of at least $859 billion, had committed to divestment. From the start of January 2017 to the end of March 2017, a further 12 organisations (none of which were health organisations) with assets worth $46.87 billion joined this total. The vast majority of these organisations are educational institutions, faith-based organisations, local (city) government entities and philanthropic foundations, mostly based in the USA, Western and Northern Europe, and Australia.

Just 18 organisations recorded as committed to divestment above are 'for-profit' corporations (however, these account for $3.16 trillion (58%) of the total asset value presented above). Pension funds and other institutional investors (e.g. insurance companies), which in 2013 held assets under management worth $93 trillion in the OECD alone (larger than the sum of global economic output in that year - $76.8 trillion), also account for a small proportion of the organisations committed to divestment (12% at the end of 2016).[170,171] Institutional investors are substantial investors in fossil fuel companies, due to the historically substantial, yet stable returns generated.

Policy makers are increasingly keen to encourage (or require) institutional investors to properly assess and disclose their exposure to climate-related risk. In December 2015, the Financial Stability Board established the 'Task Force on Climate-Related Finance Disclosures', with the aim of developing financial risk assessment and disclosure approaches related to the physical, liability and transition risks associated with climate change. In 2016, the Task Force published their first set of recommendations to achieve this objective.[172] In January 2017, the European Union (EU) introduced the recast IORP ('Institutions for occupational retirement provision') Directive, which states that IORPs (pension funds) '…as part of their risk management system… should include…risks related to climate change…[and] to the depreciation of assets due to regulatory change ('stranded assets').[173]

It is expected that fossil fuel assets held by institutional and other investors will decrease to 2030, as associated risks increase and become more apparent, and action is subsequently taken to reduce risk exposure. For institutional investors, the evidence suggests that this is happening, with 60% of the world's 500 largest asset owners and managers (with $40 trillion in AUM) now taking active action to protect their portfolios from high-carbon risk (a rise from 50% in 2016).[174]

Indicator 4.4: Economic losses due to climate-related extreme events

***Headline Finding**: In 2016, a total of xxx events resulted in xxx billion in overall economic losses, and XX,XXX fatalities. XX% of these were uninsured in LICs.*

Climate change will continue to increase the frequency and severity of extreme weather events, including meteorological (e.g. tropical storms), climatological (e.g. droughts) and hydrological (e.g. flooding) phenomena, across the world. This indicator tracks the number of events and the total economic losses (insured and uninsured) resulting from such events. In addition to the health impacts of these events (discussed in the first section), economic losses (particularly uninsured losses) will have potentially devastating impacts on the wellbeing and mental health of those who incur them. Whether it is through reduced public funds available for healthcare, or the disruptions to livelihoods, shelter, adequate nutrition, or schooling and education, the economic impacts of extreme weather events undermine many of the social determinants of health.[175]

The data upon which this indicator is based is sourced from Munich Re.[176] Economic losses (insured and uninsured) refer to physical assets, and do not include the economic value of loss of life or ill health, or health and casualty insurance. Values are first denominated in local currency, converted to US$ using the market exchange rate in the month the event occurred, and inflated to US$2016 using country-specific Consumer Price Indices (CPI). This indicator and underlying data does not seek to attribute events and associated fatalities and economic losses to climate change. For further methodological details and tabulated data, see Appendix 5.

Error! Reference source not found. presents insured and uninsured economic losses (left axis) and total fatalities (right axis) resulting from all significant meteorological, climatological and hydrological events across the world, from 2010 to 2016, by country income group. An annual average of 700 events resulted in an average of 20,000 fatalities and $127 billion in overall economic losses per year over this timeframe. Upper-middle and high-income countries experienced around two-thirds of the recorded events. Around half of the total fatalities occurred within upper-middle income countries, and around a third in lower-middle income countries. The remainder occurred in approximately equal proportions between the highest and lowest income countries. However, around 90% of economic losses occurred in upper-middle and high-income countries, with <1% attributable to those of low-income. The same ratios for the number of events and economic losses between income groups is present in the data for the period 1990-2016, despite an increasing trend in the total global number of events and associated total value economic losses (in real terms) over this period.

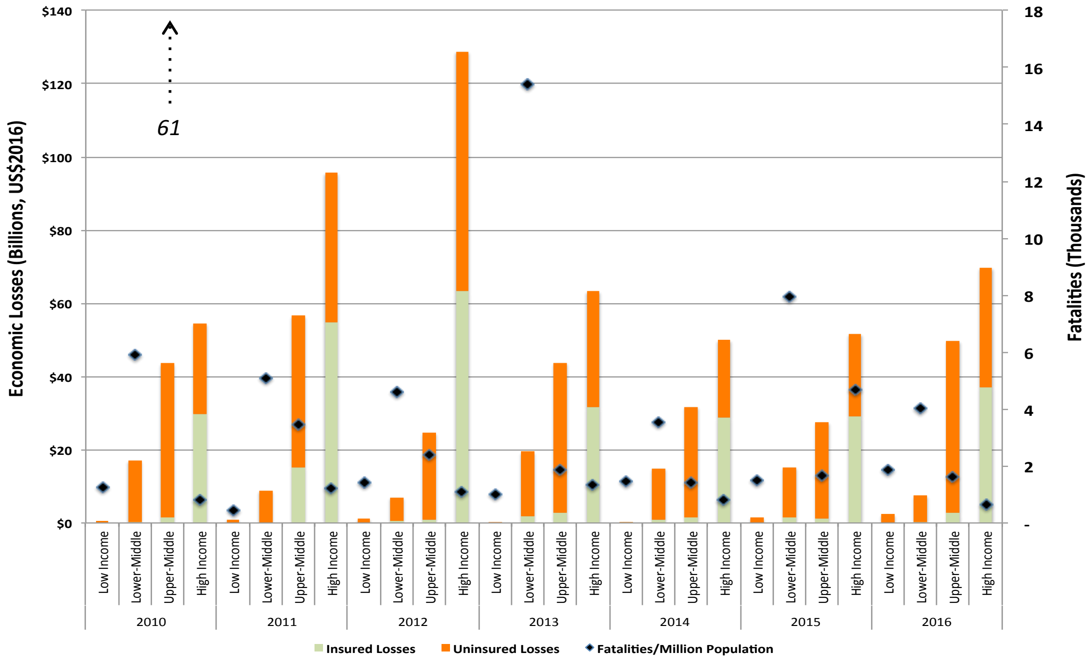

Figure 4.2. Economic Losses and Fatalities from Climate-Related Events – Absolute.[176]

However, the data as presented in **Error! Reference source not found.** does not indicate the relativity of impact across different income groups. For example, although the majority of fatalities and economic losses have occurred in upper-middle and high-income countries, these countries are among the most populous, with more economically valuable property and infrastructure (in absolute terms). Therefore, it might be expected that absolute fatalities and economic damages would be greatest in these countries (*ceteris paribus*). As such, **Error! Reference source not found.** presents the data in terms of 'intensity', i.e. and insured and uninsured economic losses per $1000 GDP (left axis, in US$2016), and fatalities per million population (right axis).

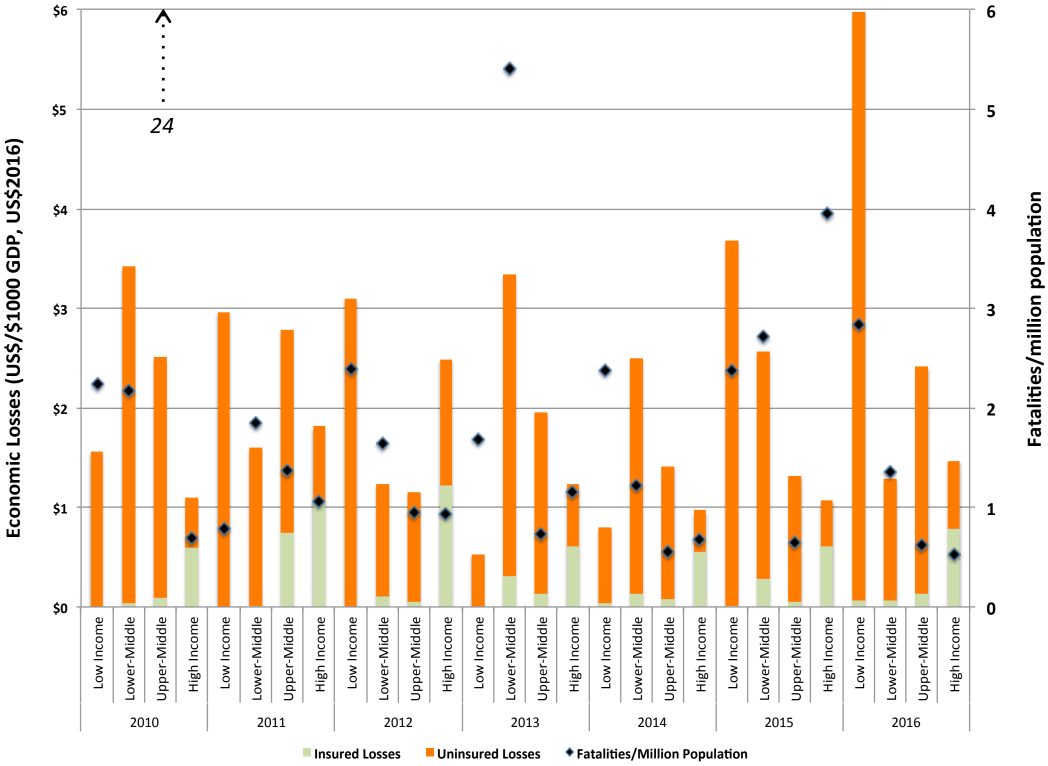

Figure 4.3. Economic Losses and fatalities from Climate-Related Events - Intensity.[176]

Between 2010 and 2016, high and upper-middle income countries experienced the least average annual economic loss as a proportion of GDP ($1.45/$1000 GDP and $1.95/$1000 GDP, respectively), with low and lower-middle income countries subject to higher, but relatively comparable values ($2.65/$1000 GDP and $2.3/$1000 GDP, respectively). However, for 1990-2016, average annual values vary substantially. Whilst high and upper-middle income countries maintain relatively similar values ($1.60/$1000 GDP and $2.9/$1000 GDP, respectively), economic losses experienced by (particularly) low and lower-middle income countries increase substantially (to $10.95/$1000 GDP and $4.22/$1000 GDP, respectively).

It is clear that on average, lower income countries tend to experience a higher fatality rate and economic loss as a proportion of GDP as a result of climate-related events than higher-income countries. However, a more striking result is the difference in the proportion of economic losses that are uninsured. In high-income countries, on average around half of economic losses experienced are insured. This drops rapidly to under 10% in upper-middle income countries, and to well under 1% in low-income countries. Over the period 1990-2016, uninsured losses in low-income countries were on average equivalent to over 1.5% of their GDP. For contrast, expenditure on healthcare in low-income countries on average for the period 1995-2015 was equivalent to 5.3% of GDP.[177]

Indicator 4.5: Valuing the health co-benefits of climate change mitigation

Air pollution data enabling the calculation of this indicator is to be provided by LSHTM/IIASA in the coming weeks.

The consequences for human health from the combustion of fossil fuels and climate change may be valued in economic terms. One part of the equation is the elements that directly impact the economy and economic activity, such as lost labour productivity and the cost of treating ill health. Another part is the value lost based on the monetary value individuals and society place on a healthy life and a high quality environment, which are diminished. As such, action to mitigate climate change and improve human health reduces this cost (against a baseline of 'no action'). This indicator places an economic value on the changes in health outcomes tracked by Indicator **3.5**.

Indicator 4.6: Employment in low-carbon and high-carbon industries

Headline Finding: *In 2016, global employment in renewable energy reached 9.8 million, with employment in fossil fuel extraction trending down, to 8.6 million.*

As the low-carbon transition gathers pace, high-carbon industries and jobs will decline. A clear example is seen in fossil fuel extraction. Some fossil fuel extraction activities, such as coal mining, have substantial impacts on human health. Coal mining accidents led to over 1,000 deaths in 2008 in China alone (a rapid decline from nearly 5,000 in 2003), with exposure to particulate matter and harmful pollutants responsible for elevated levels of cardiovascular, respiratory and kidney disease, in coal mining areas.[178-181] The low-carbon transition is also likely to stimulate the growth of new industries and employment opportunities. With appropriate planning and policy, the transition from employment in high-carbon to low-carbon industries will yield positive consequences for human health.

This indicator tracks global employment levels in fossil fuel extraction industries (coal mining and oil and gas exploration and production), and in renewable energy. **Error! Reference source not found.** presents these values for 2012-2016 (see Appendix 5 for tabulated data). The data for this indicator is sourced from IRENA (renewables), and IBIS World (fossil fuel extraction).[Error! Bookmark not defined.,Error! Bookmark not defined.,Error! Bookmark not defined.]

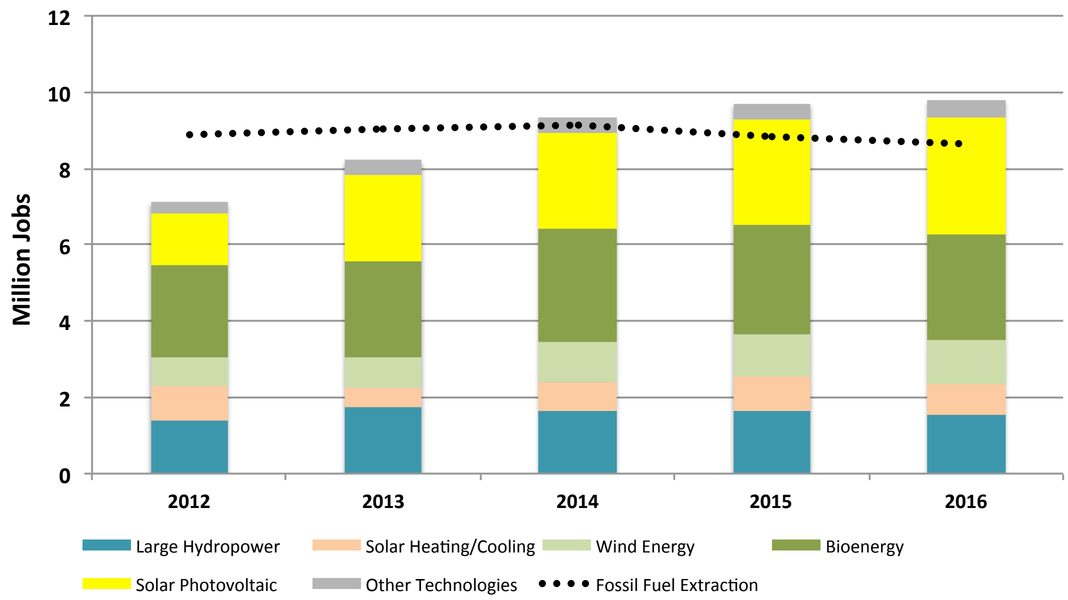

Figure 4.4. Employment in Renewable Energy and Fossil Fuel Extraction[182-184]

From a peak of 9.1 million in 2014, global fossil fuel extraction industry jobs reduced by around 250,000 to 2016 (to 8.6 million). This was driven by a reduction of over 700,000 jobs in the coal mining industry, offset by an increase of 500,000 in the oil and gas industry. The decline in the coal industry is the result of a range of factors, including the substitution for lower-cost natural gas in the power sector in many countries reducing the demand for coal and leading to overcapacity, industry consolidation, and the rising automation of extractive activities.[Error! Bookmark not defined.] Whilst delivering a low-carbon transition, it is clearly important to ensure that individuals and communities do not experience protracted economic or employment hardship.

By contrast, employment in the renewable energy industry increased rapidly from over 7.1 million jobs in 2012 to over 9.3 million in 2014, and reaching 9.8 million in 2016. This growth has largely been driven by the solar photo voltaic (PV) industry, which added over 1.7 million jobs between 2012 and 2016. Solar PV is now the largest renewable energy employer, overtaking bioenergy, which has experienced a reduction in 250,000 jobs since 2012.

For employment in both fossil fuel extraction and renewables industries the trend to 2030 will depend on a range of factors, including the change in demand for energy, the relative cost of generating energy by fossil fuels and renewables, climate and energy policy, and the spread of automation in key processes. Broadly, it would be expected (and desired) that the trends illustrated in **Error! Reference source not found.** continue.

Indicator 4.7: Fossil fuel subsidies

Headline Finding: *In 2015, fossil fuel consumption subsidies followed a trend seen since 2012, decreasing markedly to $327 billion, principally as a result of declining global oil prices.*

The combustion of fossil fuels results in a variety of harmful consequences for human health, from climate change and air pollution, to potentially dangerous employment involved in their extraction (discussed under Indicator 4.6). The presence of subsidies for fossil fuels, either for its production (e.g. fossil fuel extraction) or consumption (e.g. regulated gasoline prices), artificially lowers their price, promoting overconsumption. This indicator tracks the global value of fossil fuel consumption subsidies. 4.5 illustrates the value of fossil fuel consumption subsidies for 2010-2016 (tabulated in Appendix 5 by product and country for 2012-2016).

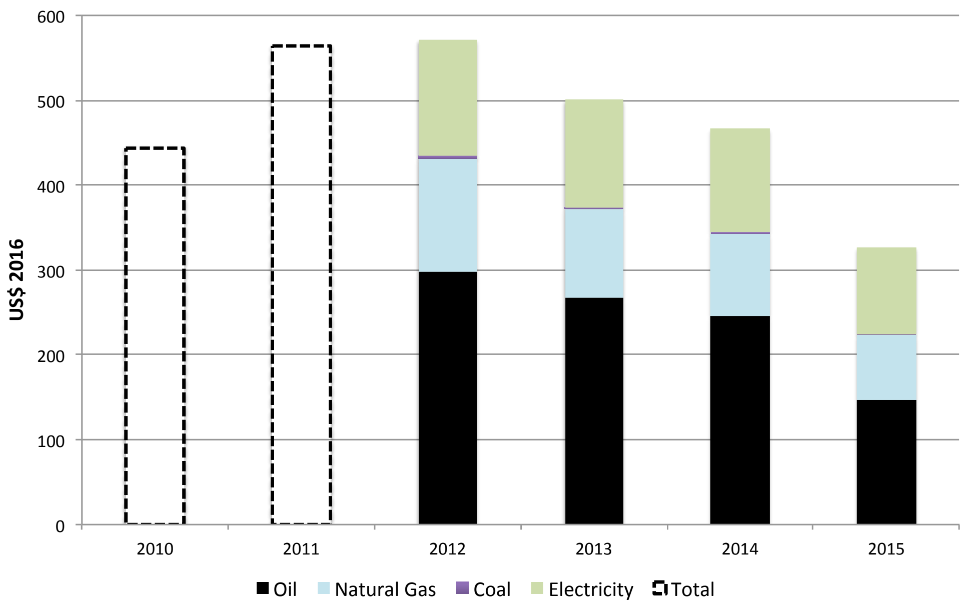

Figure 4.5. Global Fossil Fuel Consumption Subsidies - 2010-2015.[185,186]

Despite rising from $444 billion in 2010 to a peak of $571 billion in 2012, fossil fuel consumption subsidies have decreased markedly to $327 billion in 2015 (in US$2016). The principal driver for this is the change in oil price, which approximately doubled between 2010 and 2012, after which it plateaued, before falling rapidly to below 2010 levels from mid-2014. Fossil fuel consumption subsidies are typically applied in order to moderate energy costs for low-income consumers (although in practice, 65% of such subsidies in developing countries benefit the wealthiest 40% of the population).[187] As such, rising oil (and other fossil fuel) prices will tend to increase subsidy levels, as the differences between market and regulated consumer prices widen, and governments take further action to mitigate the impact on citizens. When fossil fuel prices decrease, the gap between market and regulated prices reduces, and governments are able to reform fossil fuel subsidies whilst keeping overall prices relatively constant.

Between 2014 and 2015 a number of countries took advantage of this opportunity, particularly regarding oil-based fuels, which accounted for over 60% of the reduction in total fossil fuel subsidisation between 2012 and 2015 (followed by natural gas, which often mirrors trends in oil prices, at around 25%). This included India, which in deregulating diesel prices accounted for a $19 billion subsidy reduction between 2014 and 2015 (~13% of the global total reduction), and the major oil and natural gas producing nations (e.g. Angola, Algeria, Indonesia, Iran, Qatar, Saudi Arabia and Venezuela), in which reduced hydrocarbon revenue created pressure for fiscal consolidation, and in turn for consumption subsidy reform.[Error! Bookmark not defined.]

However, it is clear that fossil fuel consumption is still subsidised to a substantial degree. Despite subsidy reforms, Iran provided the greatest subsidy at over $53 billion in 2015, - a rate of $662 per capita (and equivalent to 13.5% of its GDP). ***Compare to renewable investment levels when data received.***

The data for this indicator is provided by the IEA, and has then been calculated using the price-gap approach, for 42 mostly non-OECD countries (see Appendix 5 for further details). Fossil fuel production subsidies and consumption subsidies for most OECD countries are not included, due to the lack of consistent data. However, the vast majority of fossil fuel subsidies are consumer subsidies in non-OECD countries. In 2014, consumer subsidies in OECD countries were worth less than 14% of the non-OECD value presented in , with producer subsidies worth around 4%.[188] As such, the indicator presented provides a suitable overview of global trends in fossil fuel subsidies.

To encourage the low-carbon transition, fossil fuel subsidies should be phased out as soon as possible. The commitment made by the G7 in 2016 to achieve this goal by 2025 should be extended to all OECD counties, and to all countries globally by 2030.[189]

Indicator 4.8: Coverage and strength of carbon pricing

Headline Finding: *In 2017, various carbon pricing mechanisms provided coverage for 13.1% of global anthropogenic CO_2 emissions, up from 12.1% in 2016. This reflects a doubling in the number of national and sub-national jurisdictions with a carbon pricing mechanism over the last decade.*

This indicator tracks the extent to which carbon pricing instruments are applied around to the world as a proportion of total GHG emissions, and the weighted average carbon price such instruments provide (**Error! Reference source not found.** – see Appendix 5 for further details).

	2016	2017
Global Emissions Coverage*	12.1%	13.1%
Weighted Average Carbon Price of Instruments (*current prices, US$*)	$7.79	$8.81
Global Weighted Average Carbon Price (*current prices, US$*)	$0.94	$1.12

Table 4.1. Carbon Pricing - Global Coverage and Weighted Average Prices. *Global emissions coverage is based on 2012 total anthropogenic CO_2 emissions (see Appendix 5 for further details)[190]

Between 2016 and 2017 the proportion of global emissions covered by carbon pricing instruments, and the weighted average price of these instruments (and thus the global weighted average price for all anthropogenic GHG emissions), increased. This is due to the introduction of four new instruments in 2017 - the carbon taxes in Alberta, Chile and Colombia, and an Emissions Trading System (ETS) in Ontario. As such, over 40 national and 25 sub-national jurisdictions now put a price on at least some of their GHG emissions (with substantially varying prices, from less than $1 in Chongqing, to over $126 in Sweden). The last decade has seen a rapid increase in the number of carbon pricing instruments around the world, with the number of jurisdictions introducing them doubling over this time.[191] Over 75% of the GHG emissions covered by carbon pricing instruments are in high-income countries, with the majority of the remainder covered by the 8 pilot pricing instruments in China.

The World Bank provides the data for this indicator.[190,191] Prices for 2016 and 2017 are those as of 1st August 2016 and 1st April 2017, respectively. For 2017, the indicator includes only instruments that had been introduced by 1st April 2017. Baseline-and-credit systems are excluded. See Appendix 5 for further details.

It is expected that the number of carbon pricing instruments, and thus the global emissions coverage and global weighted average price, will continue to grow as policy makers seek to operationalise their commitments to emission reductions. **Error! Reference source not found.** illustrates carbon pricing instruments already implemented, those scheduled for implementation, and those under consideration.

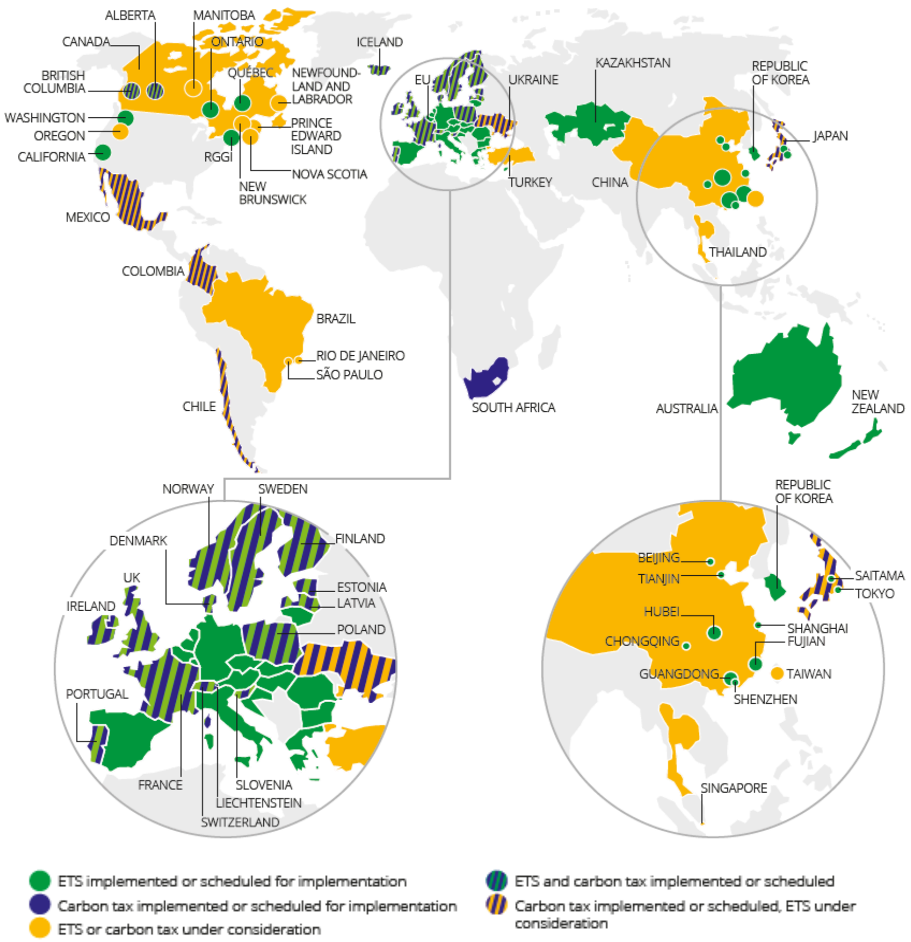

Figure 4.6. Carbon Pricing Instruments implemented, scheduled for implementation and under consideration[191]

In total, a further 21 carbon pricing instruments are either scheduled for implementation, or are under consideration. This includes the commencement of a national ETS in China in the second half of 2017. Although this would replace the 8 pilot schemes currently in place in China, it could expand their emissions coverage fourfold, surpassing the European ETS to become the largest carbon pricing instrument in the world.[Error! Bookmark not defined.] Such an increase in emissions coverage should continue to 2030, and be accompanied by increasing prices in both new and existing instruments, in order to properly incentivise a switch in investments in high-carbon to low-carbon assets and behaviours.

Indicator 4.9: Use of carbon pricing revenues

To be completed when the rest of the data has been received. 2016 data for this indicator will be available during the first week of July (made available in advance of its scheduled publication date, for the Lancet Countdown), at which point, this will be added to the draft publication.

Carbon pricing instruments require those responsible for producing the emissions concerned to pay for the ability to do, so in one form or another. In most cases this generates revenue for the governments or authorities responsible for introducing the instrument. Such revenues may be put to a range of uses, including investment in climate change mitigation or adaptation or environmental tax reform (ETR), which involves shifting the burden of tax from positive activities, such as labour or environmentally beneficial products or activities, to negative activities, such as the generation of pollution. Such options may produce a 'double dividend' of environmental improvement with social and economic benefits.[192] This indicator tracks the total government revenue from carbon pricing instruments, and how such income is allocated.

Conclusions

To be completed when most indicators are completed.

5. Public and Political Engagement

Introduction

So far, this report has presented indicators on a number of the direct and indirect health impacts of climate hazards; elucidated levels of resilience and adaptation among populations and health systems to climate change; demonstrated the health co-benefits of climate change mitigation; and highlighted the importance of economics and finance in facilitating a transition to a low-carbon economy.

Policy change requires public support and government action. This is particularly true of policies with the reach and impact to enable societies to transition to a low-carbon future.[193] The overarching theme of this section is therefore the importance of public and political engagement in addressing health and climate change, and the consequent need for indicators that track engagement in the public and political domains. To date, most evidence on public and political engagement focuses either on health or climate change, with very little attention given to these as combined issues, and with most evidence deriving primarily from cross-sectional studies in high-income countries.[194] The indicators presented are thus opening an important new field in which existing research is limited and international data sparse.

The aim is to track engagement with health and climate change in the public and political domains and identify trends since 2007. In selecting indicators, priority was given to high-level indicators which can be measured globally, tracked over time and provide a platform for more detailed analysis in future Lancet Countdown reports. The indicators relate to coverage of health and climate change in the media, science, and government. Search terms for the indicators are aligned, with analyses based on a common set of health-related and climate-related terms, and a common time-period was selected for all indicators: 2007-2016. The period runs from before the resolution on health and climate change by the 2008 World Health Assembly, which marked a watershed in global engagement in health and climate change; for the first time, member states of the UN made a multilateral commitment to protect human health from climate change.[195]

The indicators presented in this section are:

- 5.1. Media coverage of health and climate change
- 5.2. Coverage of health and climate change in scientific journals
- 5.3. Engagement with health and climate change in political statements in the United Nations General Assembly

Corresponding Appendix 6 provide more detailed discussion of the data and methods used.

Arguably, the final section of the Lancet Countdown is the most important, insofar as it provides the broader context within which all the other indicators operate. This echoes back to one of the key messages of the 2015 Lancet Commission, that “achieving a decarbonised global economy and securing the public health benefits it offers is longer primarily a technical or economic question – it is now a political one”.[7]p2. Future indicators beyond those in the 2017 report may include measures of health and climate change legislation; direct measures of public opinion; levels of private-sector engagement; and the extent to which health is explicitly captured in the UNFCCC negotiations. This full complement of eventual indicators will provide a robust understanding of the context within which all of the other indicators are operating, and the political barriers and enablers.

The mass media is an increasingly important part of everyday life and has been identified as a major component of the politics of climate change.[196] News media producers have shifted to multi-media news platforms (from print to multiple print, online and mobile formats), a process facilitated by recycling of content across platforms.[197] Consequently, while the public is increasingly accessing information from non-print media, it is often similar to and repurposed from print media.[198] The first indicator tracks coverage of health and climate change in major national newspapers, many of which have associated multi-platform formats. An analysis of a set of English and Spanish language newspapers provides a broad overview of global media coverage, complemented by in-depth analysis of two national newspapers. The media plays a key role in the public understanding of health and climate change, by communicating scientific developments and evidence. The second indicator focuses directly on the scientific sphere, tracking scientific engagement with health and climate change, providing important insights into the expertise in this field.

Surveys point to widespread concern about climate change and its health-related risks, including weather-related exposures (drought, water shortages, floods and intense storms), agricultural impacts and food.[199-201] Largely, the public sees the main responsibility for action lying with governments and other powerful institutions and most believe that their country has a responsibility to take action on climate change.[199,202] In most countries, people believe their government is not doing enough.[200,203] The final indicator shows high-level government engagement with health and climate change, by tracking references to health and climate change in the statements made by governments at the annual General Debate (GD) of the United Nations General Assembly (UNGA). The GD is a unique international forum that provides all UN member states with the opportunity to address the UNGA on issues they consider important.[204] These government UNGA statements therefore provide a measure of the salience of climate change and health for governments globally.

Indicator 5.1: Media coverage of health and climate change

Headline Finding: Global newspaper coverage has increased 78% overall since 2007, with marked spikes in 2009 and 2015, coinciding with COP15 and COP21.

The media plays a crucial role in communicating risks associated with climate change.[205] Knowledge about climate change (for example, an appreciation of the anthropogenic causes of climate change) is related to perceptions of climate change risk and intentions to act on climate change.[206,207] Public perceptions of a nation's values and identity (for example, as a country that values nature and the environment) are also an important influence on public support for national action.[208] Indicator 5.1 will therefore track media coverage of health and climate change, with a global indicator on newspaper coverage on health and climate change (5.1.1), complemented by an in-depth analysis of the nature of newspaper coverage on health and climate change for two national newspapers (5.1.2).

5.1.1. Global newspaper reporting on health and climate change

Media serves as a critical input to what becomes individual to collective public discourse on contemporary climate challenges. Focusing on English-language and Spanish-language newspapers, this indicator tracks global coverage of climate change and health in high-circulation national newspapers from 2007 to 2016. Using 18 high-circulation 'tracker' newspapers, global trends are shown and disaggregated regionally (Asia, Europe, N America, Oceania, S. America) to provide a global indicator of public exposure to news coverage of climate change and health.

Since 2007, global newspaper coverage of health and climate change has risen globally by 78% (Figure 5.1). However, this trend is largely driven by Asian newspapers, which dominate the global trend. Although this is mostly due to the higher number of Asian newspapers included in this analysis, the Asian newspapers here did have a higher than average coverage of health and climate change than other regions. For the Middle East, North America, and Oceania, there is not a strong trend in the media reporting. Some spikes are notable in 2009 in Europe, which is largely maintained for the rest of the time series, and South America, which drops until a secondary spike between 2012 and 2014. The first major spike globally was in 2009; coinciding with COP15 in Copenhagen, for which there was high expectation. Newspaper reporting then dropped around 2010, but since 2011 has been rising overall globally. This indicates that interest in the links between health and climate change has increased.

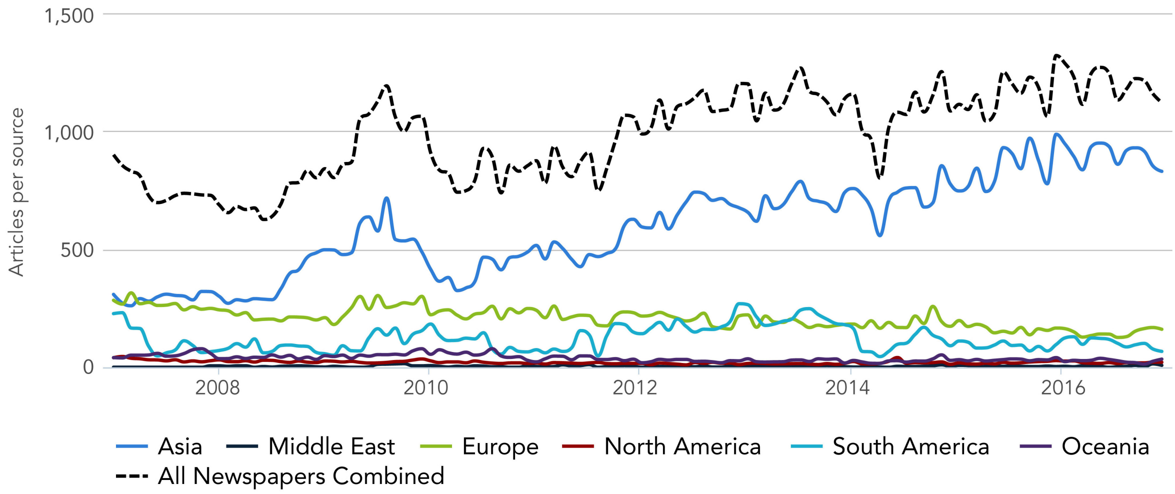

Figure 5.1. Newspaper reporting on health and climate change (for 18 newspapers) from 2007 to 2016, broken down by region.

Data was assembled by accessing archives through the Lexis Nexis, Proquest and Factiva databases. These sources were selected through the weighting of four main factors: (1) geographical diversity (favouring a greater geographical range), (2) circulation (favouring higher circulating publications), (3) national sources (rather than local/regional), and (4) reliable access to archives over time (favouring those accessible consistently for longer periods). Search terms were aligned to those used for our indicators of scientific and political engagement and searches, with Boolean searches done in English and Spanish (please see Appendix 6 for details).

There are some cautions with these findings. With this extensive Boolean string, there may be some returns that do not centrally address climate change and health together, but rather just mention them. Also, in working with newspapers, as opposed to say UN communications/documents, a narrower or more tailored approach might more effectively reduce the possibilities for false positives in the dataset. However, for consistency with the other indicators in this section, the searches were done with the established terms across the indicators. Furthermore, the results are skewed by the higher proportion of Asian newspapers, and Oceania newspapers only capture Australia and New Zealand newspaper coverage.

5.1.2. In-depth analysis of newspaper coverage on health and climate change

The second part of this indicator provides an analysis of two major national newspapers; Le Monde (France) and Frankfurter Allgemeine Zeitung (FAZ) (Germany), are reported. The analysis has shown that coverage of health and climate change increased markedly from 2007 to 2016 but the trend is non-linear. Peaks of coverage coincide with key global events in climate change action: COP13 in Bali (2007), COP15 in Copenhagen (2009) and COP21 in Paris (2015). Despite this increase in reporting, the health dimensions of climate change were covered in only a small proportion of articles on climate change. Furthermore, out of all articles on climate change, only 5% mentioned the links between health and climate change in Le Monde and just 2% in FAZ. There were also important national differences in how health and climate change were reported on. In France, 70% health and climate change was represented as an environmental issue (with a predominance of references to the planet), whereas in Germany articles have mixed references to the economy (23%), local news (20%) and politics (17%). Suggested policy responses also differed; in Le Monde, the emphasis was on adaptation strategies (41% of articles), while FAZ put more emphasis on the mitigation of greenhouse gas emissions (40% of articles). The co-benefits that public health policies can represent for mitigation were mentioned by 17% of Le Monde articles and 9% of FAZ articles. In terms of the tone of the articles (i.e. how they reported on climate change), the highest number of articles in Le Monde and FAZ reported on health and climate change neutrally (44% and 49%, respectively); the negative aspects of health and climate change were the next highest (32% Le Monde and 19% FAZ) (see Appendix 6 for more details). This highlights the variety in the content of articles on health and climate change in Le Monde and FAZ, which has important implications for the issues the public are most engaged with.

The analysis used online databases, holding both printed and online versions of Le Monde and FAZ, and was conducted in two stages. Potential articles related to health and climate change were captured through an initial search, a more detailed keyword search within each text then identified articles linking health and climate change. This second stage also collected information on the framing of health and climate change (for instance, as an environmental or economic issue), potential policy responses and co-benefits. The tracking analysis relied on a consistent set of search terms for the two newspapers, but this may have introduced a linguistic bias. Furthermore, only two newspapers were analysed here and so the findings here cannot be used to indicate the nature of newspaper coverage on health and climate change globally, or even regionally.

Indicator 5.2: Coverage of health and climate change in scientific journals

Headline Finding*: Since 2007, the number of scientific papers on health and climate change has increased by more than three times.*

Science is critical to increasing public and political understanding of the links between climate change and health; informing mitigation strategies; and accelerating the transition to low-carbon societies.[209,210] This indicator, showing scientific engagement with health and climate change, tracks the volume of peer-reviewed publications in English-language journals from PubMed and Web of Science. The results here show there has been a marked increase in published research on health and climate change in the last decade, during which time the number of scientific papers rose threefold, from 94 in 2007 to over 300 published in 2015, and in 2016. Within this overall upward trend, the volume of scientific papers increased particularly rapidly from 2007-2009 and from 2012, with a plateauing between these periods (Figure 5.2).

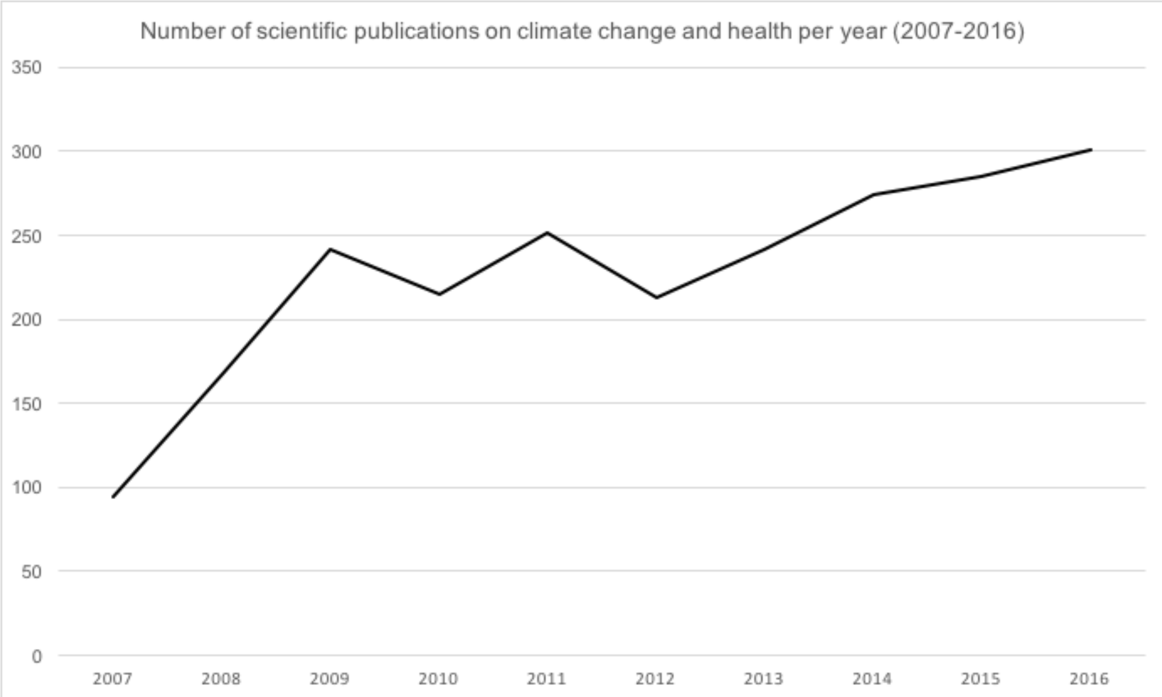

Figure 5.2. Number of scientific publication on climate change and health per year (2007-2016) from PubMed and Web of Science journals.

The two periods of growth in scientific outputs coincided with the run-up to the UNFCCC Conference of the Parties (COP) held in Copenhagen in 2009 (COP15) and in Paris in 2015 (COP21). This pattern suggests that scientific and political engagement in health and climate change are closely linked, with the scientific community responding quickly to the global climate change agenda and the need for evidence.

Most publications focus on the impacts of climate change and health in Europe and North America. Overall, more than 2000 scientific articles were identified, of which 30% papers focussed on Europe, followed by 29% on the Americas. Within the Americas, the large majority (72%) of the papers related to health and climate change in North America (see Figure S5.1 in Appendix 6). By contrast, only 10% of published articles had a focus on Africa or on the Eastern Mediterranean Region, demonstrating a marked global inequality in science of health and climate change (see Figures S5.1 and S5.2 in Appendix 6). While most of the evidence relates to the high-income countries that have contributed most to climate change, the consequences of climate change will disproportionately fall on LMICs.

Among reported journals, infectious diseases are strongly represented in the health outcomes of climate change. Infectious diseases, particularly dengue fever and other mosquito-transmitted infections, are the most frequently investigated health outcomes; approximately 30% of selected papers covered these health-related issues. Important gaps in the scientific evidence base were identified, including migration and mental ill-health.

This indicator points to the rapid growth of research on health and climate change across the last decade. Investing in science is integral to addressing the threats posed by climate change to human health, with research helping to inform and monitor investments in climate adaptation and mitigation strategies. The tracking of scientific publications on climate change and health can also help in identifying research gaps and, thereby, informing an equity-oriented research agenda to protect global health in the face of a rapidly changing climate.

For this indicator, a scoping review of peer-reviewed articles on health and climate change, published in English between 2007 and 2016, was conducted; an appropriate approach for broad and inter-disciplinary research fields.[211] Two databases were used, PubMed and Web of Science, to identify papers through a bibliometric analysis using keyword searches.[212] Inclusion and exclusion criteria were applied to capture the most relevant literature on the human health impacts of climate change within the chosen timeframe and papers were independently reviewed and screened three times to identify relevant publications.[213]

From 2012, the trend in scientific publications has been consistently upward. To sustain global efforts to address health and climate change, this trend should continue and accelerate. While the COPs in 2009 and 2015 instigated increased scientific engagement in health and climate change, the continuing upward trend points to deeper shifts in scientific activity. Changes in the strategies and priorities of research funders are likely to be facilitating this process, which suggests scientific engagement with health and climate should continue growing. Funders' strategies will be integral to addressing the inequalities in the global distribution of research identified here. These inequalities are likely to remain pronounced in the short-term, requiring sustained changes in priorities of research national and global funders to address these disparities.

Indicator 5.3: Engagement with health and climate change in political statements in the United Nations General Assembly

Headline Finding*: There is no overall trend in UNGD references to health and climate change, but two significant and expected peaks occur in 2009 and 2014.*

The GD takes place every September at the start of each new session of the UNGA. Governments use their annual statements to present their perspective on events and issues they consider the most important in global politics, and to call for greater action from the international community. All UN Member States can address the UNGA, free from external constraints. Therefore, GD statements provide an ideal data source on political engagement with health and climate change, which is comparable spatially and temporally. The indicator captures the extent to which governments prioritise health and climate change in relation to other issues in world politics. The analysis of UNGD statements focuses on the extent to which governments refer to linkages between health and climate change issues in their annual statements in the GD. Initially, this analysis was considered for UNFCCC statements too, but favour was given to UNGD statements, as these are open to any political issue; as such, the reference to health and climate change within these statements provides a stronger indicator of the level of political engagement with health and climate change. Furthermore, it allows the analysis of trends associated with external influences, such as significant UNFCCC COPs.

Health and climate change are issues frequently raised in UNGD statements. However, statements less frequently link health and climate change together. Across the 2007 to 2016 period, linked references to health and climate change in the annual UNGD ranged from 44 to 124 (Figure 5.3). The comparable figures for references to climate change alone were 378 and 989. It was found that there is no overall trend in conjoint references to health and climate change across the period (Figure 5.3), in contrast to clear trends in scientific engagement and media coverage of health and climate change.

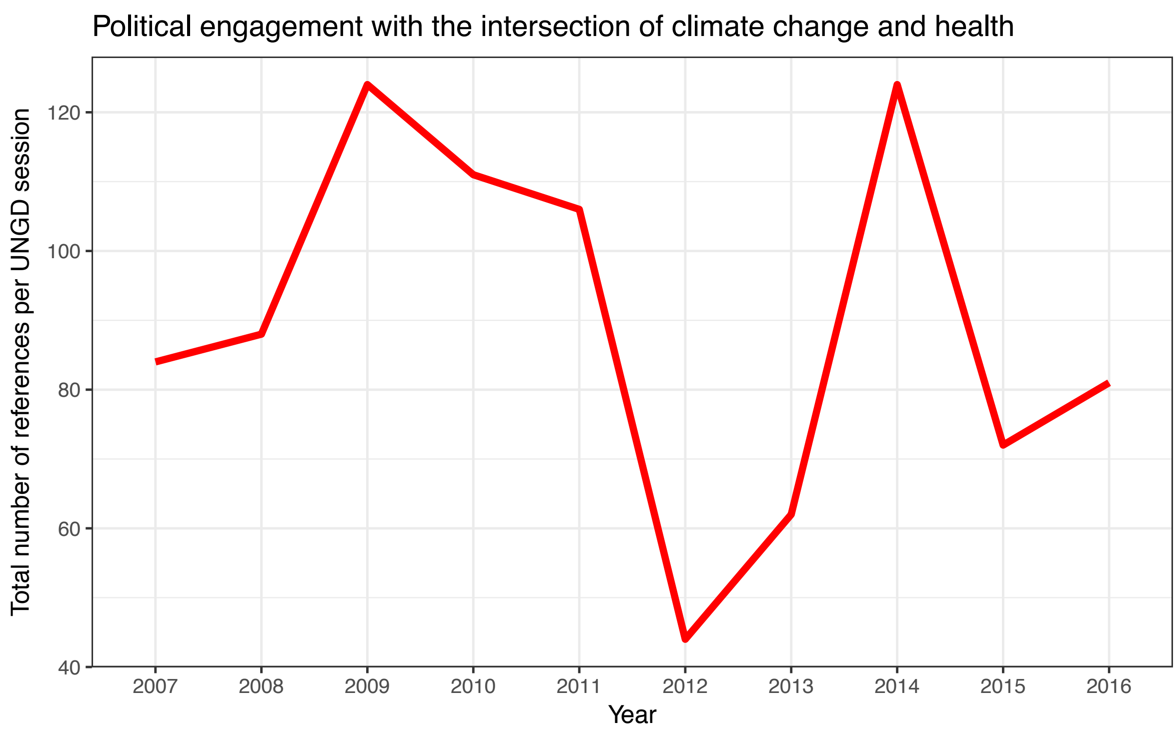

Figure 5.3. Political engagement with the intersection of health and climate change, represented by joint references to health and climate change in the UNGD.

While no overall trend is apparent, there are two distinct peaks; these occurred between 2009 and 2011 and in 2014. In both 2009 and 2014, there were 124 references linking health and climate change in the GD statements (Figure 5.3). The 2009 peak occurred after the 2008 World Health Day, which focussed on health and climate change, and in build-up to COP15 in Copenhagen in 2009. The 2014 peak is indicative of the influence of the large UNGA on climate change in 2014 and the lead up to COP21 in Paris in 2015. After 2014, conjoint references to health and climate change declined, but notably references to health and climate change linkages in 2015 and 2016 were particularly made in the context of 'natural disasters', with a number of UNGD statements making direct reference to the Sendai Framework for Disaster Risk Reduction.[214]

This irregular pattern points to the importance of key events in the global governance of health and climate change in driving high-level political engagement. The pattern of references to climate change alone (i.e. without linked references to health) again suggest the importance of global institutions and the UN particularly.

There are country-level differences in the attention given to health and climate change in UNGD statements (Figure 5.4). More frequent reference is made to the issue by countries in the Americas and Oceania, particularly by the SIDS in these regions, a noteworthy pattern given the relatively fewer UN member states in Oceania. In contrast, governments in Asia and Europe tend to make fewer references to health and climate change.

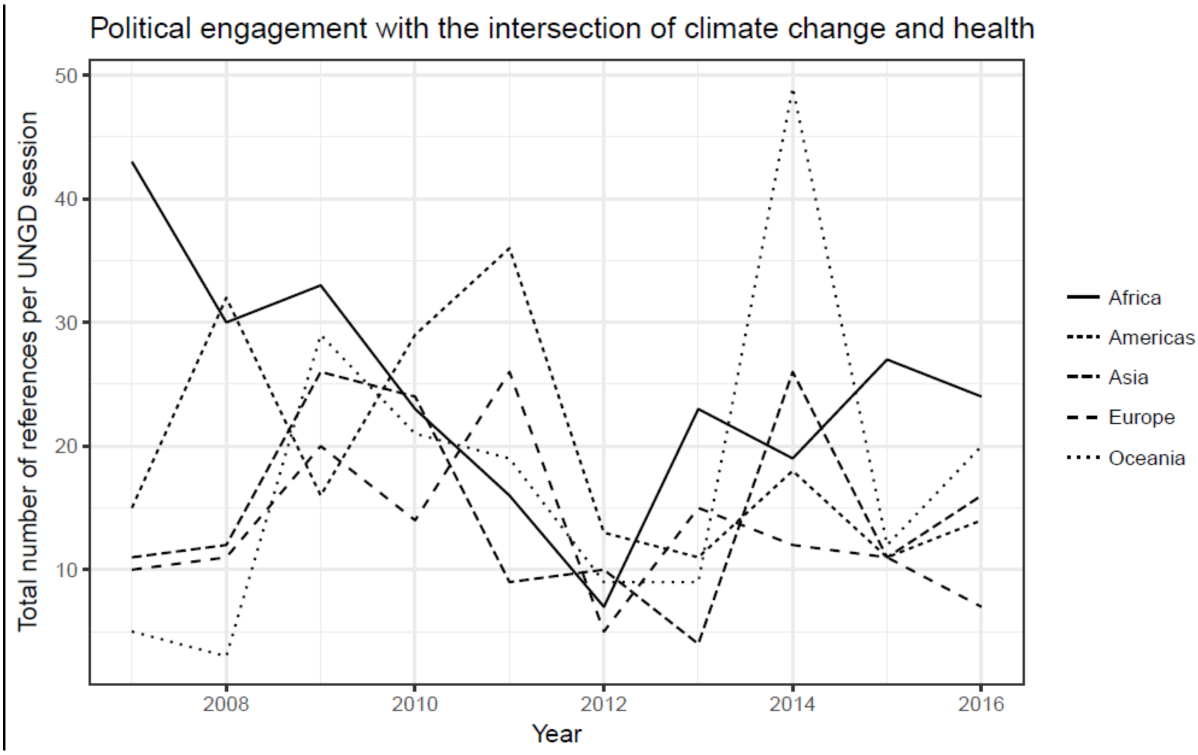

Figure 5.4. Regional political engagement with the intersection of health and climate change, represented by joint references to health and climate change in the UNGD.

This indicator is based on the application of keyword searches in the text corpus of debates. A new dataset of GD statements was used (UNGD corpus), in which the annual UNGD statements have been pre-processed and prepared for use in quantitative text analysis.[215] The dataset contains all country speeches made in the UNGD between 1970 and 2016. Here, the frequency of references to health and climate change in annual UNGD statements was considered between 2007 and 2016. Overall, 1,928 high level statements were examined. The keywords used are based on a) health-related terms and b) climate change-related terms (full list of search terms is provided in Appendix 6. To capture whether UNGD statements referred to the intersection of health and climate change, our analysis focused on if any of the health-related terms appeared immediately before or after any climate change terms in the UNGD statements. This was based on a search of the 10 words before and after a reference to a climate change related term.

Caveats for this indicator include the narrow range of search terms, which excludes reference to many of indirect links between health and climate change. Several UNGD statements in the dataset refer to such indirect connections, such as effects of climate change on water and agriculture, but these are not included. Therefore, the results present a conservative estimate of high-level political engagement with the intersecting issues of health and climate change. Future Lancet Countdown reports will consider political engagement with these indirect links, as well as providing additional forms of analysis.

Conclusion

A key message from this analysis is the importance of global governance, and the UN in particular, in mobilising public and political engagement in health and climate change. As this report demonstrates, climate change is a global challenge demanding collective action globally, nationally and locally. It requires people and governments to act as one global community; the UN stands as the embodiment of this inter-connected community, with all 193 of its Member States having equal representation under the UN Charter.[216] The dimensions of public and political engagement examined in this section – in the media, science and inter-governmental forum of the UNGD – points to the pivotal importance of UN-led processes, and most especially UNFCCC's COPs.

Taking the indicator of political engagement as an example, governments clearly prioritise the linked issues of health and climate change when the UN has successfully mobilised multilateral action. This has both negative and positive implications. Viewed negatively, it suggests that public and political engagement is reactive and transitory, stimulated by key global governance events from a steady-state of much lower levels of engagement. While there are exceptions, most countries in the UNGD analyses did not consistently engage with the linked challenges of health and climate change. Conversely, viewed positively, evidence that the UNFCCC COPs are central to the dynamics of public and political engagement suggests that ensuring health and climate change are on the agenda of a wide range of key multilateral institutions/global governance events may help to sustain longer-term engagement. This is evidenced in newspaper coverage of health and climate change that, while showing clear spikes around COP15 (2009) and COP21 (2015), also show an increasing trend in coverage over time since 2007.

A second message relates to the uneven patterns of public and political engagement in health and climate change. While scientific engagement has increased rapidly over the last decade, research has disproportionately focused on health and climate change in high-income and high-emitting countries (North America and Europe), rather than on regions bearing the brunt of the health impacts of climate change. Indicator 5.3 on political engagement again points to global inequalities in engagement. It is the governments of Oceanic countries, a group consisting of SIDS, who use their annual statements to the UNGA to speak out about health and climate change.

Future work will prioritise expanding the indicator set on public and political engagement. For instance, an indicator of corporate engagement is under development, which will be based on an analysis of corporate social responsibility and sustainability reports of major international companies (see Appendix 6 for details). Furthermore, opportunities for an indicator of public engagement that relates more directly to people's perceptions of health and climate change will be pursued, as public perceptions are key to building support for policies to address the challenges and opportunities presented by health and climate change. Governments are known to both shape and respond to public perceptions of environmental and health risks; in addition, many policies require public buy-in, through support for public investment and disinvestment, public regulation and/or lifestyle change. An indicator on professional education**,** originally planned for inclusion in this report, is also proposed for consideration for future analysis (see appendices for details).

Whilst the indicators in this section do not provide a complete representation of public and political engagement, they provide a strong baseline from which to build. The understanding of public and political engagement in health and climate change is absolutely critical. The previous sections in this report have presented findings on the impacts of climate hazards, adaptation and resilience, co-benefits of mitigation, and finance and economics. All of these hinge upon policy, which in turn is dependent upon public engagement. Thus, by better understanding the mechanisms and influences behind public and political engagement, stronger and more precise policy recommendations can be given to reduce the health impacts of climate hazards; improve resilience and adaptation; maximise the co-benefits of mitigation; and adopt the most cost-effective means of doing so.

Conclusion - the direction of travel is set

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