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The 2019 report of The *Lancet* Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate

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Executive Summary

The *Lancet* Countdown is an international, multidisciplinary collaboration, dedicated to monitoring the evolving health profile of climate change, and providing an independent

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The *Lancet* Countdown: tracking progress on health and climate change is an international multidisciplinary collaboration that builds on the foundation work of the 2015 *Lancet* Commission on health and climate change, convened by *The Lancet*. The *Lancet* Countdown's work for this report was done by its five working groups, each of which were responsible for the design, drafting, and review of their corresponding indicators and sections. All authors contributed to the overall structure and concepts of the report and provided input and expertise to the relevant sections. Authors contributing to Working Group 1 included Nigel Arnell, Jonathan Chambers, Luis E Escobar, Ilan Kelman, Tord Kjellstrom, Bruno Lemke, Yang Liu, Rachel Lowe, Jaime Martinez-Urtaza, Maziar Moradi-Lakeh, Kris Murray, Fereidoon Owfi, Mahnaz Rabbaniha, Elizabeth Robinson, Jan C Semenza, Meisam Tabatabaei, and Joaquin Trinanes. Authors contributing to Working Group 2 included Sonja Ayeb-Karlsson, Peter Byass, Diarmid Campbell-Lendrum, Robert Dubrow, Kristie L Ebi, Lucia Fernandez Montoya, Lucien Georgeson, Jeremy Hess, Dominic Kniveton, Mark Maslin, Karyn Morrissey, Tara Neville, Maria Nilsson, Maquins Odhiambo Sewe, Dung Phung, Joacim Rocklöv, and Joy Shumake-Guillemot. Authors contributing to Working Group 3 included Markus Amann, Kristine Belesova, Carole Dalin, Michael Davies, Matthew Eckelman, Ian Hamilton, Stella Hartinger, Gregor Kiesewetter, Melissa Lott, James Milner, Tadj Oreszczyn, David Pencheon, Steve Pye, Ruth Quinn, Jodi Sherman, Jonathon Taylor, and Paul Wilkinson. Authors contributing to Working Group 4 were Paul Drummond and Paul Ekins. Authors contributing to Working Group 5 included Maxwell Boykoff, Wenjia Cai, Stuart Capstick, Meaghan Daly, Niheer Dasandi, Paul Haggar, Hilary Graham, Lucy McAllister, Slava Jankin Mikhaylov, and Olivia Pearman. The coordination, strategic direction, and editorial support for this paper was provided by Anthony Costello (Co-Chair), Hugh Montgomery (Co-Chair), Peng Gong (Co-Chair), Nick Watts (Executive Director), and Alice McGushin (Programme Manager). The findings and conclusions in this Review are those of the authors and do not necessarily represent the official position of the European Centre for Disease Prevention and Control, WHO, the World Bank, or the World Meteorological Organization.

Declaration of interests

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assessment of the delivery of commitments made by governments worldwide under the Paris Agreement.

The 2019 report presents an annual update of 41 indicators across five key domains: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement. The report represents the findings and consensus of 35 leading academic institutions and UN agencies from every continent. Each year, the methods and data that underpin the *Lancet* Countdown's indicators are further developed and improved, with updates described at each stage of this report. The collaboration draws on the world-class expertise of climate scientists; ecologists; mathematicians; engineers; energy, food, and transport experts; economists; social and political scientists; public health professionals; and doctors, to generate the quality and diversity of data required.

The science of climate change describes a range of possible futures, which are largely dependent on the degree of action or inaction in the face of a warming world. The policies implemented will have far-reaching effects in determining these eventualities, with the indicators tracked here monitoring both the present-day effects of climate change, as well as the worldwide response. Understanding these decisions as a choice between one of two pathways—one that continues with the business as usual response and one that redirects to a future that remains "well below 2°C" —helps to bring the importance of recognising the effects of climate change and the necessary response to the forefront.

Evidence provided by the Intergovernmental Panel on Climate Change, the International Energy Agency, and the US National Aeronautics and Space Administration clarifies the degree and magnitude of climate change experienced today and contextualises these two pathways.

The impacts of climate change on human health—The world has observed a 1°C temperature rise above pre-industrial levels, with feedback cycles and polar amplification resulting in a rise as high as 3°C in north western Canada.[1,2] Eight of the ten hottest years on record have occurred in the past decade.[3] Such rapid change is primarily driven by the combustion of fossil fuels, consumed at a rate of 171 000 kg of coal, 116 000 000 L of gas, and 186 000 L of oil per s.[4–6] Progress in mitigating this threat is intermittent at best, with carbon dioxide emissions continuing to rise in 2018.[7] Importantly, many of the indicators contained in this report suggest the world is following this "business as usual" pathway.

The carbon intensity of the energy system has remained unchanged since 1990 (indicator 3.1.1), and from 2016 to 2018, total primary energy supply from coal increased by 1·7%, reversing a previously recorded downward trend (indicator 3.1.2). Correspondingly, the health-care sector is responsible for about 4·6% of global emissions, a value which is steadily rising across most major economies (indicator 3.6). Global fossil fuel consumption subsidies increased by 50% over the past 3 years, reaching a peak of almost US$430 billion in 2018 (indicator 4.4.1).

A child born today will experience a world that is more than four degrees warmer than the pre-industrial average, with climate change impacting human health from infancy and adolescence to adulthood and old age. Across the world, children are among the worst affected by climate change. Downward trends in global yield potential for all major crops tracked since 1960 threaten food production and food security, with infants often the worst affected by the potentially permanent effects of undernutrition (indicator 1.5.1). Children are among the most susceptible to diarrhoeal disease and experience the most severe effects of dengue fever. Trends in climate suitability for disease transmission are particularly concerning, with nine of the ten most suitable years for the transmission of dengue fever on record occurring since 2000 (indicator 1.4.1). Similarly, since an early 1980s baseline, the number of days suitable for *Vibrio* (a pathogen responsible for part of the burden of diarrhoeal disease) has doubled, and global suitability for coastal *Vibrio cholerae* has increased by 9·9% indicator 1.4.1).

Through adolescence and beyond, air pollution—principally driven by fossil fuels, and exacerbated by climate change—damages the heart, lungs, and every other vital organ. These effects accumulate over time, and into adulthood, with global deaths attributable to ambient fine particulate matter ($PM_{2·5}$) remaining at 2·9 million in 2016 (indicator 3.3.2) and total global air pollution deaths reaching 7 million.[8]

Later in life, families and livelihoods are put at risk from increases in the frequency and severity of extreme weather conditions, with women among the most vulnerable across a range of social and cultural contexts. Globally, 77% of countries experienced an increase in daily population exposure to wildfires from 2001–14 to 2015–18 (indicator 1.2.1). India and China sustained the largest increases, with an increase of over 21 million exposures in India and 17 million exposures in China over this time period. In low-income countries, almost all economic losses from extreme weather events are uninsured, placing a particularly high burden on individuals and households (indicator 4.1). Temperature rise and heatwaves are increasingly limiting the labour capacity of various populations. In 2018, 133·6 billion potential work hours were lost globally, 45 billion more than the 2000 baseline, and southern areas of the USA lost 15–20% of potential daylight work hours during the hottest month of 2018 (indicator 1.1.4).

Populations aged 65 years and older are particularly vulnerable to the health effects of climate change, and especially to extremes of heat. From 1990 to 2018, populations in every region have become more vulnerable to heat and heatwaves, with Europe and the Eastern Mediterranean remaining the most vulnerable (indicator 1.1.1). In 2018, these vulnerable populations experienced 220 million heatwave exposures globally, breaking the previous record of 209 million set in 2015 (indicator 1.1.3). Already faced with the challenge of an ageing population, Japan had 32 million heatwave exposures affecting people aged 65 years and older in 2018, the equivalent of almost every person in this age group experiencing a heatwave. Finally, although difficult to quantify, the downstream risks of climate change, such as migration, poverty exacerbation, violent conflict, and mental illness, affect people of all ages and all nationalities.

A business as usual trajectory will result in a fundamentally altered world, with the indicators described providing a glimpse of the implications of this pathway. The life of every child born today will be profoundly affected by climate change. Without accelerated intervention, this new era will come to define the health of people at every stage of their lives.

Responding to climate change for health—The Paris Agreement has set a target of “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1·5°C.” In a world that matches this ambition, a child born today would see the phase-out of all coal in the UK and Canada by their sixth and 11th birthday; they would see France ban the sale of petrol and diesel cars by their 21st birthday; and they would be 31 years old by the time the world reaches net-zero in 2050, with

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the UK's recent commitment to reach this goal one of many to come. The changes seen in this alternate pathway could result in cleaner air, safer cities, and more nutritious food, coupled with renewed investment in health systems and vital infrastructure. This second path—which limits the global average temperature rise to "well below 2°C"—is possible, and would transform the health of a child born today for the better, right the way through their life.

Considering the evidence available in the 2019 indicators, such a transition could be beginning to unfold. Despite a small increase in coal use in 2018, in key countries such as China, it continued to decrease as a share of electricity generation (indicator 3.1.2). Correspondingly, renewables accounted for 45% of global growth in power generation capacity that year, and low-carbon electricity reached a high of 32% of global electricity in 2016 (indicator 3.1.3). Global per capita use of electric vehicles increased by 20·6% between 2015 and 2016, and now represents 1·8% of China's total transportation fuel use (indicator 3.4). Improvements in air pollution seen in Europe from 2015 to 2016, could result in a reduction of Years of Life Lost (YLL) worth €5·2 billion annually, if this reduction remained constant across a lifetime (indicator 4.2). In several cases, the economic savings from a healthier and more productive workforce, with fewer health-care expenses, will cover the initial investment costs of these interventions. Similarly, cities and health systems are becoming more resilient to the effects of climate change; about 50% of countries and 69% of cities surveyed reported efforts to conduct national health adaptation plans or climate change risk assessments (indicators 2.1.1, 2.1.2, and 2.1.3). These plans are now being implemented, with the number of countries providing climate services to the health sector increasing from 55 in 2018 to 70 in 2019 (indicator 2.2) and 109 countries reporting medium to high implementation of a national health emergency framework (indicator 2.3.1). Growing demand is coupled with a steady increase in health adaptation spending, which represents 5% (£13 billion) of total adaptation funding in 2018 and has increased by 11·8% over the past 12 months (indicator 2.4). This increase is in part funded by growing revenues from carbon pricing mechanisms, with a 30% increase to US$43 billion in funds raised between 2017 and 2018 (indicator 4.4.3).

However, current progress is inadequate, and despite the beginnings of the transition described, the indicators published in the *Lancet* Countdown's 2019 report are suggestive of a world struggling to cope with warming that is occurring faster than governments are able, or willing to respond. Opportunities are being missed, with the Green Climate Fund yet to receive projects specifically focused on improving climate-related public health, despite the fact that in other forums, leaders of small island developing states are recognising the links between health and climate change (indicator 5.3). In response, the generation that will be most affected by climate change has led a wave of school strikes across the world.

Bold new approaches to policy making, research, and business are needed in order to change course. An unprecedented challenge demands an unprecedented response, and it will take the work of the 7·5 billion people currently alive to ensure that the health of a child born today is not defined by a changing climate.

Introduction

Human wellbeing, and the stability of local communities, health systems, and governments, all depend on how they interface with the changing global climate.[9,10] Across the world, an

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average temperature increase of 1°C from a pre-industrial baseline[1,2] has already resulted in extreme climatic and environmental changes, with severe storms and floods, prolonged heatwaves and droughts, new and emerging infectious diseases,[11–13] and compounding threats to food security. Left unabated, climate change will define the health profile of current and future generations, will challenge already overwhelmed health systems, and undermine progress towards the UN Sustainable Development Goals (SDGs) and universal health coverage (UHC).[14,15]

The Intergovernmental Panel on Climate Change (IPCC)'s 2018 Special Report on Global Warming of 1·5°C emphasises the scale of the response required: global annual emissions must halve by 2030 and reach net-zero by 2050 to limit warming to 1·5°C, while recognising that no amount of climate change is considered safe.[2] Placing health at the centre of this transition will yield enormous dividends for the public and the economy, with cleaner air, safer cities, and healthier diets. Analysis focused on one of these pathways—cleaner air through more sustainable transport and power generation systems—suggests that the economic gains from the health benefits of meeting the Paris Agreement substantially outweigh the cost of any intervention by a ratio of 1·45 to 2·45, resulting in trillions of dollars of savings worldwide.[16] When the health benefits of any increase in physical activity that results from modal shift are taken into account, the economic gains increase significantly.[17] These analyses complement an assessment from outside the health sector, which estimates that a robust response to climate change could yield more than US$26 trillion and 65 million new low-carbon jobs by 2030, compared with a business as usual scenario.[18]

Monitoring this transition from threat to opportunity and demonstrating the benefits of realising the Paris Agreement is precisely why the *Lancet* Countdown on health and climate change was formed. As an international, independent research collaboration, the partnership brings together 35 academic institutions and UN agencies from every continent. The indicators and report presented here represent the work and consensus of climate scientists; geographers; engineers; energy, food and transport experts; economists; social and political scientists; public health professionals; and doctors.

The 41 indicators of the 2019 report span five domains: climate change impacts, exposures, and vulnerability; adaptation planning and resilience for health; mitigation actions and their health co-benefits; economics and finance; and public and political engagement (panel 1).

Strengthening a global monitoring system for health and climate change

This collaboration builds on three decades of work around the world, which has sought to understand and assess the scientific pathways that link climate change to public health.[13] In 2016, The *Lancet* Countdown launched a global consultation process, actively seeking input from experts and policy makers on which aspects of these pathways could and should be tracked as part of a global monitoring process. A large number of indicators were initially considered, and then narrowed down into the five indicator domains and published, along with a request for further input.[19] The final set of indicators were selected on the basis of the presence of credible scientific links to climate change and to public health; the presence of reliable and regularly updated data, available across temporal and geographic scales; and the importance of this information to policy makers.[20]

Overcoming the data and capacity limitations inherent in this field, and remaining adaptable to a rapidly evolving scientific landscape has required a commitment to an open and iterative approach. This has meant that the analysis provided in each subsequent annual report replaces analyses from previous years, with methods and datasets being continuously improved and updated. In every case, a full description of these changes is provided in the appendix, which is intended as an essential companion to the main report, rather than a more traditional addendum.

The 2019 report presents 12 months of work refining the metrics and analysis. In addition to updating each indicator with the information collated over the course of 1 year, three key developments have occurred.

Firstly, methodologies and datasets have been strengthened for indicators that capture heat and heatwaves; labour capacity loss; the lethality of weather-related disasters; terrestrial food security and undernutrition; health adaptation planning and vulnerability assessments; air pollution mortality in cities; household fuel use for cooking; and qualitative validation of engagement from the media and national governments in health and climate change.

Secondly, the geographical and temporal coverage has been expanded for indicators that capture marine food security; national adaptation planning for health; health vulnerability assessments; climate information services for health; the carbon intensity of the energy system; access to clean energy; and Chinese media engagement in health and climate change.

Finally, new indicators were constructed that capture exposure to wildfires; the transmission suitability for *V cholerae*; the benefits and harms of air conditioning; emissions from livestock and crop production; global health-care system emissions; economic cost of air pollution; and individual online engagement in health and climate change.

Ongoing research aims to establish indicators for concepts that are inherently difficult to quantify, such as the mental health effects of climate change. Three indicators included in previous years—covering migration, global health adaptation funding, and academic engagement in health and climate change—are not presented in the 2019 report, as further work is being done to improve their methods and to ensure that they are able to be sustainably reproduced in the future. These indicators will be re-introduced in subsequent years.

For the second consecutive year, these changes represent substantial updates to most of the indicators, and knowledge is increasing at a pace that will only accelerate as funding and capacity from the Wellcome Trust and the *Lancet* Countdown's partners grows. Going forward, the collaboration will seek to further strengthen its scientific processes, continuously review its indicators, and produce internally coherent frameworks to guide the development of new indicators. To this end, The *Lancet* Countdown remains open to

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new input and participation from experts and academic institutions willing to build on the analysis published in this report.

Health and climate change in 2018

The 2019 report discusses the worsening health effects of climate change. Over 220 million additional exposures to heatwaves (with each exposure defined as one person aged 65 years or older exposed to one heatwave) occurred in 2018, compared with a 1986–2005 climatological baseline, higher than ever previously tracked (indicator 1.1.3). This occurred at a time when demographic vulnerability to these extremes continued to increase across every region (indicator 1.1.1), and the warming experienced by human populations reached four times that of the global average temperature rise (indicator 1.1.2). Around the world, resultant losses in labour capacity were reported, with several southern states in the USA losing as much as 15–20% of daylight capacity (for workers in construction and agriculture; indicator 1.1.4). The effects of this warming extended to other extremes, with 152 countries experiencing a marked increase in the daily population exposures to wildfires compared with baseline (indicator 1.2.1). Regarding infectious diseases, 2018 was ranked second on record as having the most suitable conditions for the transmission of diarrhoeal disease and wound infections from *Vibrio* bacteria, and 9 of the past 10 most suitable years for the transmission of dengue fever have occurred since 2000 (indicator 1.4.1). The distribution of exposure and effect is not equal, with several indicators reporting greater changes in low-income settings than in high-income settings—for example, in parts of Africa, South-East Asia, and the Western Pacific (indicator 4.1).

Despite these worsening effects, the carbon intensity of the global energy system has remained flat since 1990 (indicator 3.1.1) and use of clean fuels for household services is stagnating (indicator 3.2). Perhaps of greatest concern is that total primary energy supply from coal increased by 1·7% from 2016 to 2018, reversing a previously observed downward trend (indicator 3.1.2), and carbon dioxide (CO_2) emissions from the energy sector, far from falling, rose by 2·6% from 2016 to 2018 (indicator 3.1.1). Global fossil fuel subsidies rose to US$427 billion in 2018—a 33% rise from 2017 (indicator 4.4.1)—and emissions associated with health care now represent 4·6% of global emissions, rising across most major economies (indicator 3.6). Fossil fuel use continues to contribute to ambient air pollution, which resulted in 2·9 million premature deaths globally in 2016 (indicator 3.3.2).

Although these emerging health impacts and the lack of a coordinated global response portray a bleak picture, they also mask important promising trends. Several encouraging trends continue, such as reductions in investment in new coal capacity and a fall in coal as a share of total electricity generation (indicators 4.3.1 and 3.1.2). Renewable energy accounted for 45% of total growth in 2018 (indicator 3.1.3), and low-carbon electricity represented an impressive 32% share of total global electricity generation in 2016 (indicator 3.1.3). The reduction in air pollution recorded in Europe from 2015 to 2016, if maintained across a lifetime, could result in an annual reduction in YLL valued at €5·2 billion (indicator 4.2). These changes are reinforced by new commitments from the UK[21] and France[22] to reach net zero by 2050, with other countries soon expected to follow.

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Notably, the world is beginning to adapt, with 50% of countries and 69% of cities surveyed reporting the completion or undertaking of a climate change risk assessment or adaptation plan (indicators 2.1.2 and 2.1.3). Increasingly, these plans are being implemented, with 70 countries providing meteorological services targeted towards the health sector in 2019 and 109 countries achieving medium to high implementation of a national health emergency framework (indicators 2.2 and 2.3.1).

In the health sector, the UK's Royal College of General Practitioners and Faculty of Public Health divested their fossil fuel investments in 2018, joining many universities, non-governmental organisations, and pension funds from across the world (indicator 4.3.4). Alongside this, new analysis suggests a growing and more sophisticated recognition of the health benefits of the response to climate change in the media (indicator 5.1).

Many of the trends identified in the 2019 *Lancet* Countdown report are deeply concerning. Greenhouse-gas emissions continue to rise. Nevertheless, the continued expansion of renewable energy, increased investment in health system adaptation, improvements in sustainable transport, and growth in public engagement suggests ongoing reasons for cautious optimism. At a time when the UN Framework Convention on Climate Change is preparing to review commitments under the Paris Agreement in 2020, accelerated ambition and action is required in order to meet the world commitment to remaining "well below 2°C".[23]

Section 1: climate change impacts, exposures, and vulnerabilities

Climate change and human health are interconnected in a myriad of complex ways.[13] Building on the *Lancet* Countdown's previous work, section 1 of the 2019 report continues to track quantitative metrics along pathways of population vulnerability, exposure, and health outcomes that are indicative of the cost to human health of climate change, and thus of the urgent need to reduce greenhousegas emissions. The impacts tracked here in turn motivate and guide climate change adaptation (section 2) and mitigation (section 3) interventions.

Changes in warming and weather events are not evenly distributed across the globe, and some populations, including children, the elderly, and outdoor workers, are more vulnerable than others. Efforts to track the unequal effects of climate change are reflected through indicators that focus on particularly vulnerable populations, and low-income and middle-income countries experiencing the worst of these effects.

Although it is certainly true that the effects of climate change vary by geographical location and that these effects will not always be negative, any so-called positive effects are often short-term in nature, and quickly outweighed by other exposures. One such example is seen in Australia, where any benefit that might have been gained from CO_2 fertilisation is both small and largely outweighed by greater climate variation, with crop yields now stalling as harvests are increasingly affected by more frequent drought.[24] Even disregarding the negative effects of temperature change, any CO_2 fertilisation benefits are likely to be short-term, as rising CO_2 concentrations will negatively affect grain quality.[25–28]

For 2019, a new metric tracking exposure to wildfires has been added (indicator 1.2.1), as has an expansion of climate suitability of infectious diseases (indicator 1.4.1), to now include *V cholerae* transmission risk. These indicators portray a world which is rapidly warming, where environmental and social systems are already being exposed to the effects of climate change, which are subsequently affecting human health.

Indicator 1.1: health and heat

The most immediate and direct impact of a changing global climate on human health is seen in the steady increase in global average temperature, and the increased frequency, intensity, and duration of extremes of heat. The pathophysiological consequences of heat exposure in humans are well documented and understood, and include heat stress and heat stroke, acute kidney injury, exacerbation of congestive heart failure,[29] and increased risk of interpersonal,[30] and collective violence.[31] In particular, during periods of extreme heat, young children have a greater risk of electrolyte imbalance, fever, respiratory disease, and kidney disease.[32] Four indicators that are related to heat are discussed here, tracking the vulnerabilities, exposures, and labour implications of a warming world.

Indicator 1.1.1: vulnerability to extremes of heat—headline finding: vulnerability to extremes of heat continues to rise among older populations in every region of the world, with the Western Pacific, South-East Asia and African regions all seeing an increase in vulnerability of more than 10% since 1990—Certain populations are more vulnerable to the health effects of heat than others. Older populations are particularly vulnerable, especially those with pre-existing medical conditions (such as diabetes and cardiovascular, respiratory, and renal disease).[33] Outdoor workers, while younger and healthier overall, are also vulnerable due to heightened exposure to heat and sunlight. This indicator presents a heat vulnerability index which ranges from 0 to 100 and includes the proportion of the population older than age 65 years, prevalence of chronic diseases, and proportion of the population living in urban areas, with the data and methods unchanged from previous years (appendix p 1).

Populations older than age 65 years, in all regions of the world, are becoming increasingly vulnerable. However, the highest increase in vulnerability from 1990 to 2017 has been seen in the Western Pacific (33·1% to 36·6%) and African (28·4% to 31·2%) regions. Overall, Europe remains the most vulnerable region to heat exposure (followed closely by the Eastern Mediterranean region), due to its ageing population, high rates of urbanisation, and high prevalence of cardiovascular and respiratory diseases, and diabetes.

Indicator 1.1.2: health and exposure to warming—headline finding: human populations are concentrated in the areas most exposed to warming, experiencing a mean summer temperature change that is four times higher than the global average—This indicator compares the population-weighted summer temperature change from a 1986–2005 baseline with the global average summer temperature change over the same period, using weather data from the European Centre for Medium-Range Weather Forecasts,[34] ERA-Interim project and population data from the NASA Socioeconomic Data and Applications Center (SEDAC) Gridded Population of the World

(GPWv4).[35] Full details, along with an explanation of improvements for the 2019 report, which uses higher resolution climate and population data (0·5°C grid instead of 0·75°C grid) are provided (appendix p 3).

The population-weighted temperatures continue to grow at a substantially faster pace than the global average, increasing the human health risk. The global average population-weighted temperature has risen by 0·8°C from the 1986–2005 baseline to 2018, compared with a global average temperature rise of 0·2°C over the course of the same time period.

Indicator 1.1.3: exposure of vulnerable populations to heatwaves—headline finding: in 2018, an increase of 220 million heatwave exposures affecting older populations was observed, breaking the previous record set in 2015. Japan alone experienced 32 million heatwave exposures, the equivalent of almost every person aged 65 years and older enduring effects of a heatwave in 2018—Heatwaves across the northern hemisphere made headlines in 2018, reaching new highs for a number of countries.[36] The definition of a heatwave, the demographic data,[35] and methods used here remain unchanged from previous reports (appendix pp 4).[37] Each heatwave exposure event is defined as one heatwave experienced by one person older than age 65 years. This indicator was also improved with a higher resolution (0·5°C grid instead of 0·75°C grid).

The change in heatwave exposure events relative to the 1986–2005 average are presented (figure 1). The increase in heatwave exposure events (220 million, which is 11 million more than the 2015 record) was due to a series of heatwaves across India (45 million additional exposures); across central and northern Europe (31 million additional exposures in the EU); and across northeast Asia, where heatwaves affected Japan, the Korean peninsula, and Northern China. 32 million exposures affected people older than age 65 years in Japan alone, the equivalent of almost every person in this age group experiencing effects of a heatwave in 2018.[38]

Indicator 1.1.4: change in labour capacity—headline finding: higher temperatures continue to affect people's ability to work. In 2018, 45 billion additional potential work hours were lost due to rising temperatures, compared with in the year 2000—General work productivity and ability to work are affected by temperature and humidity, which are both captured in the Wet Bulb Globe Temperature (WBGT) measurement. Labour productivity loss estimates for every degree increase of WBGT beyond 24°C range from 0·8% to 5%.[39] Reduced labour productivity is often the first symptom of the health effects of heat, and, if not addressed, could lead to more severe health effects, such as heat exhaustion and heat stroke.

This indicator emphasises the important impact of climate change on labour capacity in vulnerable populations.[40] It assigns work-fraction loss functions to different activity sectors (service, manufacturing, and agriculture), linking WBGT with the power (metabolic rate) typically expended by a worker within each of these three sectors. This is then coupled with the proportion of the population working within each of these three sectors to calculate potential work hours lost (WHL) by country. This indicator has been improved to include

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the effect of sunlight on the potential WHL by calculating the increase in WBGT using solar radiation data available from the ERA database (appendix pp 5–6).[35,41,42]

The global atmospheric temperature and humidity in 2018 were slightly more favourable for work than in 2017, but the upward trend of potential WHL since 2000 remains clear (figure 2). In 2018, 133·6 billion potential work hours were lost; 45 billion hours more than in 2000.

Additionally, a map is presented of the equivalent potential annual full-time work lost in the sun and the shade (figure 3). Of note, for 300 Watts (W) work in the shade (typical for manufacturing), over 10% potential daily work hours were lost in densely populated regions such as south Asia. For 400 W work in the sun (typical for agriculture and construction), even workers in the southern parts of the USA (below a latitude of 34°N, with Alabama, Georgia, Florida, Louisiana, Mississippi, and Texas particularly affected), lost 15–20% of potential daylight work hours in the hottest month of 2018.

Indicator 1.2: health and extreme weather events

Indicator 1.2.1: wildfires—headline finding: 152 of 196 countries saw an increase in annual daily population exposure to wildfires in 2015–18, compared with in 2001–04, with India alone experiencing an increase of 21 million annual daily exposures. This increase not only poses a threat to public health, but also results in major economic and social burdens in both high-income and low-income countries—The health effects of wildfires range from direct thermal injuries and death, to the exacerbation of acute and chronic respiratory symptoms due to exposure to wildfire smoke.[43] Additionally, the global economic burden per person affected by wildfires is more than twice that of earthquakes and 48 times higher than that of floods, although the global number of events and number of people affected by floods are much higher than for wildfires.[44] Furthermore, climatic changes, including increasing temperature and earlier snowmelt, contribute to hotter, drier conditions, which increase the risk of wildfires. Yet, wildfires remain an important component of many ecosystems, although they can be ecologically harmful through human ignition or when forest management practices do not fully account for periodic, natural burning.

This new indicator represents the change in the average annual number of days people were exposed to wildfire in each country. It was developed using the Collection 6 active fire product from the Moderate Resolution Imaging Spectroradiometer aboard the NASA Terra and Aqua satellites.[45] Fire point locations were matched to a political border shapefile from the Global Burden of Disease (GBD), and consequently joined with population count per square kilometre, taken from NASA SEDAC GPWv4.[35] The result is an annual sum of people experiencing a fire event per day. The mean number of person-days exposed to wildfire was recorded for years 2001–04 (the earliest years for which data with adequate coverage and resolution is available) and compared with the mean from 2015–18.

Overall, this indicator reports a mean increase of 464 032 person-days exposed to wildfire per year over the period studied; however, the increase in person-days recorded in some countries is far greater than the mean global increase (appendix pp 7–8). India, China, the Democratic Republic of Congo, Iraq, and Mexico sustained the largest increase in the

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number of person-days affected by wildfires, with a maximum increase of nearly 21 807 000 person-days in India followed by 17 003 000 person-days in China (figure 4). Countries including Spain, Russia, and Uzbekistan saw substantial reductions in the number of people affected.

Crucially, this indicator will evolve over time to cover the health risks of wildfire smoke,[43] which can travel far distances and affect areas that are not directly exposed to fires.[46]

Indicator 1.2.2: flood and drought—headline finding: extremes of precipitation, resulting in flood and drought, have impacted human health and wellbeing, with South American and South-East Asian populations experiencing long-term increases in both of these natural disasters—This indicator tracks exposure to extremes of precipitation, using weather and population data presented in previous reports (appendix pp 8–9).[20,37] Analysis across time and space reveals regional trends for drought and extreme heavy rain that are more significant than global trends, reflecting the varying nature of climate change depending on the geographical region.

Floods are particularly problematic for health, resulting in direct injuries and death, the spread of vector-borne and water-borne diseases, and mental health sequelae.[47] The average number of extreme rainfall events in the 2000–18 period reveals that South America and South-East Asia are experiencing the largest increases.

Prolonged drought remains one of the most dangerous environmental determinants of premature mortality, affecting hygiene and sanitation, as well as resulting in reduced crop yields, food insecurity, and malnutrition.[47] The change in the number of severe droughts in 2018 demonstrates areas of significantly increased exposure in all six WHO regions, with areas of Brazil experiencing a full 12 months of drought throughout 2018.

Indicator 1.2.3: lethality of weather-related disasters—headline finding: a statistically significant long-term upward trend has been observed in the number of flood-related and storm-related disasters in Africa, Asia, and the Americas, since 1990. At the same time, Africa has experienced a statistically significant increase in the number of people affected by these types of disasters—This indicator tracks the number of occurrences of weather-related disasters, the number of people affected, and the lethality of these events. These are formulated as a function of the hazard (magnitude and frequency) and the vulnerability and exposure of populations at risk, using data from the Centre for Research on the Epidemiology of Disasters.[48] For the 2019 report, disasters have been separated into two categories: flood-related and storm-related disasters; and heatwave, extreme temperature, and drought-related disasters. Details of these methods and data are summarised (appendix pp 10–13).

For heatwaves, extreme temperature, and drought-related disasters, no statistically significant global trend was identified. One explanation for this could be the geographically local nature of such events. However, in the case of floods and storms, a statistically significant trend in occurrence was identified individually across Africa, Asia, and the

Americas. A statistically significant increase in the number of people affected by floods and storms in Africa was also noted, although no statistically significant increase in the lethality of these events was identified.

The relative stability of the lethality and number of people affected by these disasters could possibly be linked to improved disaster preparedness (including improved early warning systems) as well as increased investments in health-care services, and is discussed further in section 2.[49–51] Importantly, work from the 2015 *Lancet* Commission shows that a business as usual trajectory is expected to result in an additional 2 billion flood-exposure events per year by 2090, which will likely overwhelm health systems and public infrastructure.[13]

Indicator 1.3: global health trends in climate-sensitive diseases

Headline finding: although mortality due to diarrhoeal diseases, malnutrition, and malaria is improving, mortality due to dengue is rising in the regions most affected by these diseases—As described in the preceding indicators, climate change affects a wide range of disease processes. Corresponding health outcomes result from a complex interaction between the direct and indirect effects of climate change and social dynamics, such as population demographics, economic development, and access to health services.[13] This indicator provides a macro view of these interactions, using GBD data to track mortality from diseases that are sensitive to climate change.[52] Mortality due to earthquake and volcano events has been removed from the GBD forces of nature category for estimates of weather-related events.

Global trends in climate-sensitive disease mortality from 1990 to 2017 are shown, with all-cause mortality presented as a reference (figure 5). Death from diarrhoeal diseases and protein-energy malnutrition has declined considerably over this period in regions most affected (Africa, South-East Asia, and Eastern Mediterranean). Similarly, a marked decrease in mortality from malaria since 2000 has been observed in Africa. Socioeconomic development, improved access to health care, and major global health initiatives in sanitation and hygiene, and vector control, have all contributed to these improvements in health outcomes.[13,53] However, mortality from dengue fever continues to rise, particularly in South-East Asia.

Indicator 1.4: climate-sensitive infectious diseases

Indicator 1.4.1: climate suitability for infectious disease transmission—headline finding: suitability for disease transmission has increased for dengue, malaria, *V cholerae* and other pathogenic *Vibrio* species. The number of suitable days per year in the Baltic for pathogenic *Vibrio* transmission reached 107 in 2018, the highest since records began, and two times higher than the early 1980s baseline—Climate change affects the distribution and risk of many infectious diseases.[47] The 2019 *Lancet* Countdown report provides an updated analysis of the environmental suitability for transmission of dengue virus, malaria, and *Vibrio*, with the most recently available data, and presents an additional analysis of *V cholerae* environmental suitability in coastal areas.

Malaria and dengue fever are endemic in many parts of the world and, as described in the previous indicator, continue to contribute substantially to burden of disease, with young children particularly vulnerable. Suitability for transmission of mosquito-borne infectious diseases is affected by factors including temperature, humidity and precipitation. For dengue, vectorial capacity, which expresses the average daily rate of subsequent cases in a susceptible population resulting from one infected case, is calculated using a formula including the vector to human transmission probability per bite, the human infectious period, the average vector biting rate, the extrinsic incubation period, and the daily survival period.[54] For malaria, the number of months suitable for transmission of *Plasmodium falciparum* and *P vivax* malaria parasites is calculated on the basis of temperature, precipitation, and humidity. Climate suitability for these mosquito-borne diseases is averaged for the most recent five years for which data is available and compared with a 1950s baseline.

Vibrio species cause a range of human infections, including gastroenteritis, wound infections, septicaemia, and cholera. These bacteria are found in brackish marine waters and cases of infections are influenced by sea surface salinity, sea surface temperature, and chlorophyll A concentrations.[55–57] Climate suitability for *Vibrio* species was estimated on the basis of sea surface salinity and sea surface temperature globally and focally for two regions (the Baltic and US northeast coastlines) where *Vibrio* (excluding *V cholerae*) infections are most frequently observed. For pathogenic *Vibrio* species (excluding *V cholerae*), an average of the 5 most recent years for which data is available is compared with a 1980s baseline, whereas the new *V cholerae* specific analysis compares data from the most recent 3 years with a 2003–05 baseline (based on data availability). Full details on methods used are presented (appendix pp 14–24).

Climate suitability for transmission is rising for each of the pathogens studied. The second highest vectorial capacity for both dengue vectors was recorded in 2017, with the 2012–17 average 7·2% and 9·8% above baseline for *Aedes aegypti* and *Aedes albopictus*, respectively (figure 6). This change emphasises the continued upward trend of climate suitability for transmission of dengue, with 9 of the 10 most suitable years occurring since the year 2000. Malaria suitability continues to increase in highland areas of Africa, with the 2012–17 average 29·9% above baseline. The percentage of coastal area suitable for *Vibrio* infections from 2010 has increased at northern latitudes (40–70° N) by 3·8%, compared with the 1980s baseline, with 2018 the second most suitable year on record (5% above the baseline; figure 7). The area of coastline suitable for *Vibrio* has increased by 31% in the Baltic coastline and 29% in the northeastern coastline of the USA. Additionally, the number of days per year suitable for *Vibrio* in the Baltic reached 107 in 2018, which is double that of the early 1980s baseline and the highest on record. Globally, environmental suitability for coastal *V cholerae sensu lato* has increased by 9·9%, driven by regional increases in Asia, Europe, the Middle East, North America, and northern and western Africa.

Indicator 1.4.2: vulnerability to mosquito-borne diseases—headline finding: climate change induced risk of mosquito-borne diseases could be offset by improvements in public health systems. Investments in public health have resulted in a 31% fall in global vulnerability observed from 2010–17. However,

this success is not spread equally, with vulnerability to recurrent dengue outbreaks increasing in the Western Pacific and South-East Asia over the same period—While the previous indicator describes the influence of climate over the transmission of several infectious diseases, this indicator tracks vulnerability to one of these (dengue). Importantly, population vulnerability to dengue is modulated by human, social, financial, and physical factors, as well as the adaptive capacity of a community.[53,58]

Country-level data relating to surveillance, preparedness, and response from WHO International Health Regulations' (IHR) core capacities for the years 2010–17,[59] are used as a proxy for adaptive capacity. *Aedes aegypti* vulnerability is defined by abundance and vectorial capacity as described in indicator 1.4.1. This index estimates the population-level risk of exposure to *Aedes* mosquitoes, accounting for the public health core capacity to cope with the potential effects. A full description of the methods used is provided (appendix pp 24–25).

A contraction of the vulnerability to dengue is observed from 2010 to 2017 in tropical and sub-tropical areas of South America, Africa, and Asia. However, this decrease in vulnerability has levelled off since 2014, with a reversing trend in the Western Pacific and South-East Asia regions.

Indicator 1.5: food security and undernutrition

Indicator 1.5.1: terrestrial food security and undernutrition—headline finding: data from all major crops tracked—maize, wheat, rice, and soybean—showed that increases in temperature have reduced global crop yield potential— Currently, improvements in nutrient and water management, as well as expansion of agricultural areas in lower income countries, are resulting in increases in global food production.[60,61] However, the number of undernourished people worldwide appears to have been increasing since 2014, driven by challenges to access, availability, and affordability of food.[62] Undernutrition overwhelmingly affects children younger than age 5 years, causing intrauterine growth restriction, stunting, severe wasting, micronutrient deficiencies, and poor breastfeeding.[63] Evidence suggests that crop production is threatened in complex ways by changes in the incidence of pests and pathogens;[64] increasing water scarcity;[65] and increases in frequency and strength of extreme weather conditions that can damage or even wipe out harvests.[66]

Change in crop growth duration is used as a proxy for yield potential for maize, wheat, rice and soybean, and is based on the time taken in a year to accumulate a reference period (1981–2010) accumulated thermal time. A reduction in crop growth duration means the crop matures too quickly with lower seed yield.[67] This methodology is discussed alongside a full description of the Climatic Research Unit database used (appendix p 26).[45]

Globally, crop yield potential for maize, winter wheat, and soybean has reduced in concert with increases in temperature (figure 8), challenging efforts to achieve SDG 2 to end hunger by 2030.[66] This data resonates with a meta-analysis of the literature by Zhao and colleagues,[68] which suggests that global yields of these four key crops are reduced respectively by 6%, 3·2%, 7·4%, and 3·1%, globally for each 1°C increase in global mean temperatures.

Indicator 1.5.2: marine food security and undernutrition—headline finding: between 2003 and 2018, sea surface temperature rose in 34 of 64 investigated territorial waters, presenting risk to marine food security—Fish provide almost 20% of animal protein intake to 3·2 billion people, with a greater reliance on fish sources of protein in low-income and middle-income countries, particularly small island developing states.[69] Climate change threatens fisheries and aquaculture in a number of ways, including through sea surface temperature rise; change in intensity, frequency, and seasonality of extreme events; sea level rise; and ocean acidification.[70] Acute disturbances such as thermal stress lead to impaired recovery of the coral reefs, which threatens marine fish populations and subsequently marine primary productivity—a key source of omega-3 fatty acids for many populations.[71]

This indicator tracks sea surface temperature in territorial waters, selected for their geographical coverage and importance to marine food security, using data sourced from Food and Agriculture Organization of the UN (FAO), NASA, and National Oceanic and Atmospheric Administration.[72–74] Following a period of development, this indicator now includes 64 territorial waters (including countries for which data is available) located in 16 FAO fishing areas, and is complemented by monitoring of coral bleaching due to thermal stress (abiotic indicators), and per-capita capture-based fish consumption (biotic indicator; appendix pp 27–47). Between 2003 and 2018, sea surface temperature has risen in 34 of the 64 territorial waters, with a maximum increase of 3·5°C observed in Finland.

Conclusion

The indicators presented in this section provide evidence of the exposures, vulnerabilities, and impacts of climate change on health. They show worsening exposures and vulnerabilities along a range of temperature and precipitation pathways, with reductions in crop yield potentials, and increases in vectorial capacity for a number of climate-sensitive diseases. These effects are felt most acutely by low-income and middle-income countries across the world.

Continued work on attribution remains an important consideration with regards to outcome. For example, migration was addressed in earlier reports, in which questions of attribution to climate change remained particularly challenging.[20,37] Irrespective of how climate change migrants are counted,[75] many factors contribute to health risks faced by migration. Resulting health impacts depend on both pre-existing conditions (eg, mental health and nutritional status, desire to migrate, and existing health systems) along with interventions (eg, health-care access, provision of food and shelter, and changing health-related resources).

Similarly, in 2018, the links between climate change and mental health were presented.[37] Mental health might be negatively affected in various ways by heatwaves, loss of property, and loss of livelihoods due to floods, or climate-induced migration. However, although many varied links have been identified between climate and mental health, they are highly socially and culturally mediated. Attempting to operationalise these linkages as a single-

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number indicator—linking climate change and mental health outcomes—remains elusive, yet quantifying these effects is of clear importance.[76]

Section 2: adaptation, planning, and resilience for health

As knowledge of the health consequences of climate change increases, so too does the urgent need to increase efforts to protect people from adverse effects, particularly given the slow progress of mitigation of these effects. Health systems will be placed under increasing and overwhelming pressure, and adaptation to climate change is essential, even with the most ambitious mitigation efforts.[58] An adaptation gap is apparent, emphasised in some of the aforementioned impacts, and the rapid introduction of adaptation initiatives with better development strategies and funding across all sectors is necessary to close this divide. The health sector was selected as one of the top three priority areas for adaptation in an analysis of Intended Nationally Determined Contributions prepared for the Paris Agreement.[77]

By their very nature, adaptation and resilience measures are local and specific to regional hazards and underlying population health needs. Identifying readily available global metrics, with adequate data and proximity to climate change and to health adaptation, is particularly challenging.[78–80] Additionally, evaluating the success of any intervention is difficult, given that the goals of adaptation are inherently long-term, and no counterfactual is readily available. Rising to this challenge, the work in this section has expanded, from the initial three indicators proposed in 2016,[19] to the eight presented here. The structure of these indicators, and this section, builds on the WHO Operational Framework for building climate resilient health systems,[81] monitoring progress across the following selected domains: adaptation planning and assessment (indicators 2.1.1, 2.1.2, and 2.1.3), adaptive information systems (indicator 2.2), adaptation delivery and implementation (indicators 2.3.1 and 2.3.2), and adaptation financing (indicator 2.4.1).

True to an iterative approach, many indicators have been further developed. For the indicators evaluating national health adaptation planning and vulnerability mapping (indicators 2.1.1 and 2.1.2), the number of country respondents has increased from 40 to 101. Additional information on implementation and government funding is included alongside qualitative analysis, which was undertaken as part of the validation of the self-reported data. A new indicator has been added, focusing on air conditioning use as an adaptive measure to heat mortality (indicator 2.3.2). This is the first of a new suite of indicators under development, which monitor adaptation to a specific exposure pathway, complementing existing work on health adaptation efforts.

Several indicators in this section rely on self-reported data in surveys of national and subnational governments to track health adaptation, with clear strengths and limitations to this approach. Self-reported survey data is subject to response and non-response error, with local verification difficult;[79] however, the datasets here—from the WHO and the Carbon Disclosure Project (CDP)—provide the best available information on national-level and city-level specific health adaptation measures, globally. Further information on the validation techniques of the national data is summarised (appendix pp 48–49).

Indicator 2.1: adaptation planning and assessment

Indicator 2.1.1: national adaptation plans for health—headline finding: recognition of the need for health adaptation to climate change is widespread, and development planning is underway. In 2018, almost half of the countries surveyed declared that a national health and climate change plan was in place—Over the past decade, a steady increase in countries scaling up health adaptation projects to build climate resilience has been observed.[82] This indicator, based on data from the 2018 WHO Health and Climate Change Country Survey,[83] tracks the number of countries that have a national health and climate change plan or strategy, current levels of their implementation, and the commitment of national health funds for achieving the health adaptation and mitigation priorities outlined by governments in these documents. Importantly, the country response rate has more than doubled, with 101 of the 194 Member States reporting in the 2018 survey compared with 40 reporting in the 2015 survey presented in earlier *Lancet* Countdown reports.[20]

Global coverage of national adaptation plans for health is growing, with 51 of 101 countries now having a national health and climate change plan in place. Just over half of these countries report at least a moderate level of implementation of their plans; however, challenges to full implementation remain, with less than 20% of countries reporting actions underway or plans in place to address most of their key priorities (figure 9). National funding for implementation of health and climate change plans was identified as a central constraint with fewer than 4 in 10 countries reporting at least partial funding for the implementation of their main health adaptation and mitigation priorities.

A further analysis of approximately 40 strategies or plans, collected as part of the survey, emphasises that the comprehensiveness and scope of the national health and climate strategies or plans varied widely, with only a small number of plans directly linked to the National Adaptation Plan (NAP) process as part of the UN Framework Convention on Climate Change (UNFCCC). About 30% of the national health and climate change plans were published more than 5 years ago. Opportunities exist in national health and climate planning to update and expand the comprehensiveness of plans and for these to be developed into health components of NAP,[81] thereby anchoring health within national climate processes and potentially strengthening access to international climate finance for health adaptation.

Indicator 2.1.2: national assessments of climate change impacts, vulnerability, and adaptation for health—headline finding: of 101 countries surveyed in 2018, 48 indicated that a national assessment of health vulnerability to climate change had been done. However, of these 48 countries, just over 40% reported that assessment findings had influenced the allocation of human and financial resources—An adequate health adaptation response requires an assessment of the vulnerability of populations to different kinds of health effects, an assessment of local geographical and meteorological trends, and assessment of the corresponding capacity of health services. A health vulnerability and adaptation assessment serves as a baseline analysis, against which changes in disease risks and protective measures can be monitored, and strengthens the case for investment in health protection.[84] Data for this indicator is sourced from the 2018 WHO Health and Climate Change Country Survey.[83] Additional information on the survey methods and data is presented (appendix pp 49).

An increasing number of countries are implementing national vulnerability and adaptation assessments, with most countries indicating that these assessments are having at least some influence over policy prioritisation. However, translating evidence into funding decisions remains an issue, with only 40% of countries reporting that resource allocation is guided by evidence generated from vulnerability and adaptation assessments for health.

Indicator 2.1.3: city-level climate change risk assessments—headline finding: in 2018, 54% of global cities surveyed expected climate change to seriously compromise their public health infrastructure, with 69% of cities actively developing or having completed a comprehensive climate change risk or vulnerability assessment—The effects of climate change are experienced locally, with cities and local governments forming a crucial component of any health adaptation response. For this indicator, The *Lancet* Countdown works with the CDP to include data from their annual global survey of cities.[85] Two components of this data are analysed: the number of global cities that have undertaken a city-wide climate change risk or vulnerability assessment; and their perceived vulnerability to climate change of critical health infrastructure. In 2018, 489 cities participated in the survey, with 297 (61%) from high-income countries.

Just over half (52%) of all responding cities have undertaken an assessment and about a quarter either have an assessment in progress (17%) or intend to undertake an assessment in the future (7%). These values represent a small, but steady increase from 2017.[37] The health impacts of climate change are of increasing concern for cities, with 54% of responding cities noting that critical assets or services related to public health would be affected by climate change, compared with 51% in 2017.[37]

Indicator 2.2: climate information services for health

Headline finding: progress has been observed in the number of countries providing climate services to the health sector, increasing from 55 in 2018 to 70 in 2019—Meteorological and hydrological services should work with health services to monitor and prepare for the climate-related risks to health tracked in section 1.[81] This indicator tracks national climate information services for health, which help monitor and prepare for climate-related health risks, using data reported by national meteorological and hydrological services to the World Meteorological Organization (WMO) Country Profile Database integrated questionnaire.

70 national meteorological and hydrological services of WMO Member States reported providing climate services to the health sector, 15 more than reported in the 2018 *Lancet* Countdown report.[37] Of these, 18 were from Africa, 5 from the Eastern Mediterranean, 22 from Europe, 13 from the Americas, 4 from South-East Asia, and 8 from the Western Pacific. Additional detail was provided by 47 respondents, with several services working with the health sector and creating products accessible to the health sector. However,

although climate services can be used for health in a range of ways, including monitoring, provision of early warning systems, and forecasting of environmental risks, application of these services to policy making remains low, with only 4 of the 47 Member States reporting that climate services are guiding health sector policy decisions and investment plans.

Indicator 2.3: adaptation delivery and implementation

Indicator 2.3.1: detection, preparedness, and response to health emergencies—headline finding: 109 countries have medium to high implementation of a national health emergency framework in place, in preparation for all public health events and emergencies—The IHR are an international legal instrument aimed at helping the global community prevent and respond to acute public health risks.[59] Countries are assessed through a set of core capacities, reported in an annual survey of State Parties. The survey was initially a yes or no questionnaire from 2010, and in 2018 was updated to a more detailed tool that assesses the degree of implementation of each of the core capacities (appendix pp 53–61). Capacity 8 (C8) of the IHR focuses on countries' national health emergency framework, which applies to all public health events and emergencies, covering disease outbreaks, air pollution, extreme temperatures, droughts, floods, and storms, as well as societal hazards (such as conflict and financial crisis). The survey encompasses three components: planning for emergency preparedness and response mechanism; management of health emergency response operations; and emergency resource mobilisation.[86]

In 2018, 182 WHO Member States completed the survey relating to C8. Of these, 109 countries had medium to high implementation of the three components for this core capacity. However, the degree of implementation varied greatly by region, with Africa reporting having achieved 21·3% and Europe having achieved 75·5% medium to high implementation of the framework, corresponding to an average score of the three C8 components of 50–74% and 75–100%.

Indicator 2.3.2: benefits and harms of air conditioning—headline finding: use of air conditioning as an adaptation measure is a double-edged sword: on the one hand, global air conditioning use in 2016 was estimated to reduce heatwave-related mortality by 23% compared with the complete absence of air conditioning; on the other hand, it also confers harms, by contributing to climate change, worsening air pollution, substantially adding to peak electricity demand on hot days, and enhancing the urban heat island effect—Indoor cooling is an important adaptation to extreme heat, with air conditioning emerging as a primary mechanism. Access to household air conditioning is highly protective against heatwave-related mortality;[87] however, it is also associated with substantial indirect harms. On hot days in locations with high air conditioning prevalence, this can account for more than half of peak electricity demand[88] which, if sourced from fossil fuels, contributes to both CO_2 and particulate matter $(PM)_{2·5}$ emissions. Additionally, waste heat from air conditioning can paradoxically increase external night temperatures by more than 1°C.[89] Hydrofluorocarbon refrigerants used for air conditioning can escape into the atmosphere where they act as powerful greenhouse gases. In baseline scenarios, these hydrofluorocarbon emissions will increase to 1–2 gigatons of CO_2 equivalent ($GtCO_2e$) per year by 2050.[90,91] Consequently, a nuanced approach to heat adaptation must be deployed, which protects vulnerable populations across the world from heat-related morbidity and mortality, while minimising the health-associated harms of air pollution, the urban heat island effect, and contribution to climate change.

This new indicator includes four components: the proportion of households using air conditioning; the prevented fraction of heatwave-related mortality attributable to air conditioning use; CO_2 emissions attributable to air conditioning use; and premature mortality from air conditioning attributable to $PM_{2·5}$. Unpublished data for household air conditioning use, electricity consumption, and CO_2 emissions was provided by the International Energy Agency (IEA). The prevented fraction,[92] (the percent reduction in heatwave-related deaths due to a given proportion of the population having household air conditioning, compared with a complete absence of household air conditioning) was calculated using a relative risk for heatwave-related mortality of 0·23 for having household air conditioning compared with not having household air conditioning,[87] and the proportion of populations with household air conditioning. The relative risk estimate used for these calculations is based on studies focused on European and US populations, and further research is required to fully understand the effect modification across different contexts.[87] The air pollution source attribution methods discussed in section 3 (indicator 3.3.2) were used to calculate deaths due to $PM_{2·5}$ emissions from air conditioning.

Between 2000 and 2016, the world's air conditioning stock (residential and commercial) more than doubled to 1·62 billion units and the proportion of households with air conditioning increased from 21% to about 30% (figure 10). In 2016, this proportion was 4% in India, 14% in the EU, 58% in China, and more than 90% in the USA and Japan. Correspondingly, the global prevented fraction of heatwave-related mortality increased from 16% in 2000 to 23% in 2016, ranging from less than 10% in India, Indonesia, and South Africa to more than 66% in the USA, Japan, and Korea.

These trends have also been associated with increased harms. In 2016, air conditioning accounted for 10% of global electricity consumption and 18·5% of electricity used in buildings.[93] Under the IEA's baseline scenario, these figures will increase in 2050 to 16% and 30%, respectively.[93] Following the trend in the proportion of households with air conditioning, CO_2 emissions from air conditioning use tripled from 0·35 gigatons in 1990 to about 1·1 gigatons in 2016 (figure 10), and are projected to rise to 2 gigatons in 2050 in the IEA's baseline scenario.[93] In 2016, the number of premature deaths due to $PM_{2·5}$ exposure attributable to air conditioning was 2480 in India, 2662 in China, 1088 in the EU, and 749 in the USA.

Fortunately, various paths forward provide for adaptation against heat-related mortality for those who need it, without the associated harms of greenhouse gases and $PM_{2·5}$ emissions, excessive electricity demand, and undue contribution to the urban heat island effect. Air conditioning use could be reduced by promoting energy efficient appliances and energy efficient building design through strong, enforced building codes.[93] Traditional building designs in tropical and sub-tropical regions reduce thermal stresses by providing shade,

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thermal mass, insulation, and ventilation.[93] Harms associated with air conditioning can be greatly reduced by increasing its efficiency,[93] by generating electricity from non-fossil-fuel sources, and by implementing the Kigali Amendment to the Montreal Protocol to phase-down hydrofluorocarbons.[94]

Indicator 2.4: spending on adaptation for health and health-related activities

Headline finding: in 2018, global spending on health adaptation to climate change was estimated to be £13 billion (5%) of all adaptation spending, and health-related spending was estimated at £35 billion (13·5%). These estimates represent increases in absolute and relative terms over previous data—A higher demand for health adaptation measures requires increased adaptation funding. This indicator tracks adaptation spending, using 2015–16, 2016–17, and 2017–18 data from the Adaptation and Resilience to Climate Change dataset produced by kMatrix,[95] as described in the 2017 and 2018 reports.[20,37] Health adaptation spending is defined as national adaptation spending specifically within the formal health-care sector, whereas health-related adaptation follows adaptation spending for disaster preparedness and agriculture, in addition to health care. Data in this year's indicator covers 191 countries and territories reported in the Adaptation and Resilience to Climate Change dataset. Per-capita values are based on 183 countries with population estimates from the International Monetary Fund (IMF) World Economic Outlook.[96]

Spending on adaptation to climate change in health and health care increased by 11·2% in 2017–18, compared with 2016–17 data. This percentage increase is notably larger than the change in total adaptation spending generally (an increase of 6·5% from 2016–2017). At the country level, growth of health adaptation spending ranged from 17·5% (UK) to 10% (Latvia); however, smaller increases and less variation were recorded for health-related values, from 11·1% (UK) to 6·8% (Kazakhstan). Importantly, health still represented a small proportion of the total adaptation spend, having grown from 4·6% in 2015–16 to 5·0% in 2017–18.

Grouped by WHO Region, the highest per-capita spending for 2017–18 is in the Americas (£4·2 for health, £11·2 for health-related spending; figure 11). By contrast, in the African, Eastern Mediterranean, and South-East Asian regions, per-capita health adaptation spending is less than £1.

Conclusion

Although many of the indicators presented in section 2 are moving in a positive direction, the pace of the adaptation response from the health community remains slow. The number of countries with national adaptation plans for health and the number of countries and cities that have assessed health risk and vulnerabilities has increased, along with the spending on health adaptation. Thorough consideration of the best adaptation options is required before implementation. For example, the health benefits of adaptation measures such as air conditioning might be counteracted by harms caused through a contribution to heat generation, climate change, and air pollution (indicator 2.3.2).

These findings and those from the UN Environment Adaptation reports show that further work is required globally, both in terms of the planning and implementation of adaptation measures, to improve health.[97,98]

Section 3: mitigation actions and health co-benefits

As emphasised in section 1, climate change has already impacted human health and requires an urgent response, both in terms of health adaptation (section 2) and importantly, in mitigation, to minimise future effects from climate change.

In keeping with the Paris Agreement's commitment of limiting temperature increase to "well below 2°C", and to pursue the 1·5°C target, global emissions must peak as soon as possible (some studies suggest as early as 2020) and then follow a steep decline to 2050.[2] However, current mitigation actions and commitments are not consistent with this goal. Total global greenhouse-gas emissions for 2017 were the highest ever recorded, at 53·5 $GtCO_2e$.[99] The sum of all nations' current commitments under the Paris Agreement is far from sufficient, with 2030 emissions estimated to be lowered by only 6 $GtCO_2e$—which is only a half of the reduction required to achieve the 2°C scenario, and a fifth of that necessary to achieve the 1·5°C goal.[97]

Discussions of greenhouse-gas emission reductions must be directly interlinked with any associated potential positive economic and health benefits. Mitigation actions not only improve health in the long term, through minimising climate change, but can also have near-term benefits through numerous pathways such as reductions in risk of respiratory and cardiovascular disease attributable to air pollution,[8] reductions in the risk of diseases associated with physical inactivity and obesity (because of increased cycling and walking),[100] and a variety of improvements that could result from healthier diets.[101]

This section of the *Lancet* Countdown 2019 report tracks mitigation and its health consequences in different sectors including: energy (indicators 3.1.1, 3.1.2, 3.2); air pollution (indicators 3.3.1, 3.3.2); transport (indicator 3.4); agriculture (indicator 3.5); and health care (indicator 3.6).

Crucially, two new indicators of great importance to health have been added to the section: emissions attributable to livestock and crops (allowing a more nuanced discussion about the health and climate benefits of reductions in ruminant meat consumption), and emissions from national health-care systems. This section will continue to expand in future years by monitoring mitigation and health co-benefits in other important sectors, including industry, buildings, and land use.

Overall, CO_2 emissions from fossil fuels have risen by 2·6% from 2016 to 2018 (indicator 3.1.1). Concerningly, the previous downward trend in coal supply has reversed, with a 1·7% increase recorded in total primary energy supply from 2016 to 2018 (indicator 3.1.2). However, more encouragingly, growth in renewables continues apace and comprised 45% of total growth in electricity generation. At present, modern renewables represent 5·5% of global electricity generation (indicator 3.1.3), but are predicted to reach 30% by 2023.[102] The implications of maintenance of both of these trends are important for air pollution. A continued demand for fossil fuels and an increase in coal consumption have resulted in the number of deaths attributable to ambient air pollution remaining stagnant (2·9 million deaths in 2016; indicator 3.3.2).

The transport sector is an equally entrenched emitter of greenhouse gases, with emissions and fuel use maintaining a modest growth trajectory of 0·7% per capita CO_2e in 2016. Although use of electric vehicles has increased, they continue to represent a small proportion of the global vehicles worldwide. Yet, countries such as China have positioned electric vehicles as the future of driving with electricity in transport, with 21·4% growth in per capita usage from 2015 to 2016, rising from 1·5% to 1·8% of total fuel use (indicator 3.4).

Feeding the global population is a crucially important aspect of health and wellbeing along with ensuring economic stability and security. However, the agriculture and food sector are both energy and carbon intense and an important area for climate change mitigation. Global agricultural greenhouse-gas emissions (indicator 3.5) have increased between 2000 and 2016 by 14% for livestock and 10% for crops.

As outlined in sections 1 and 2, the health sector is on the frontline of climate change and plays a vital role in any response. This sector is also a major contributor of greenhouse-gas emissions (indicator 3·6), with global estimates as high as 4·6% of global emissions in 2016.

Indicator 3.1: emissions from the energy system

Indicator 3·1.1: carbon intensity of the energy system—headline finding: in 2018, the carbon intensity of the energy system remained unchanged from 1990. However, greenhouse-gas emissions from fossil fuel combustion have returned to a growth trajectory, rising by 2·6% from 2016 to 2018. Limiting warming to 1·5°C would require a 7·4% year-on-year reduction from 2019 to 2050—In the 2019 *Lancet* Countdown report, this indicator includes data up to 2016, supplemented with additional statistics for global CO_2 emissions from energy combustion for 2017[103] and 2018.[104] It tracks the carbon intensity of the energy system, monitoring the CO_2 emitted per terajoule of total primary energy supply (TPES). TPES reflects the total amount of primary energy used in a specific country, accounting for the flow of energy imports and exports. Key improvements in this analysis are seen in the disaggregation of fuel type, the extension of data from 1970, and the inclusion of new projections forward to 2050. A full description of data and methods is provided (appendix pp 68–69).

Global emissions of CO_2 from fossil fuel combustion, having been flat between 2014–16, have increased to a new high of 33·1 $GtCO_2$ in 2018 (figure 12).[104] This 2·6% increase over the past two years has resulted from continued growth in energy demand—energy mostly from fossil fuels.

The carbon intensity of the energy system will need to reduce to near zero by 2050. Over the past 15 years, carbon intensity has largely plateaued, as the growth of low-carbon energy has been insufficient to displace fossil fuels. However, IEA data suggest that carbon intensity could be starting to reduce, with gas slowly displacing coal (figure 12).[104]

Indicator 3.1.2: coal phase-out—headline finding: TPES from coal increased by 1·7% from 2016 to 2018, driven by growth in China and other countries in Asia—Coal phase-out is essential, not only as a key measure to mitigate climate change, but also to reduce morbidity and mortality from air pollution.[8] As of December, 2018, 30 national governments, along with many sub-national governments and businesses, have committed to coal phase-out for power generation through the Powering Past Coal Alliance.[105] In this year's *Lancet* Countdown report, this indicator tracks TPES from coal, plus projections for coal phase-out, using the scenarios that informed the IPCC Special Report on Global Warming of 1·5°C.[2]

Coal has returned to a growth trajectory from 2016 to 2018 (figure 13); however, because of the overall growth in global energy demand, the share of coal in primary energy supply continues to fall (appendix pp 70–73). Coal continues to be the second largest contributor to global primary energy supply (after oil) and the largest source of electricity generation (at 38%, compared with gas, the next highest at 23%). Most of the growth in TPES of coal has been in Asia, notably China, India, and southeast Asia.

Rapidly decreasing coal use to zero is crucial to meeting the commitments of the Paris Agreement. For example, no less than an 80% reduction in coal use from 2017 to 2050 (a 5·6% annual reduction rate) is consistent with a 1·5°C trajectory (appendix pp 70–73). However, given that the technology to support coal phase-out exists, a more rapid reduction rate is probably feasible.

Indicator 3.1.3: low-carbon emission electricity—headline finding: in 2018, renewable energy continues to account for a large share (45%) of growth in electricity generation, with 27% of growth from wind and solar sources—With the power generation sector accounting for 38% of total energy-related CO_2 emissions, the displacement of fossil fuels with renewable energy sources is of crucial importance.This indicator tracks total low carbon electricity generation (which includes nuclear sources and all renewables, including hydro) and new renewable electricity generation (excluding hydro), using the World Extended Energy Balances dataset from the IEA.[104] Renewable electricity generation was also projected using the scenarios that informed the IPCC Special Report on Global Warming of 1·5°C.[2] A full description of the datasets, methods, and projections is presented (appendix pp 73–75).

In 2016, low-carbon electricity globally accounted for 32% of total global electricity generation (figure 14). Promisingly, renewable energy accounted for 45% of growth in electricity generation in 2018,[106] and solar generation continues to grow at an unprecedented rate of around 30% per annum (but still only accounting for 2% of total global generation).[107]

An assessment of scenarios compliant with the 1·5°C goal emphasises that generation from new renewable sources (solar, wind, geothermal, wave and tidal) need to increase by 9·7% per annum, so that generation in 2050 is larger than total global electricity use today. Since 1990, the annual growth rate for these renewable sources was more than 14%, a very promising trend, but one that must be maintained for a further three decades.

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Indicator 3.2: access and use of clean energy

Headline finding: almost 3 billion people live without access to clean fuels and technologies for cooking, and only 7·5% of households in low-income countries report using such fuels—Globally, 3·8 million deaths per year are estimated to be attributable to household air pollution,[108] largely arising from use of solid fuels, such as coal, wood, charcoal, and biomass, for cooking. Efforts to provide clean cooking and heating technologies could result in substantial health co-benefits in addition to reducing greenhouse-gas emissions and short-lived climate pollutants.[108–111] Additionally, universal access to affordable, reliable, sustainable, and modern energy for all is a key determinant of economic and social development and is central to health and wellbeing.[112,113]

This indicator combines both a top-down and bottom-up approach from IEA and WHO datasets, capturing total household energy use and household fuel use for cooking, respectively.[114,115] The new data on household clean fuel use represents an impressive effort from WHO, combining the results of thousands of national household surveys done across three decades and in more than 140 countries. Details of the methods, definitions, and data for this indicator are presented (appendix pp 75–76).

Use of clean fuels and technologies for cooking for 2015–17 remained low, at 7·5% in households in low-income countries, and 40% in households in lower middle-income countries (figure 15). These data reflect a slow improvement in global access to clean cooking fuels and technologies, which has increased by just 1% since 2010, with almost 3 billion people remaining in access-deficit.[116]

Concerningly, although access to electricity has risen from 83% in 2010 to 87% in 2016, residential clean energy usage—which, at point of demand, includes electricity of all sources, solar thermal and geothermal—remains low. In 2016, the global proportion of clean energy use in the residential sector was approximately 24%, an increase from 17% recorded in 2010.[114] Solid biomass, which contributes to respiratory and cardiovascular diseases attributable to household air pollution,[117] is currently estimated to account for 36% of total residential sector energy use.

Future forms of this indicator will work to link residential energy and fuel use to household air pollution morbidity and mortality across the world. One possible approach to achieving this linkage is presented, discussing slum housing in Viwandani in Nairobi, Kenya (panel 2).

Indicator 3.3: air pollution, transport, and energy

Exposure to ambient air pollution, most importantly fine particulate matter ($PM_{2·5}$), constitutes the largest global environmental risk factor for premature mortality, and results in several million premature deaths from cardiovascular and respiratory diseases every year.[8,123,124] More than 90% of children are exposed to $PM_{2·5}$ concentrations that are above the WHO guidelines,[125] which can affect their health throughout their life, with an increased risk of lung damage, impaired lung growth and pneumonia, and a subsequent risk of developing asthma and chronic obstructive pulmonary disease.[126] Most of the exposure to $PM_{2·5}$ results from anthropogenic activities, and much of this is associated with combustion of coal and other fossil fuels for electricity generation, industrial production, transport, and household heating and cooking; therefore, $PM_{2·5}$ emissions share many of the same sources as greenhouse-gas emissions.[127]

Indicators 3.3.1 and 3.3.2 report on source contributions to ambient air pollution and its health effects, drawing from the GAINS model,[128] which calculates emissions of all precursors of $PM_{2·5}$ by use of a detailed breakdown of economic sectors and fuels used. Underlying activity data are based on statistics reported by the IEA.[129]

Indicator 3.3.1: exposure to air pollution in cities—headline finding: urban citizens have continued exposure to high levels of air pollution, with 83% of cities exceeding the WHO's recommended safe concentrations. Energy use, particularly residential combustion, is a major contributor to this pollution

The world is becoming increasingly urbanised, with almost 70% urbanisation of the global population expected by 2050.[130] Because of the increased population and higher concentrations of emissions, many cities have become hot spots of air pollution. Few cities worldwide have achieved $PM_{2·5}$ concentrations that are below the WHO guideline of an annual mean of 10 μg/m^3, and many cities exceed this guideline amount several-fold.[131] The highest measured concentrations currently have been reported in south and east Asia, while data gaps exist in other world regions. The fact that these high $PM_{2·5}$ concentrations have been further increasing or stagnant in many regions of the developing world is particularly concerning. A positive exception to this trend is China, where many highly polluted cities have improved air quality because of their ambitious emission control efforts. Cities in Europe and the USA have seen slowly decreasing $PM_{2·5}$ concentrations with effective implementation of air pollution control legislation and regulation.

This analysis estimates source contributions to ambient $PM_{2·5}$ concentrations in urban areas outside Europe (more than 3500 cities with more than 100 000 inhabitants), with results aggregated to the WHO world regions—83% of these cities do not meet the WHO guideline regarding ambient $PM_{2·5}$ concentrations.

In most regions, residential combustion of solid fuels for cooking and heating was the dominant source of high $PM_{2·5}$ concentrations in 2016. Although coal is prominent in some countries, most of the burden arises from the use of biomass in traditional stoves, which is often associated with net greenhouse-gas emissions due to unsustainable harvesting.

Indicator 3.3.2: premature mortality from ambient air pollution—headline finding: in 2016 there were 2·9 million premature deaths globally that were associated with ambient $PM_{2·5}$ pollution, with minimal improvement in global mortality from 2015. On a decadal scale, improvements are seen in some regions because of efficient emission controls, particularly from industrial processes and power generation

Knowledge of the sources of ambient air pollution is essential for designing efficient mitigation measures that maximise benefits for human health and climate. This indicator estimates the source contributions to ambient $PM_{2·5}$ and their global health impacts, quantifying contributions from individual economic sectors and assessing coal combustion across sectors.

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Results for 2016 are similar to the estimates for 2015, with an overall number of premature deaths attributable to ambient $PM_{2\cdot5}$ estimated at 2·9 million. The dominant contribution varies between and within world regions: in Africa, household cooking primarily contributes to high $PM_{2\cdot5}$ concentrations; whereas in other regions, industry, transport, electricity generation, and agriculture are the primary contributors (figure 16). Small decreases in the number of premature deaths have been observed in the European region and the Western Pacific region (mainly from closing of coal power plants). Sustained improvements over the past 10 years have been recorded in these regions, presumably due to implementation of end-of-pipe emission controls on power plants (Western Pacific) and on other emission sectors in Europe. However, worldwide, more than 440 000 premature deaths are still estimated to be associated with coal burning.

Indicator 3.4: sustainable and healthy transport

Headline finding: global road transport fuel use increased by 0·7% from 2015 to 2016 on a per-capita basis. Fossil fuels continue to dominate as the primary transport fuel, but their growth is being tempered somewhat by rapid increases in biofuels and electricity—As with electricity generation, the transition to cleaner fuels for transport is important for climate change mitigation and will have the added benefit of reducing mortality from air pollution.[100] Fuels used for transport currently produce more than half of the nitrogen oxides emitted globally and a substantial proportion of particulate matter, posing a large threat to human health, particularly in urban areas (indicator 3.3).[132] Additionally, the health benefits of increasing uptake of active forms of travel (walking and cycling) have been shown through a large number of epidemiological and modelling analyses.[17,49,100,133,134] Encouraging active travel (particularly cycling) has become increasingly central to transport planning, and growing evidence suggests that bikeway infrastructure, if appropriately designed and implemented, can increase cycling in various settings.[135] A modal shift in transport could also result in reductions in air pollution from tyre, brake, and road surface wear, in addition to a reduction in exhaust-related particulates.[136]

Global trends in fuel efficiency and the transition away from the most polluting and carbon-intensive transport fuels are monitored using data from the IEA; specifically, it follows the metric of fuel use for road transportation on a per-capita basis (TJ/person) by type of fuel.[37,137] In response to feedback, this year's indicator displays data in three categories of fuel: fossil fuels, biofuels, and electricity.

Globally, per-capita fuel use increased by 0·7% from 2015 to 2016 (figure 17). Although fossil fuels continue to contribute 95·8% of total fuel use for road transport, the use of clean fuels is growing at an increasing rate: fossil fuel use increased by 0·5%, compared with 3·3% growth in use of biofuels and 20·6% growth in use of electricity. In China, electricity now represents 1·8% of total transportation fuel use. This is more than any other country and an 80% higher share than observed in Norway (0·85%), who have committed to 100% of new vehicles sold being zero-emission by 2025.[138] A growing number of countries and cities have announced plans to ban vehicles powered by fossil fuels and automaker

Volkswagen has announced that they will stop developing engines fuelled by petrol or diesel after 2026.[139]

A number of cities have made considerable progress towards improving the amount of cycling. Notably, cycling mode share has increased from almost zero to about 15% in Vitoria-Gasteiz, Spain, in less than a decade.[140] The city's transport policy has strongly promoted cycling though the expansion of the cycle lane network, improved cycle parking facilities, and the introduction of safety courses and new cycling regulations, in addition to enhanced communication on the health benefits of cycling.[141] The search for a more comprehensive metric of active transport remains elusive, principally limited by scarcity of data access in this field.

Indicator 3.5: emissions from livestock and crop production

Headline finding: total emissions from livestock have increased by 14% and emissions from crop production have increased by 10%, from 2000 to 2016, with 93% of livestock emissions attributed to ruminants—Obesity and undernutrition present two great challenges to global public health, and both these forms of malnutrition share many common systemic drivers with climate change.[142] Current dietary trends are contributing to both non-communicable diseases and greenhouse-gas emissions, with further planetary impacts including biodiversity loss and changes in water and land use.[101] In particular, excess red meat consumption contributes to the risk of cardiovascular disease and type 2 diabetes as well as increased greenhouse-gas emissions.[143] Although total emissions from crops and livestock will need to substantially decline in the future, particular attention should be given to capitalising on low-carbon production processes, and reducing the consumption of ruminant meat and other animal source foods, particularly in high-income settings.[20,37] Importantly, the nuance and complexity of any such indicator must be emphasised, and no one-diet-fits-all solution exists.[101]

For the 2019 *Lancet* Countdown report, this indicator focuses on emissions from livestock and crop production. The new analysis added here provides a novel method of understanding the emissions profile of agricultural groups—for example, ruminant livestock. A full description of the methods and data is provided (appendix pp 81–84).

Overall emissions from livestock have increased by 14% since 2000 to over 3·2 $GtCO_2e$ in 2016 (figure 18). Ruminants contribute 93% of total livestock emissions (3 $GtCO_2e$ per year), with 62–65% of this value attributed to non-dairy cattle (used for meat; appendix pp 81–84). However, the largest increase in emissions from 2000 to 2016 has come from poultry, with a recorded increase in emissions of 58% (an increase from 30·6 million tonnes CO_2e in 2000 to 48·5 million in 2016), more than double the increase from non-dairy cattle.

Total emissions from crop production have increased by 10% since 2000, to around 2 $GtCO_2e$ in 2016. Paddy rice cultivation, which releases methane, contributes around half of these emissions (47–50%), with cultivation of organic soils (such as peatlands) contributing 27–29%, and addition of nitrogen fertilisers (synthetic and manure) to soils contributing 21–25%.

Indicator 3.6: mitigation in the health-care sector

Headline finding: greenhouse-gas emissions from the global health-care sector were approximately 4·6% of the global total emissions—section 2 emphasises the central role of the health-care sector in managing the damages to health resulting from a changing climate; however, this sector is also a large contributor of greenhouse-gas emissions, both directly and indirectly through purchased goods and services. National-level studies for the USA,[144] Canada,[145] and Australia,[146] have used environmentally-extended input-output (EEIO) modelling to show that health-care sector emissions contribute between 4% and 10% of total greenhouse-gas emissions in these countries. EEIO models have been widely used since the 1970s,[147] and underpin consumption-based accounting of emissions done at national and global scales.[148] An important advantage of using EEIO modelling is that health-care sector emissions are estimated on a life cycle basis, meaning that all emissions are accounted for, from the electricity use of health-care facilities, to the energy to produce and transport medical equipment and pharmaceuticals.

National-level studies cannot easily be compared because of differences in how emission inventories, monetary input-output tables, and health expenditure data are collected in each country. Additionally, a proportion of health-care sector emissions in each country is imported from other countries as embodied carbon in traded commodities, thus requiring a global scope and the use of multi-region input-output (MRIO) models that cover more than one country. For this edition of The *Lancet* Countdown, a standardised, international measure of health-care sector greenhouse-gas emissions was created using multiple MRIO models (EXIOBASE, WIOD; figure 19) that cover 40–47 countries and rest-of-world regions, in combination with WHO health expenditure data for 187 countries, assigned to the MRIO model geographic units.

Variations in per-capita greenhouse-gas emissions associated with health care as a function of time, affluence, and the proportion of national economic output spent on health care are shown (figure 19). Per capita, US emissions are substantially higher than those of any other country and have risen steadily over the study period 2007–16, with a 19% increase. However, per-capita health-care emissions of other countries have increased even more substantially, albeit from a lower base, including China (CN, 180% increase), South Korea (KR, 75%) and Japan (JP, 37%). By contrast, health-care greenhouse-gas emissions in Greece showed a marked decrease (GR, –35%), probably reflecting the economic hardships. Results using the WIOD MRIO model show similar trends but slightly lower absolute greenhouse-gas emissions. The lowest per capita emissions modelled were for India (IN) and Indonesia (ID), which were less than 2·5% of values recorded for the USA. Comparison of emissions per capita and Gross Domestic Product (GDP) per capita show a levelling off trend for health-care emissions versus affluence, except for in the USA.

Overall, health care was responsible for approximately 2250 metric tonnes of CO_2e in 2016, or 4·6% of the global total emissions (excluding land use change). A parallel global analysis using a different MRIO model (EORA) measuring CO_2 only (excluding other greenhouse gases) for 36 countries determined a health-care contribution of 4·4% to the global total for the countries considered,[149] corroborating the results presented here. Although global health-sector greenhouse-gas emissions are rising, efforts to reduce these have begun (panel 3).

Conclusion

The indicators of section 3 present a mix of encouraging and concerning trends. Renewable electricity generation continues to grow, as does access to energy, and electric vehicle sales. However, the carbon intensity of the energy system remains unchanged, with coal supply increasing, reversing the 2014–16 downward trend, and a substantial effort is required to decarbonise the agricultural sector and the health-care sector. In summary, greenhouse-gas emissions continue to rise. Notably, the year 2020 is important for two reasons—it is the year that the implementation period of the Paris Agreement begins, and the year during which most studies suggest global emissions must peak to remain on the path to achieving the 1·5°C goal. To meet both commitments, a substantially stronger global response is urgently required, to reduce greenhouse-gas emissions and minimise the future health risks of climate change. The health sector has an important role to play in achieving these goals, both by reducing its own emissions and working with policy makers to help design and implement measures that reduce greenhouse-gas emissions and maximise health co-benefits.

Section 4: economics and finance

Section 4 examines the financial and economic dimensions of the effects of climate change, and of mitigation efforts required to respond to these changes. Although many indicators in this section could appear to be distant from human health, they are key to tracking the low-carbon transition that underpins current and future determinants of human health and wellbeing described in sections 1–3.

The projected economic cost of inaction to tackle climate change is enormous. For example, compared with maintaining a 2°C limit, the costs of 3°C of warming are expected to reach US$4 trillion per year by 2100 (around 5% of total global GDP in 2018), and the total economic costs of a 4°C rise are estimated at US$17·5 trillion (over 20% of GDP in 2018).[152]

Investment to mitigate climate change substantially reduces these risks and generates further economic benefits. For example, the UK's independent Committee on Climate Change calculated that achieving net-zero emissions in the UK in 2050, in line with the more ambitious objective of the Paris Agreement, is likely to require investments of 1–2% of the UK's GDP in 2050. However, if the economic value of co-benefits to human health (and savings to the NHS—for example, from reduced air pollution), and the creation of low-carbon industrial opportunities are considered, the economic implications are likely to be positive.[153] Global economic benefits are likely to be maximised (and costs minimised) if strong policy action is taken as soon as possible to accelerate the low-carbon transition.

The nine indicators in this section fall into four broad themes: economic costs of climate change (indicator 4.1); economic benefits of tackling climate change and air pollution

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(indicator 4.2); investing in a low-carbon economy (indicators 4.3.1, 4.3.2, 4.3.3, and 4.3.4); and pricing greenhouse-gas emissions from fossil fuels (indicators 4.4.1, 4.4.2, and 4.4.3).

The 2019 report adds an additional indicator tracking the economic value of change in mortality associated with air pollution (indicator 4.2).

Indicator 4.1: economic losses associated with climate-related extreme events

Headline finding: in 2018, a total of 831 climate-related extreme events resulted in overall global economic losses of US$166 billion. Although most losses were in high-income countries and insured, no measurable losses from events in low-income countries were covered by insurance—The indicators in section 1 presented changes in exposures and resulting effects on health of climate-related extreme events (indicators 1.2.1, 1.2.2, and 1.2.3). The economic costs of extreme climate-related events might exacerbate the direct health impacts that these events produce. This indicator tracks the total annual economic losses (insured and uninsured) across country income groups relative to GDP, resulting from climate-related extreme events.

The data for this indicator is sourced from Munich Re's NatCatSERVICE,[154] with climate-related events categorised as meteorological, climatological, and hydrological events (geophysical events are excluded) as well as data from the World Bank Development Indicator Database.[155] The methodology remains the same as was used in the 2018 *Lancet* Countdown report.[37] Full methodology, along with data for 1990–2018 are presented (appendix p 87–90).

Insured and uninsured economic losses resulting from extreme climate-related events, relative to GDP, are shown (figure 20). Absolute global economic losses in 2018 were US$166 billion, around half the value experienced in 2017, but still higher than any other year since 2005. Economic losses are highest in high-income countries, but more than half of these losses in high-income countries were insured. By contrast, although in previous years less than 1% of losses in low-income countries were insured (for example, US$20 million of $1·9 billion losses in 2017), in 2018, not a single event recorded created measurable losses covered by insurance.

Indicator 4.2: economic costs of air pollution

Headline finding: across Europe, improvements in particulate air pollution from human activity were seen from 2015 to 2016. If the change in pollution over these 2 years remained the same over the course of a person's life, this difference would lead to an annual average reduction in YLL worth €5·2 billion —indicator 4.2 is a new indicator for the 2019 report and is the first indicator tracking the economics of the health co-benefits of climate change mitigation, capturing the economic costs of the effect of air pollution on human health (indicator 3.3.2). It will be developed into a full suite of metrics over the coming years, with 2019 presenting values for the EU alone.

This indicator is based on estimates of the total YLL to the 2015 population of EU Member States that results from the change in anthropogenic $PM_{2·5}$ exposure from 2015 to 2016, if such emissions and subsequent population exposure were to remain constant over the course of their remaining lifetimes. Each YLL is assigned a Value of a Life Year of €50 000, which is the lower bound estimate as suggested by the EU Impact Assessment Guidelines.[156] Further details regarding this indicator are discussed (appendix pp 90–93).

As described under indicator 3.3.2, anthropogenic $PM_{2·5}$ pollution decreased between 2015 and 2016 in Europe, largely because of a reduction in emissions from the power sector. If the population of the EU in 2015 were exposed to anthropogenic $PM_{2·5}$ emissions at the concentrations recorded in 2016 (rather than the concentration recorded in 2015) consistently to the year 2115, the total annual average economic value of the reduction in YLLs would be about €5·2 billion. However, even at the concentrations of anthropogenic $PM_{2·5}$ pollution recorded in 2016, the total annual average cost to the population of 2015 would still be €129 billion, with the greatest costs generally found in countries with the largest populations. The greatest projected average life lost per person due to high ambient $PM_{2·5}$ concentrations is seen in Hungary, Romania, and Poland (at more than 8 months per person), with an EU average of 5·7 months of life lost per person.

For the first iteration of this indicator, calculation of annual YLLs attributable to $PM_{2·5}$ exposure in a given year was not possible. However, methodological refinements should allow this metric to be reported in the 2020 report.

Indicator 4.3: investing in a low-carbon economy

Indicator 4.3.1: investment in new coal capacity—headline finding: global investment in new coal-fired electricity capacity declined again in 2018, continuing the downward trend observed since 2011—Indicator 3.1.2 tracks progress on coal phase-out through the total primary energy supply of coal, while this indicator discusses the future of coal-fired power generation through tracking investments in coal-fired capacity.

The data source for this indicator (IEA) remains the same as in the 2017 *Lancet* Countdown report;[20] however, the methodology has altered and has been retrospectively applied to reanalyse all data presented. The revised approach considers ongoing capital spending, with investment in a new plant spread evenly from the year new construction begins, to the year it becomes operational. Previously, data was presented as a so-called overnight investment, in which all capital spending on a new plant is assigned to the year in which the plant became operational (appendix p 93). Data for 2006–17 using the overnight method are presented for comparison with the ongoing capital spending method (figure 21).

Although TPES for coal increased in 2018 (indicator 3.1.2), investment in new coal-fired electricity generating capacity continued the downward trend observed since 2011. Notably, this decline was mostly due to reduced investment in the same countries that increased their coal TPES in 2018 (China and India), providing hope for coal phase-out. The number of total Final Investment Decisions (ie, the decision to begin construction) declined by 30% in 2018, with costs and construction times for new plants generally increasing because of larger, more efficient, and complex designs, and the use of advanced pollution control systems, in response to concerns regarding air quality.[157]

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Indicator 4.3.2: investments in low-carbon energy and energy efficiency—headline finding: trends in energy investments are currently heading in the wrong direction. In 2018, investments in fossil fuels increased, whereas investments in low-carbon energy decreased—Indicator 4.3 monitors global investment in low-carbon energy, energy efficiency, fossil fuels, and electricity networks. It complements the tracking of low-carbon electricity generation (indicator 3.1.3) in section 3 and potentially predicts future trends in this indicator. All values reported are based on the value of the US dollar in 2018 with data sourced from the IEA.[157] The data sources for this indicator remain the same as described in the 2017 *Lancet* Countdown report;[20] however, the methodology has been updated (appendix pp 94–95).

Total investment in the global energy system remained stable at around US$1·85 trillion in 2018, following a steady decline between 2015 and 2017 (figure 22). Investment in fossil fuels increased slightly, driven by an increasing oil price, and investment in low-carbon energy slightly decreased, driven by reduced investment in renewable electricity—partly the result of continually declining costs. Investments in energy efficiency and electricity networks remained stable between 2017 and 2018.

In contrast to the growth in low-carbon electricity generation (indicator 3.1.3), these investment trends are not consistent with limiting warming to "well below 2°C". The IEA estimate that in order to achieve a pathway consistent with the goals of the Paris Agreement, investment in low-carbon energy, electricity networks that enable it, and energy efficiency, must collectively increase 2·5-fold by 2030 (even with further expected reductions in the cost of such technologies and actions), and account for at least 65% of total annual investment in the global energy system.[157,158]

Indicator 4.3.3: employment in renewable and fossil fuel energy industries—headline finding: in 2018, renewable energy provided 11 million jobs—an increase of 4·2% from in 2017. Employment in fossil fuel extraction industries also increased to 12·9 million—a 2% increase from in 2017—Occupational health consequences of working in certain key fossil fuel industries, such as risk of injury and respiratory disease, and risk of damage to hearing and skin, are well documented.[20] However, with appropriate planning and policy, the transition of employment opportunities from high-carbon to low-carbon industries could yield positive consequences for both the economy and human health.[159]

This indicator tracks global direct employment in fossil fuel extraction industries (coal mining and oil and gas exploration and production) and direct and indirect (supply chain) employment in renewable energy (figure 23). The data for this indicator are sourced from the International Renewable Energy Agency (IRENA) (renewables) and IBISWorld (fossil fuel extraction).[160–162] The data for fossil fuel extraction employment for 2012–2017 differs substantially from that presented in the 2018 Countdown report, because of improved data collection and estimation methods for global coal mining employment by IBISWorld. Similarly, values for hydro-power and other technologies for renewable energy employment have been revised, following methodological changes (appendix pp 95–96).

In 2018, around 11 million people were employed either directly or indirectly in the global renewable energy industry. This value represents a 4·2% increase from 2016, with growth in five of the six renewable energy categories. Employment in the solar photovoltaic industry increased by more than 7%, and remains the largest employer, with China responsible for nearly two-thirds of jobs in this industry. Overall, 32% of global renewable energy jobs are held by women.[162]

Growth in employment in the fossil fuel extractive industries has been driven by both the growth of coal mining in China and other emerging markets (particularly India), despite a decline in many high-income countries, and the upstream oil and gas industries, following rising prices in 2018. However, employment in both industries is expected to decrease in the coming years because of the slowing growth in demand for coal in key markets such as China, and a decline in other (particularly high-income) markets, as the transition to low-carbon electricity continues, along with a potential decline in oil and gas prices—coupled with increasing productivity.[160,161]

Indicator 4.3.4: funds divested from fossil fuels—headline finding: the global value of new funds committed to fossil fuel divestment in 2018 was US$2·135 trillion, of which health institutions accounted for around US$66·5 million; this represents a cumulative sum of US$7·94 trillion since 2008, with health institutions accounting for US$42 billion—Originating in the late 2000s, the divestment movement aims to remove the so-called social licence to operate from the fossil fuel industry and guard against the risk of losses from stranded assets, by encouraging investors to commit to divest themselves of assets related to the industry. The debate on the direct and indirect consequences of these approaches is nuanced and complex, with evidence regarding their effects only beginning to emerge.[163]

This indicator tracks the total global value of funds divested from fossil fuels and the value of divested funds from health institutions, by use of data provided by 350.org.[164]

From 2008 to the end of 2018, 1026 organisations with cumulative assets worth at least US$7·94 trillion, including 23 health organisations with assets of around US$42 billion, had committed to divestment, including the World Medical Association, the British Medical Association, the Canadian Medical Association, the UK Royal College of General Practitioners, and the Royal Australasian College of Physicians. The annual value of new funds committing to divesting increased from US$428 billion in 2017 to $2·135 trillion in 2018. However, health institutions have divested at a reduced rate, with just US$866·5 million divested in 2018, compared with $3·28 billion in 2017.

Indicator 4.4: pricing greenhouse-gas emissions from fossil fuels

Indicator 4.4.1: fossil fuel subsidies–headline finding: in 2018, fossil fuel consumption subsidies increased to US$427 billion, more than a third higher than 2017 subsidies, and more than 50% higher than 2016 subsidies—Negative externalities, including the various direct and indirect consequences for human health and the natural environment, mean that the true cost of fossil fuels is far greater than their market price.[165] Fossil fuel subsidies (both for their consumption and their extraction) artificially lower prices even further, promoting overconsumption, further exacerbating both greenhouse-gas emissions and air pollution.

This indicator tracks the value of fossil fuel consumption subsidies in 42 countries, most of which are not members of the Organization for Economic Cooperation and Development. Although these countries account for a large proportion of such subsidies around the world, they are by no means comprehensive, meaning that the values reported are conservative. The methodology and data source (IEA) for this indicator remains unchanged since the 2018 *Lancet* Countdown report[37] Data for 2008 and 2017, which was previously not available, is now included (appendix pp 97–102).

Although fossil fuel subsidies declined between 2012 and 2016, this trend was reversed in both 2017 and 2018, reaching US$319 billion and $427 billion, respectively (figure 24). These values do not include the economic value of the unpriced negative externalities. If these values were to be included, the IMF estimated that in 2017 global subsidies to fossil fuels increased to US$5·2 trillion—equivalent to 6·3% of Gross World Product.[166]

Indicator 4.4.2: coverage and strength of carbon pricing—headline finding: carbon pricing instruments in early 2019 continue to cover 13·1% of global anthropogenic greenhouse-gas emissions, but average prices were around 13% higher than in 2018—Adequately pricing carbon emissions is an essential component in shifting investment to develop a low-carbon economy. This indicator tracks the extent to which greenhouse-gas emissions are priced, and the weighted-average price these instruments provide (table 1), using data from the World Bank Carbon Pricing Dashboard.[167] The full methodology is presented and remains unchanged from the 2017 *Lancet* Countdown report (appendix pp 102–104).

The coverage of carbon-pricing instruments remained at around 13·1% of global anthropogenic greenhouse-gas emissions between 2018 and 2019, implemented through 44 national and 27 sub-national instruments.

Carbon prices across instruments are widely varied, from less than US$1/tonne CO_2e (tCO_2e) in Poland, Ukraine and the Chongqing and Shenzhen pilot schemes in China, to $127/$tCO_2e$ in Sweden. Weighted-average prices in early 2019 were 13% higher than 2018 prices, driven in large part by an increasing price under the EU Emissions Trading Scheme (EU ETS; the largest carbon pricing instrument in the world, responsible for nearly half of the economic value of all instruments combined). However, the weighted average of these carbon pricing instruments remains insufficient to remain "well below 2°C", which would require a carbon price of US$40–80/$tCO_2e$ by 2020,[168] and the revenue generated through carbon pricing (described in indicator 4.4.3) is far less than the potential annual impacts of unmitigated climate change on global GDP.[152]

Further carbon pricing instruments are under consideration (figure 25). With the addition of these instruments—and in particular the Chinese national Emissions Trading Scheme (ETS; replacing the existing subnational so-called pilots), more than 20% of global anthropogenic green-house-gas emissions will be covered by carbon price.[169]

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Indicator 4.4.3: use of carbon pricing revenues—headline finding: revenues from carbon pricing instruments increased by US$10 billion between 2017 and 2018, reaching $43 billion, with $24·4 billion allocated to further climate change mitigation activities—As the previous indicator outlined, adequately pricing carbon is essential for mitigating greenhouse-gas emissions. How the revenue generated by these pricing instruments is used will also have important consequences. Four ways the revenue could be used include: investment in further mitigation; investment in adaptation; recycling for other purposes (such as enabling the reduction of other taxes or levies); and contributing to other general government funds. This indicator tracks the total government revenue from carbon pricing instruments and the area in which it will be allocated.

Data on revenue generated is provided on the WBG Carbon Pricing Dashboard,[167] with revenue allocation information obtained from various sources. Only instruments with revenue estimates and with revenue received by the administering authority before redistribution are considered. Further information regarding the methodology and various sources used to obtain information on revenue allocation are presented (appendix pp 104–106).

Government revenue generated from carbon pricing instruments in 2018 totalled over US$43 billion; a $10 billion increase from the $33 billion generated in 2017. This change was driven by increasing prices of allowances sold at auction in the EU ETS; higher tax rates for instruments in Alberta, British Columbia, and France; and allowance sales in California and Quebec.[169]

The revenue allocated to mitigation activities increased by about US$10 billion between 2017 and 2018, and revenue allocated to revenue recycling and general funds also increased (table 2). Revenue allocated to adaptation reduced substantially, from more than US$1·5 billion to around $250 million.

Conclusion

Section 4 has presented indicators on the economic impacts of climate change, the financial and economic underpinnings of climate change mitigation, and the economic value of the associated health benefits. The results of these indicators suggest that the shift to a low carbon global economy is slowing in various sectors, and previously promising trends emphasised in the 2018 report have been reversed. Given the need to transition the global economy to net-zero greenhouse-gas emissions by 2050 to limit warming to well below 2°C, governments at all levels—in collaboration with the private sector and the population—must take immediate steps towards implementing strong, ambitious policies and related actions to steer and rapidly accelerate their economies towards a low-carbon state. The health sector and health professionals can contribute through the removal of institutional investment in fossil fuels, assessments of the health economics of mitigation co-benefits, and by communicating the negative externalities associated with the continued use of fossil fuels.

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Section 5: public and political engagement

As the previous sections have emphasised, climate change is human in both origins and effects. Its origins lie in the burning of fossil fuels, particularly during early industrial periods, and its effects include an increasing toll on human health. Reductions in global greenhouse-gas emissions at the speed required by the Paris Agreement depend on engagement by all sectors of society.

In the 2019 *Lancet* Countdown report, section 5 focuses on engagement in four domains: the media, government, corporate sector and, for the first time, individual engagement. It tracks trends in engagement across the last decade, complementing this evidence with analyses of the content and dynamics of engagement in 2018. The methods for an indicator relating to a fifth domain, scientific engagement, are being refined to ensure the long-term sustainability of this work, and will be reported again in 2020. In every case, indicators in this section build on methods used in earlier *Lancet* Countdown reports, which continue to be refined and extended.

The media is central to public understanding of climate change; it provides a key resource through which people make sense of climate change and assess the actions of governments to address it.[170–173] The media indicator (5.1) includes an analysis of global coverage of health and climate change in 62 newspapers from 2007 to 2018. For the 2019 *Lancet* Countdown report, this has expanded to include coverage of health and climate change in China's *People's Daily* (in its Chinese-language edition, *Renmin Ribao*). As the official outlet of the Chinese party-state, the *People's Daily* is China's most influential newspaper.[174] The indicator has been further enhanced by a content analysis of the elite press in two contrasting societies, India and the USA. Elite newspapers both reflect and shape engagement in climate change by governments and elite groups.[175–179]

The internet is an increasingly important medium of civic engagement and has transformed individual access to global knowledge and debates. The second indicator tracks engagement in health and climate change through individuals' information-seeking behaviour on the online encyclopaedia, Wikipedia.[180] Because of its accessibility, breadth, and user trust, Wikipedia is one of the most widely used online resources.[181–185]

Recognising that climate change is harming people, the global public support government action to decrease greenhouse-gas emissions.[186–188] The third indicator relates to government engagement in health and climate change and focuses on high-level government engagement in health and climate change at the UN General Assembly. It tracks references at the UN General Debate, the major international forum during which national leaders have the opportunity to address the global community on issues they consider important.[189,190]

The fourth indicator relates to the corporate sector, recognised to be central to a rapid transition to a carbon-free economy, both through its business practices and wider political and public influence.[191–193] Focusing on the health sector, the indicator tracks engagement in health and climate change through analyses of the annual reports submitted by companies signed up to the UN Global Compact—the world's largest corporate sustainability initiative.[194]

Indicator 5.1: media coverage of health and climate change

Headline finding: media coverage of health and climate change continued to increase between 2007 and 2018 with the elite press emphasising the health impacts of climate change and the co-benefits of climate change action—This indicator tracks coverage of health and climate change in the global media, including in the Chinese *People's Daily*. Additionally, it provides insight into which aspects of the health–climate change nexus are receiving attention in the elite media in India and the USA. For the 2019 *Lancet* Countdown report, methods to track newspaper coverage have been improved and greater attention is also given to the content of coverage.

Global media coverage of health and climate change has increased since 2010. Alongside broader coverage of climate change, spikes in media engagement with health and climate change coincided with major events in climate governance.[195] These include the 2009 and 2015 UNFCCC Conferences of Parties (COPs) in Copenhagen and Paris and, in 2016, the Paris Agreement and the Sustainable Development Goals coming into force. However, health continued to represent only a small proportion of the wider coverage of climate change. Analysis details, together with data sources and methodological enhancements are described (appendix pp 107–127). The indicator is based on 62 newspapers (English, German, Portuguese, Spanish) selected to provide a global spread of higher-circulation papers.

Additionally, coverage of health and climate change in the *People's Daily* was tracked to extend the analysis (figure 26). Although the Chinese media has changed and diversified in recent decades, the *People's Daily* retains its dominance.[174,196,197] Across the 2008–18 period, an average of 2519 articles per year were published discussing climate change. A small proportion of these related to human health, with a mean of 14 articles per year. Spikes in coverage are less closely tied to important events in global climate change governance (such as the signing of the Paris Agreement in 2015) than in the global media. An explanation for this difference in reporting might be the timing of *People's Daily* coverage of global events, including the COPs, which occurs after their conclusion; coverage of November and December COPs might occur in the following calendar year.

This addition to indicator 5.1 was based on the *People's Daily* online archive,[198] and combined electronic searching of the text corpus (keyword searches and algorithm-based natural language processing) with manual screening of the filtered articles (appendix pp 110–117).

The analysis of the content of coverage focused on the high-circulation elite press in India and the USA: *Times of India, Hindustan Times, New York Times*, and *Washington Post*. Two time-periods were selected to cover months July–September, during which both countries experienced extreme weather events (monsoon flooding and wildfires, respectively) together with months November–December covering the 2018 COP in Katowice. Articles in international news databases Nexis and Factiva were keyword searched and manually screened for inclusion. Template analysis was used to identify themes; a priori coding derived from *Lancet* Countdown indicators and inductive coding from recurrent topics in the data were employed.[199] Additional analyses and full details of methods are provided (appendix pp 117–127).

Coverage of health and climate change clustered around three broad connections between the two areas (panel 4). The first theme is associated with the health impacts of climate change. These impacts related to climate change-related stressors (eg, increased temperatures, wildfires, precipitation extremes, food security, population displacement) and health sequelae (eg, vector-borne disease, heat stress, mental health disorders) and were discussed in 62% of the articles. The health effects resulting from heat were the most commonly-mentioned impact. The second theme focused on the common determinants of health and climate change, particularly air pollution, and the co-benefits to be derived from mitigation strategies to address them (eg, investment in clean energy, active travel, and plant-based diets) and was discussed in 44% of articles. The third theme is related to adaptation. Evident in 13% of the articles, it included both emergency response and longer-term planning. The three themes were represented in similar proportions in *Hindustan Times, New York Times*, and *Washington Post*, but *Times of India* gave greater emphasis to common causes and co-benefits than did the other newspapers.

Indicator 5.2: individual engagement in health and climate change

Headline finding: individuals typically seek information about either health or climate change; when individuals seek information across these areas, it is primarily driven by an initial interest in health-related content—The internet is an increasingly important domain of public engagement, particularly for information-seeking on issues that engage people’s attention.[200] This indicator tracks individual-level engagement in health and climate change in 2018 through an analysis of use of Wikipedia, the world’s largest encyclopaedia. With reviews noting its accuracy,[181,201] Wikipedia is one of the most-visited websites worldwide,[182] with a high correlation between user visits to Wikipedia and search activity on Google.[202] The analysis is based on the English Wikipedia, which represents around 50% of global traffic to all Wikipedia language editions.

This is a new indicator for the 2019 *Lancet* Countdown report and its analysis uses the online footprint of Wikipedia users to map the dynamics of public information-seeking in health and climate change.[180,203] It analyses clickstream activity, reported on a monthly basis, that captures visits to pairs of articles, for example an individual clicking from a page on human health to one on climate change.[204]

Articles were identified via keywords and relevant hyperlinks within articles, refined using Wikipedia categories, and then filtered by the initial keywords. Data and methods are described along with further analysis (appendix pp 127–137).

Articles on health and on climate change are internally networked, with extensive co-visiting within these clusters (figure 27). However, the co-clicks suggest little connectivity between the clusters. Health and climate change are seldom topics that an individual connects when they visit Wikipedia; initial engagement in one topic rarely triggers engagement in the other. The proportion of co-clicks from a health article to a climate change article represented only 0·18% of total health article co-clicks to articles discussing any topics, and only 1·12% of climate change article co-clicks were to a health article. This data also reflects the greater interest of the individual in health articles compared with climate change articles, with the majority (79%) of co-visits originating from a health-related webpage.

Indicator 5.3: government engagement in health and climate change

Headline finding: national leaders are increasingly drawing attention to health and climate change at the UN General Debate in a trend led by small island developing states, which make up 10 of 28 countries referencing the climate change–health link at the UN General Debate in 2018—This indicator tracks high-level political engagement with climate change and health through references to this topic in annual statements made by national leaders in the UN General Debate (UNGD). The UNGD takes place at the start of the annual UN General Assembly and provides a global platform for all UN member states to speak about their priorities and concerns.

An updated dataset, the UN General Debate corpus, was used for the analysis, based on 8093 statements made between 1970 and 2018.[205,206] Keyword searches used sets of terms associated with health and with climate change, and engagement in the health–climate change nexus was determined by the proximity of relevant keywords within the statement. Methods and data, as well as further analyses are presented (appendix pp 138–151).

The proportion of countries that refer to the links between health and climate change in their UNGD statements, together with the proportion referring separately to climate change or to health, or both, are presented (figure 28). In 2018, 28 countries referenced the climate change and health link at the UNGD.

The data points to an upward trend in government engagement in health and climate change since 1970; a trend that is consistent with broader trends for engagement in climate change. This increase is particularly noticeable since 2004, peaking in 2014, when more than 20% of national leaders spoke of the links between climate change and health. This spike coincided with the transition from the Millennium Development Goals to the SDGs and preparations for the COP 21 in Paris. Since 2014, conjoint references to health and climate change have remained broadly stable; in 2018, 13% of countries made such references. However, increased engagement in health and climate change as separate issues has been noted (figure 28). Around 75% of all countries referred to climate change and 50% to health issues in their 2018 UNGD statements.

The upward trend in engagement in health and climate change is led by the small island developing states, for example, Fiji, Palau, Samoa, Dominica, and St Kitts and Nevis, with ten of these developing states referring to the climate change–health link in 2018. In these speeches, connections between climate change and health are explicitly made and linked to wider inequalities between and within countries. For example, the 2018 address by St Kitts and Nevis notes that "NCDs [non-communicable diseases] and climate change are two sides of the same coin" and Dominica's statement makes clear that "climate change arises from activities that support and reflect inequalities…it is the poor whose lands are impacted by severe droughts and flooding and whose homes are destroyed and whose loved ones perish. It is the poor who have the least capacity to escape the heavy burdens of poverty, disease and death." The social justice theme is echoed in other speeches; for example, the Malawi address notes that "the hostile consequences of climate change, food insecurity and malnutrition are serious threats in a country that still relies on rain-fed subsistence agriculture."

Indicator 5.4: corporate sector engagement in health and climate change

Headline finding: engagement in health and climate change remains low among companies within the UN Global Compact, including companies in the health-care sector—This indicator tracks corporate sector engagement through references to health and climate change in companies that are part of the UN Global Compact (UNGC), a UN-supported platform to encourage companies to put a set of principles—including environmental responsibility and human rights—at the heart of their corporate practices.[207] Although the UNGC has been the topic of criticism, it remains the world's largest corporate citizenship initiative.[208–210]

Companies submit annual Communication of Progress reports with respect to their progress in advancing UNGC principles. Over 12 000 companies have signed up to the UN Global Compact from more than 160 countries.[194]

Analysis was based on keyword searches of sets of health-related and of climate change-related terms in Communication of Progress reports in the UNGC database;[194] conjoint engagement in health and climate change was identified by the proximity of relevant key words within the Communication of Progress report. Methods, data, and additional analyses are presented (appendix pp 151–164). The analysis focuses on the period from 2011 to 2018 because very few reports are available with data from before 2011.

A small proportion of companies referred to the links between health and climate change before 2017.[37] This pattern continues in the 2018 Communication of Progress reports. Although about 45% of the 2018 reports refer to climate change, and 60% refer to health, only 15% refer to a linkage between the two topics (appendix pp 151–164). This pattern was even more pronounced in the corporate health-care sector, which might be expected to be the global leader in addressing links between health and climate change. In 2018, although most companies in the health sector referred to health (72%) and an increasing minority to climate change (47%), only 12% made a conjoint reference to both.

Conclusion

Engagement by all sectors of society is essential if action on climate change is to be mobilised and sustained. Section 5 has focused on key domains of engagement, including the media, governments, the corporate sector and, in a new indicator, individual-level engagement. Each sector is recognised to be central to moving global emissions onto a pathway that maintains global temperature increases to below 1·5°C.[211]

Two broad conclusions can be drawn from the analyses presented in section 5. First, engagement in health and climate change has increased over the last decade, with a more pronounced upward trend for engagement by the media and government than by the corporate sector. With respect to the elite media, there is evidence of informed and

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detailed engagement with the health impacts of climate change and with the co-benefits of climate change action. At the global forum of the UN General Assembly, an increasing number of countries are giving attention to the health–climate change nexus. Led by the small island developing states, these countries are underlining the north–south inequalities in responsibility for, and vulnerability to, climate change and its adverse health impacts.

Although media engagement is increasing, it is episodic rather than sustained, with so-called issue attention increasing at key moments in global climate governance, particularly the UNFCCC COPs. The role of the COPs in public and political engagement has been noted in other reports,[195,212] with the meetings providing a global stage for both national leaders and non-government organisations (including scientists, religious leaders, and health professionals), to contribute to the public debate. The pattern for the corporate sector, including the health-care sector, is different; it does not display spikes in engagement linked to the global governance of the planet.

Second, although engagement has increased over the past decade, these indicators suggest that climate change is being more broadly represented in the media and by governments in ways that do not connect it to human health. As this suggests, the human face of climate change can be easily obscured and the analysis of individual engagement illustrates this pattern. The online footprint of Wikipedia users confirms that although health is a major area of individual interest, it is rarely connected with climate change. In the mind of the public, health and climate change represent different and separate realms of knowledge and concern and, when connections between the two areas are made, this is driven by an interest in health rather than in climate change.

Taken together, these two conclusions point to modest progress in making health central to public and political engagement in climate change, but underline the challenge of mobilising action at the speed and magnitude required to protect the health of the planet and its populations.

Conclusion: The *Lancet* Countdown in 2019

The *Lancet* Countdown: tracking progress on health and climate change was formed 4 years ago, building on the work of the 2015 *Lancet* Commission. It remains committed to an open and iterative process, always aiming to strengthen its methods, source new and novel forms of data, and partner with global leaders in public health and in climate change. The 41 indicators presented in the 2019 report represent the consensus and work of the past 12 months and are grouped into five categories: climate change impacts, exposures, and vulnerabilities; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement.

The data published here elucidate the ongoing trends of a warming world with effects that threaten human wellbeing. As the fourth hottest year on record, 2018 saw a record-breaking 220 million additional exposures to extremes of heat, coupled with corresponding increased vulnerability to heat across every continent. As a result of this and broader climatic changes, vectorial capacity for the transmission of dengue fever was the second highest recorded, with 9 of the past 10 most suitable years occurring since 2000. Progress in mitigation and adaptation remains insufficient, with the carbon intensity of the energy system remaining flat; 2·9 million ambient air pollution deaths; and a reversal of the previous downward trend of coal use.

Despite this slow progress, as the material effects of climate change reveal themselves, so too does the world's response. 51 of the 101 countries tracked have developed national health adaptation plans, 70 countries provide climate information services to the health sector, 109 countries have medium to high implementation of a national health emergency framework, and 69% of cities have mapped out risk and vulnerability assessments. Health adaptation funding continues to climb, with health-related funding now responsible for 11·8% of the global adaptation spend. Finally, public and political engagement continues to grow, with heightened interest around the school climate strikes, the UNFCCC's annual meetings, and divestment announcements from medical and health associations.

The last three decades have witnessed the release of increasingly concerning scientific data showing the importance of a reduction in greenhouse-gas emissions. Although the report discusses several positive indicators, CO_2 emissions continue to rise. The health implications of this are apparent today and will most certainly worsen without immediate intervention.

Despite increasing public attention over the past 12 months, the world is yet to see a response from governments which matches the scale of the challenge. The role of the health profession is essential—communicating the health risks of climate change and driving the implementation of a robust response which will improve human health and wellbeing.

With the full force of the Paris Agreement to be implemented in 2020, a crucial shift must occur—one which moves from discussion and commitment, to meaningful reductions in emissions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Panel 1

The *Lancet* Countdown indicators

Climate change impacts, exposures, and vulnerability

- 1.1: health and heat
  - 1.1.1: vulnerability to extremes of heat
  - 1.1.2: health and exposure to warming
  - 1.1.3: exposure of vulnerable populations to heatwaves
  - 1.1.4: change in labour capacity
- 1.2: health and extreme weather events
  - 1.2.1: wildfires
  - 1.2.2: flood and drought
  - 1.2.3: lethality of weather-related disasters
- 1.3: global health trends in climate-sensitive diseases
- 1.4: climate-sensitive infectious diseases
  - 1.4.1: climate suitability for infectious disease transmission
  - 1.4.2: vulnerability to mosquito-borne diseases
- 1.5: food security and undernutrition
  - 1.5.1: terrestrial food security and undernutrition
  - 1.5.2: marine food security and undernutrition

Adaptation, planning, and resilience for health

- 2.1: adaptation planning and assessment
  - 2.1.1: national adaptation plans for health
  - 2.1.2: national assessments of climate change impacts, vulnerability, and adaptation for health
  - 2.1.3: city-level climate change risk assessments
- 2.2: climate information services for health
- 2.3: adaptation delivery and implementation
  - 2.3.1: detection, preparedness, and response to health emergencies
  - 2.3.2: air conditioning—benefits and harms
- 2.4: spending on adaptation for health and health-related activities

Mitigation actions and health co-benefits

- 3.1: energy system and health

- 3.1.1: carbon intensity of the energy system
- 3.1.2: coal phase-out
- 3.1.3: low-carbon emission electricity

- 3.2: access and use of clean energy
- 3.3: air pollution, energy, and transport
  - 3.3.1: exposure to air pollution in cities
  - 3.3.2: premature mortality from ambient air pollution by sector
- 3.4: sustainable and healthy transport
- 3.5: food, agriculture, and health
- 3.6: mitigation in the health-care sector

Economics and finance

- 4.1: economic losses due to climate-related extreme events
- 4.2: economic costs of air pollution
- 4.3: investing in a low-carbon economy
  - 4.3.1: investment in new coal capacity
  - 4.3.2: investments in low-carbon energy and energy efficiency
  - 4.3.3: employment in low-carbon and high-carbon industries
  - 4.3.4: funds divested from fossil fuels
- 4.4: pricing greenhouse-gas emissions from fossil fuels
  - 4.4.1: fossil fuel subsidies
  - 4.4.2: coverage and strength of carbon pricing
  - 4.4.3: use of carbon pricing revenues

Public and political engagement

- 5.1: media coverage of health and climate change
- 5.2: individual engagement in health and climate change
- 5.3: engagement in health and climate change in the UN General Assembly
- 5.4: engagement in health and climate change in the corporate sector

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Panel 2

Case study of household air pollution conditions in Nairobi, Kenya

This case study focuses on indoor exposure to fine particulate matter $(PM)_{2·5}$, the mortality attributable to this exposure, and carbon dioxide equivalent (CO_2e) emissions in slum housing in Viwandani, Nairobi, Kenya. In this setting, cooking is done with solid fuels (14·6%), kerosene (72·9%), or electricity (12·5%). Most dwellings do not have space heating (84·6%), with the rest using solid fuel heaters from June to August. Houses without electricity use kerosene-burning koroboi lamps for lighting for the whole year, and 8 h average ambient outdoor pollution levels are around 67 $\mu g/m^3$.[118]

Indoor exposure and space heating estimates were estimated on the basis of 2016 levels using EnergyPlus,[119] calibrated to monitored indoor levels in dwellings using different fuel types and ventilation behaviours.[120] Two scenarios were modelled, involving the following changes in exposure and heating energy consumption.

The first scenario modelled electrification of all existing stoves, lamps, and heaters using the standard electrical network, which was assumed to reduce outdoor pollution by 40% on the basis of the estimated contribution of residential combustion to annual mean air pollution in Nairobi from the GAINS model.[121]

The second scenario modelled electrification as in the first scenario, but with low energy lighting, and heater installation extended to all dwellings. Additionally, upgrades to dwelling energy efficiency and airtightness inline with local sustainable design guidelines were modelled.[122]

Current mean 24-hour exposures in Viwandani are estimated to average 60 $\mu g/m^3$ with the fuels producing an estimated 425 kg of CO_2e per household year. Electrification was estimated to result in halving of both greenhouse-gas emissions and $PM_{2·5}$ air pollution (and hence premature deaths associated with $PM_{2·5}$), with annual greenhouse-gas emissions reduced to 210 kg of CO_2e per year and an annual average $PM_{2.5}$ concentration of 31 $\mu g/m^3$. For upgrades to the building envelope and increased electric heating and lighting coverage, the decrease in CO_2e emissions was similar to that for electrification, but with a substantially greater reduction in $PM_{2·5}$ concentrations down to an annual average of 25 $\mu g/m^3$, and hence a reduction in premature deaths associated with air pollution. However, these changes do not reduce indoor exposures to less than the WHO-recommended limit of 10 $\mu g/m^3$. Therefore, reduction of indoor $PM_{2·5}$ to adequate and safe concentrations would also necessitate further substantial reductions in outdoor ambient levels or the application of additional technologies such as air filtration systems.

Panel 3

Response of the health-care sector to climate change

Health systems are increasingly faced with the dual challenges of responding to the health impacts of climate change and reducing the contribution of the health-care sector to greenhouse-gas emissions. From 2013 to 2018, participants from health systems, health centres, and hospitals, from 19 different countries, and representing 9199 health centres and 1693 hospitals, have participated in the Health Care Climate Challenge. The Challenge addresses key areas including local climate change risk assessments, health adaptation plans, fossil fuel and renewable energy project investments, and works with government agencies to support greenhouse-gas emission reductions and health-care sector adaptation.

A leader in climate action progress is Kaiser Permanente (KP), one of the largest not-for-profit health systems in the USA, serving 12·3 million members. Between 2008 and 2017, KP reduced its operational greenhouse-gas emissions by 29%, and increased its membership by 36%. As of early 2018, 36 KP facilities hosted onsite solar panels. KP is working to increase its purchasing of renewable electricity to 100% of total usage by 2020. Anaesthetic gases account for 3% of KP's greenhouse-gas emissions. Between 2014 and 2018, KP achieved a 24% reduction in greenhouse-gas emissions associated with its use of anaesthetic gases through progressive elimination of the drug Desflurane.[150]

The largest example of a health system taking steps to reduce greenhouse-gas emissions and other environmental effects comes in the form of the UK National Health Service (NHS). A national-level detailed analysis of government funded health care shows that the NHS public health and social sector in England reduced its greenhouse-gas emissions (excluding chlorofluorocarbons) by 18·5% from 2007 to 2017, while clinical activity increased by 27·5% over the same time period.[151] Efforts are also being made to reduce water use, plastic waste, and air pollution from the NHS.

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Panel 4

Dominant themes in elite newspaper coverage of health and climate change in India and the USA in 2018

Health impacts of climate change

"Climate change [is] making mosquitoes bolder and the germs they transmit stronger, leading to a spurt in mosquito-borne diseases, particularly chikungunya."

(*Times of India*, August 9)

"As large wildfires become more common—spurred by dryness linked to climate change—health risks will almost surely rise…a person's short-term exposure to wildfire can spur a lifetime of asthma, allergy and constricted breathing." (*New York Times*, November 17)

Benefits of addressing climate change and health together

"To protect our future, new infrastructure must be low-carbon, sustainable and resilient… in 2030, this kind of climate action could also prevent over 700 000 premature deaths from air pollution annually…if cities are built in more compact, connected and coordinated ways, they can improve residents' access to jobs, services and amenities while increasing carbon efficiency." (*Hindustan Times*, December 5)

"For a short time on Thursday night, a small but fiercely determined group of marchers took over a busy DC street to demand better safety for pedestrians and bicyclists…the district has reported 31 traffic deaths so far this year, up from 29 in all 2017…yet lives could be spared…even if it means taking the space from curbside parking. Gove said. "This is a public health crisis. This is a climate change crisis."" (*Washington Post*, November 16)

Adaptation

"Ahmedabad Municipal Corporation (AMC) has adopted a heat action plan which necessitates measures such as building heat shelters, ensuring availability of water and removing neonatal ICU from the top floor of hospitals…it has helped bring down the impact of heatwave on vulnerable populations." (*Times of India*, November 29)

"We rarely do much to protect our cities until disaster strikes… (the) effects of climate change, including the ways it boosts droughts, floods and wildfires, would put more pressure on cities to adapt, mitigate the effects of climate change and become resilient… preparing for disasters and recovering from weather challenges require many different strategies, including holding that rainwater, keeping the flow from going into the drains faster, raising your homes above the flood line." (*New York Times*, December 13)

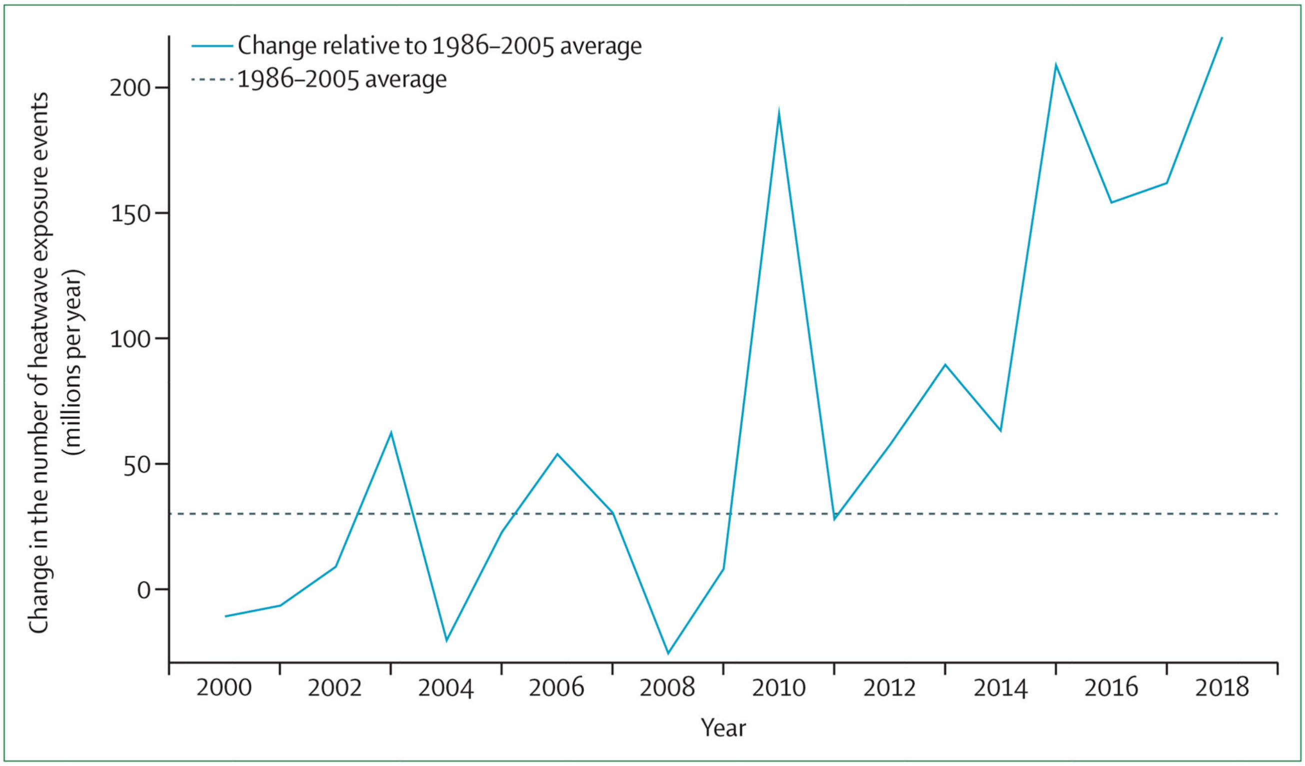

Figure 1. Change in the number of heatwave exposure events in people aged 65 years and older, compared with the historical 1986–2005 average number of events

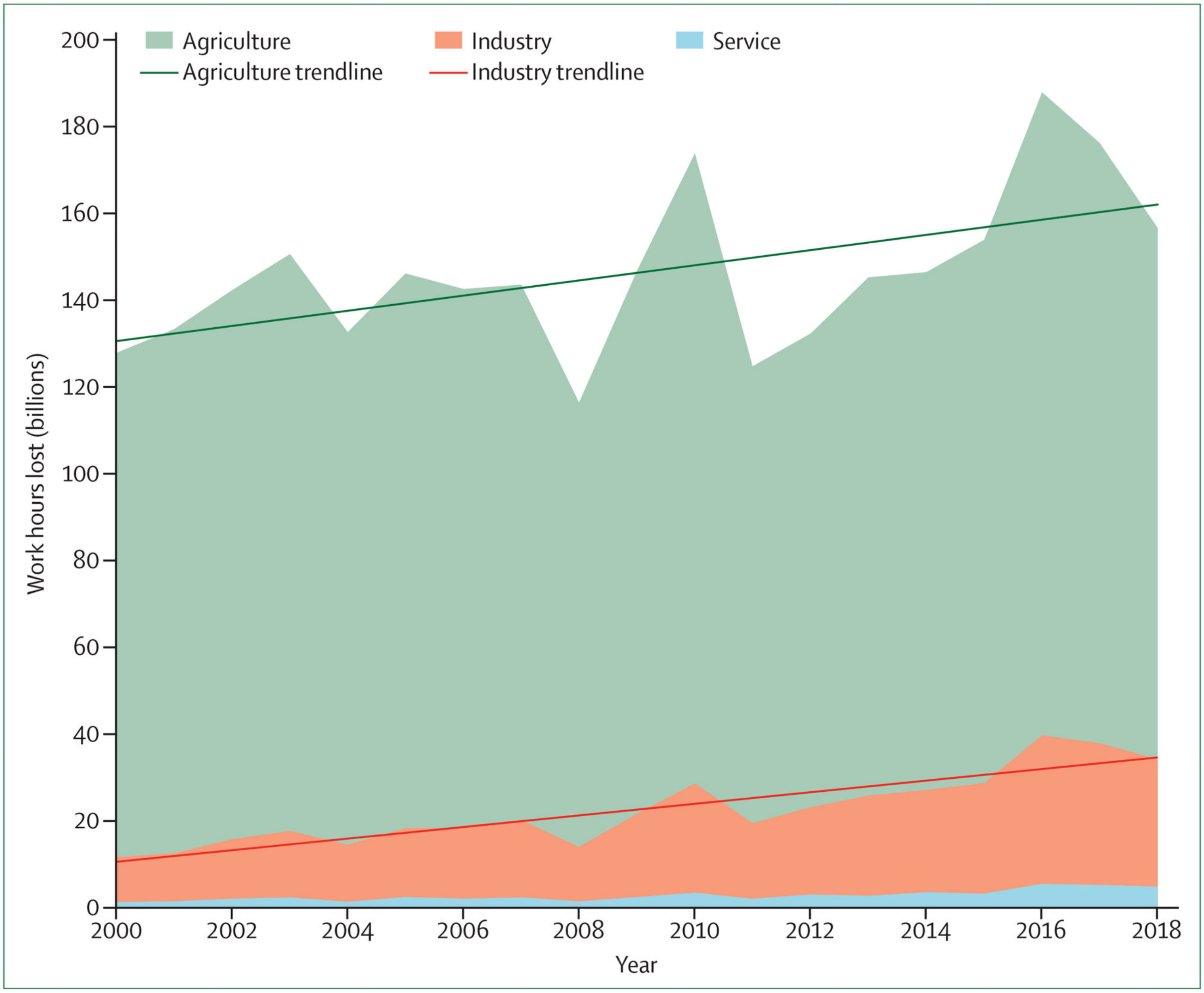

Figure 2. Potential global work hours lost per sector due to heat, 2000–18

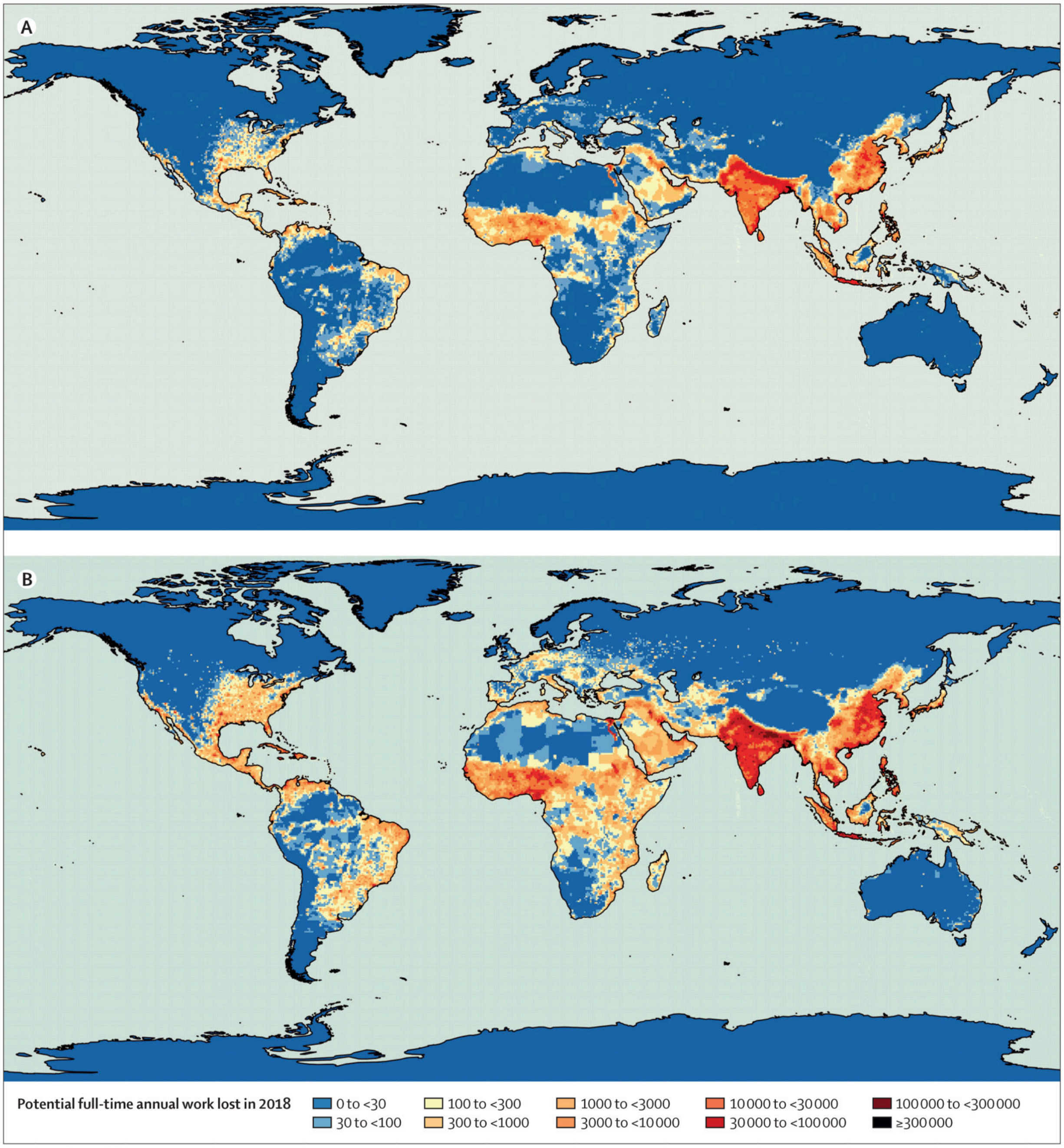

Figure 3. Potential full-time annual work lost in the shade (A) or in the sun (B) based on the percentage of people working in agriculture (400 W), industry (300 W), and services (200 W)
W=Watts.

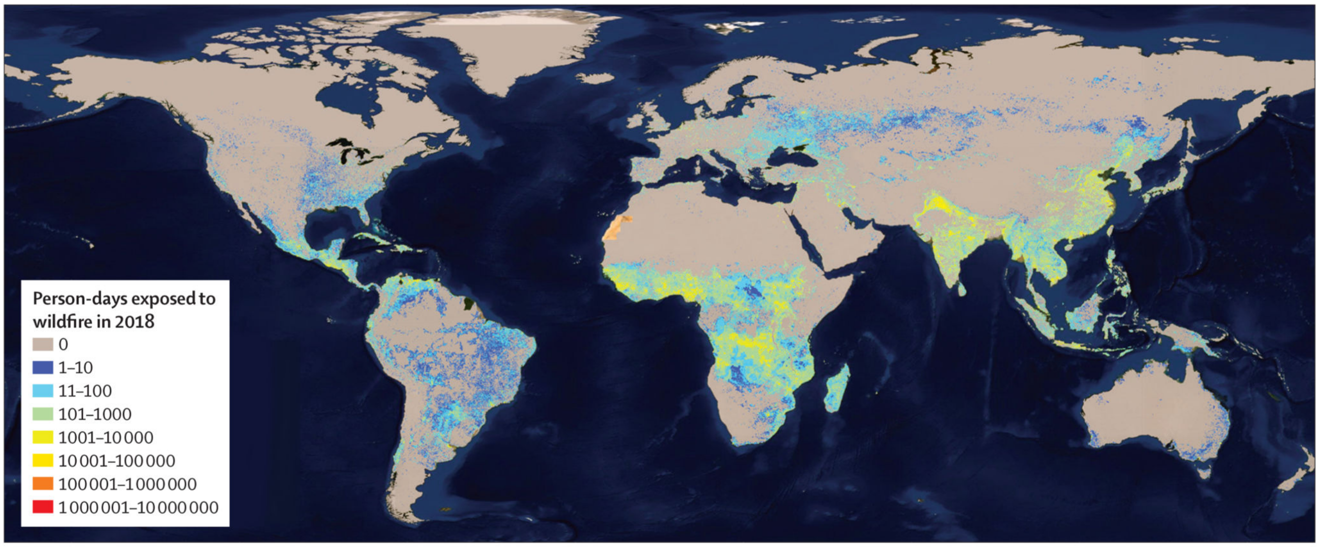

Figure 4. Map showing the average annual number of days people were exposed to wildfires in 2018

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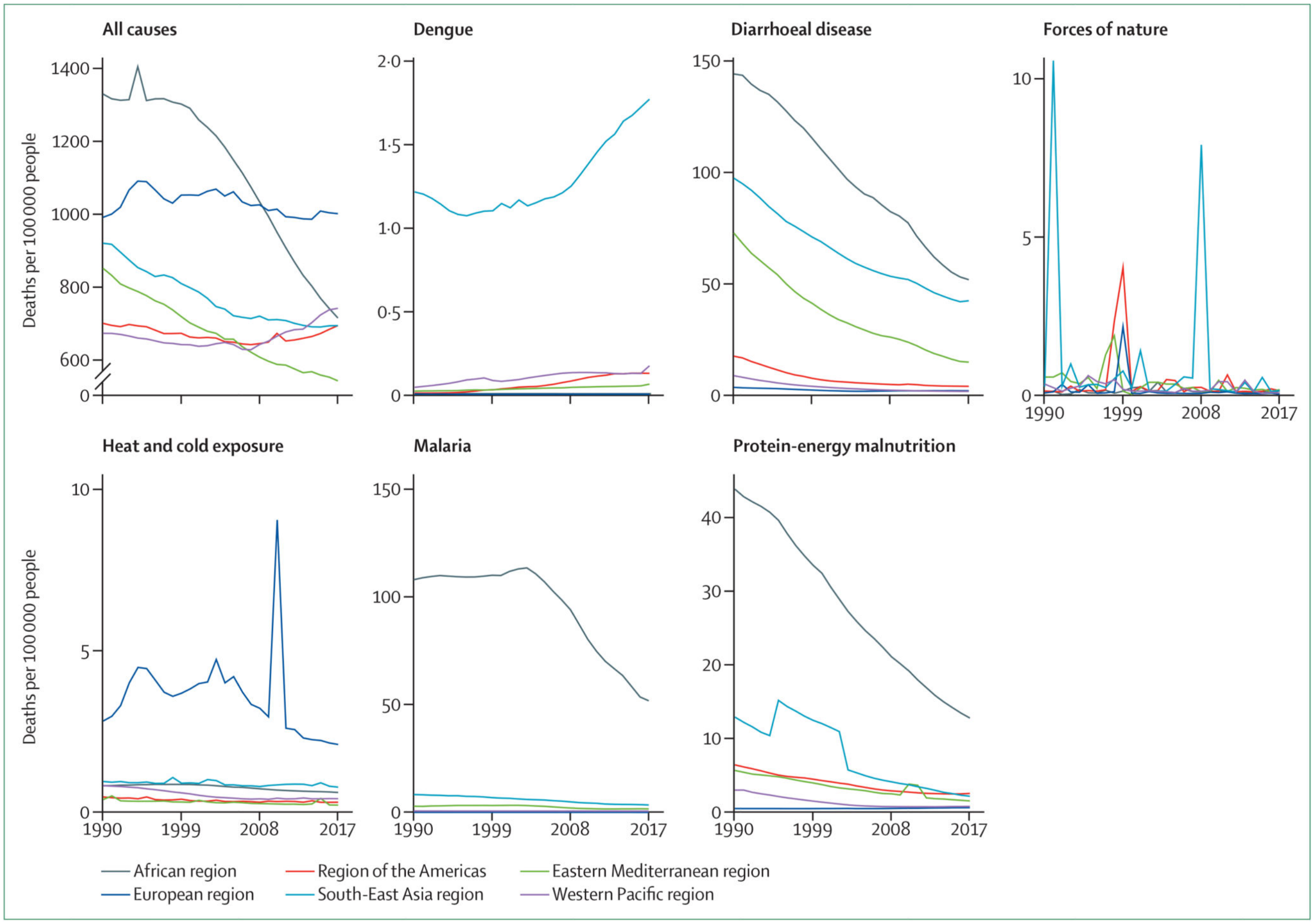

Figure 5. Global trends in all-cause mortality and mortality from selected causes as estimated by the Global Burden of Disease 2017 study[52] for the 1990–2017 period, by WHO region

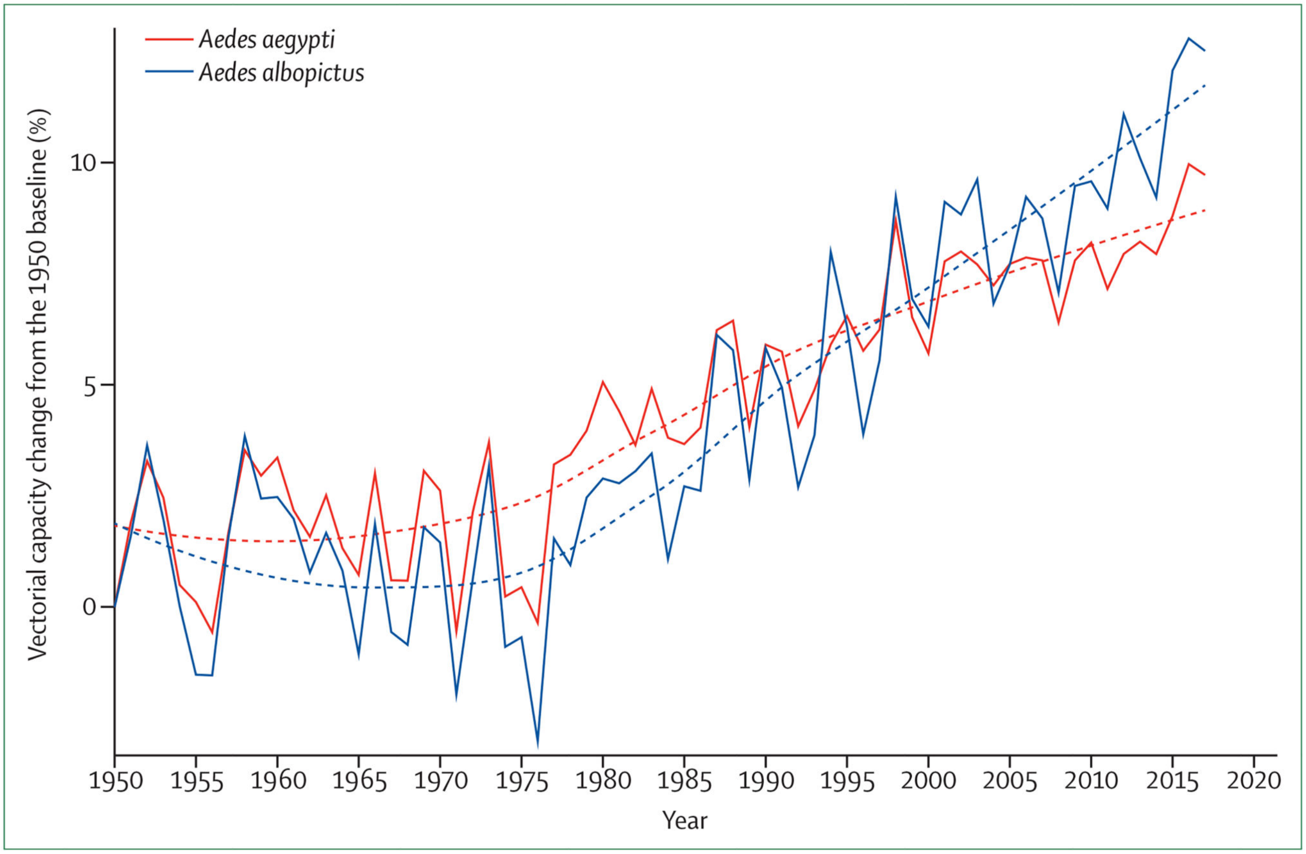

Figure 6. Changes in global vectorial capacity for the dengue virus vectors *Aedes aegypti* and *Aedes albopictus* since 1950

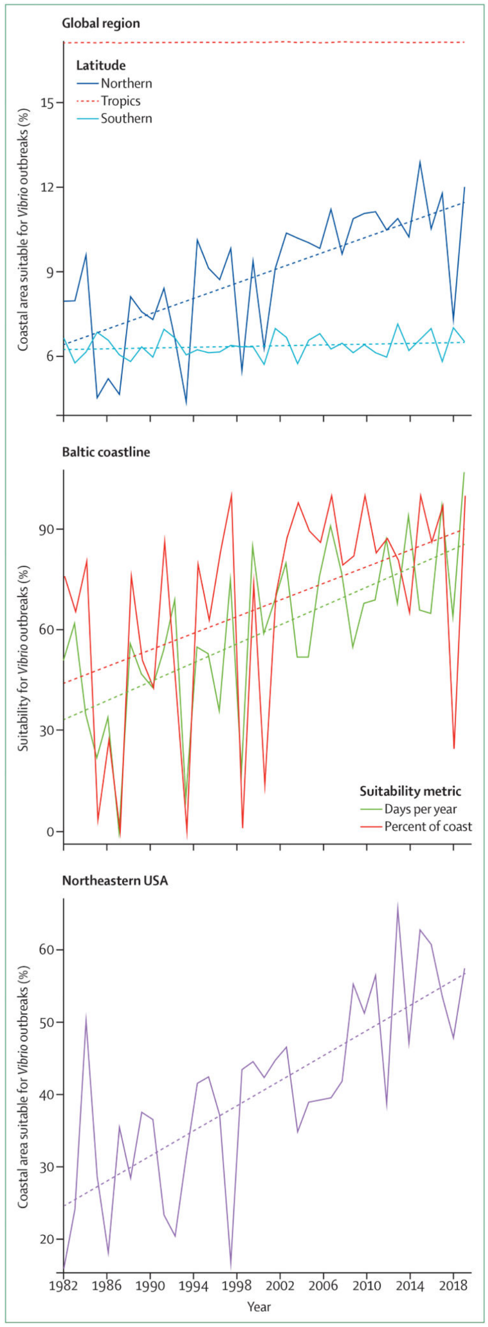

Figure 7. Change in suitability for pathogenic *Vibrio* outbreaks as a result of changing sea surface salinity and sea surface temperatures

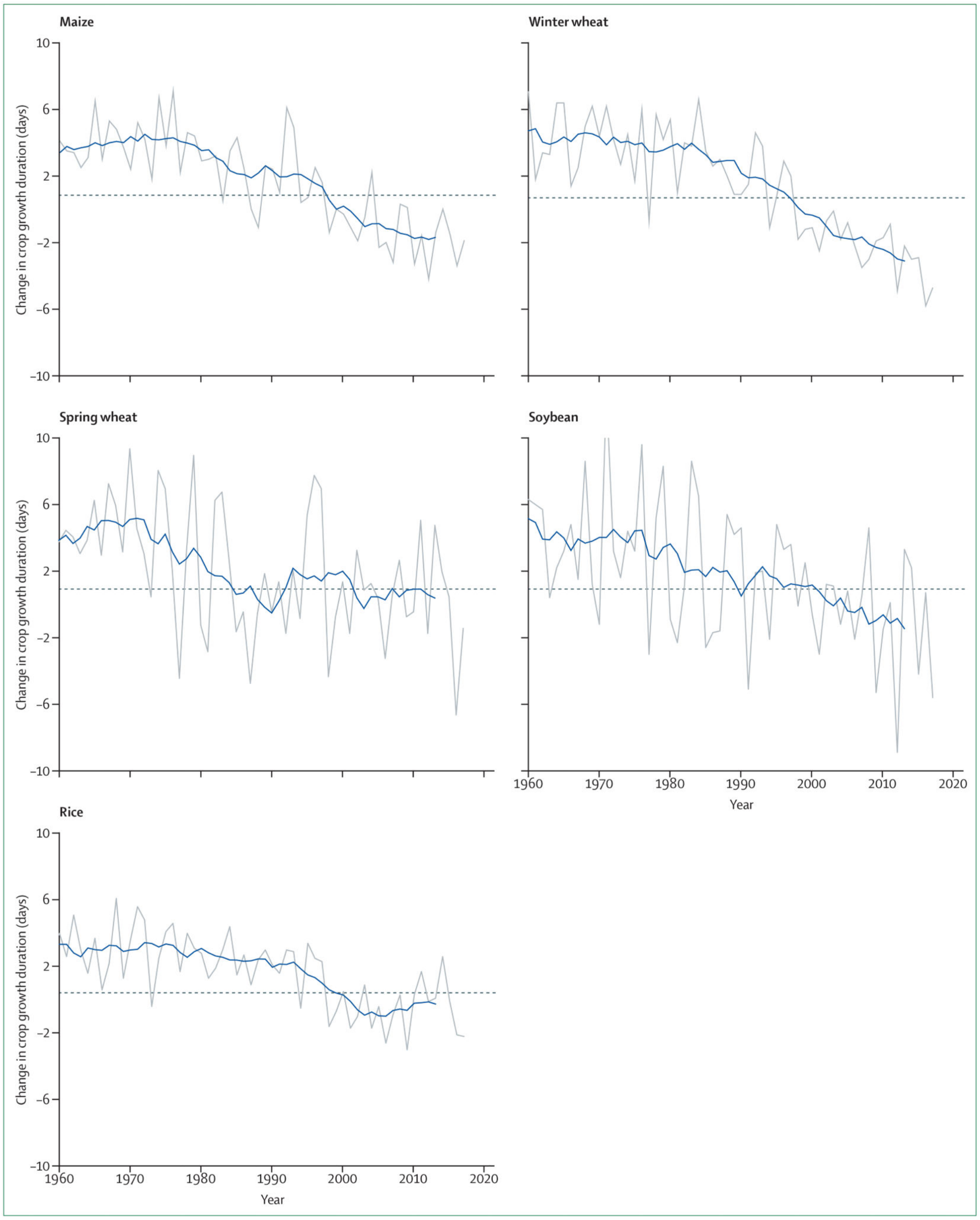

Figure 8. Change in global crop growth duration as a proxy for crop yield

Dashed line=the average change in crop duration of the 1981–2010 baseline. Grey line=annual global area-weighted change. Blue line=running mean over 11 years (5 years forward, 5 years backward).

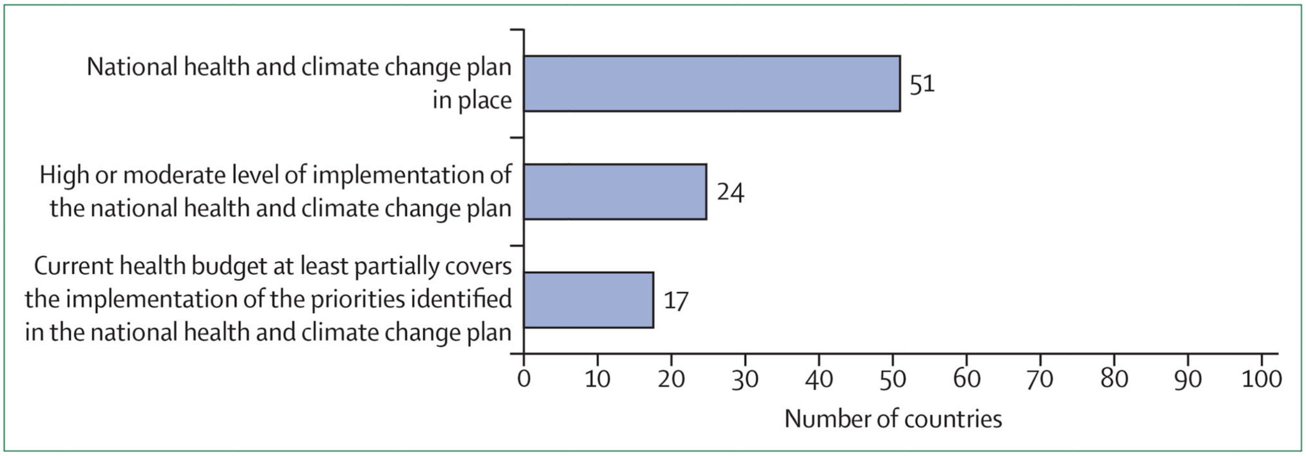

Figure 9. Number of countries with a national health and climate change plan or strategy

Data from 101 country respondents of the 2018 WHO Health and Climate Change Country Survey,[83] by permission of the World Health Organization.

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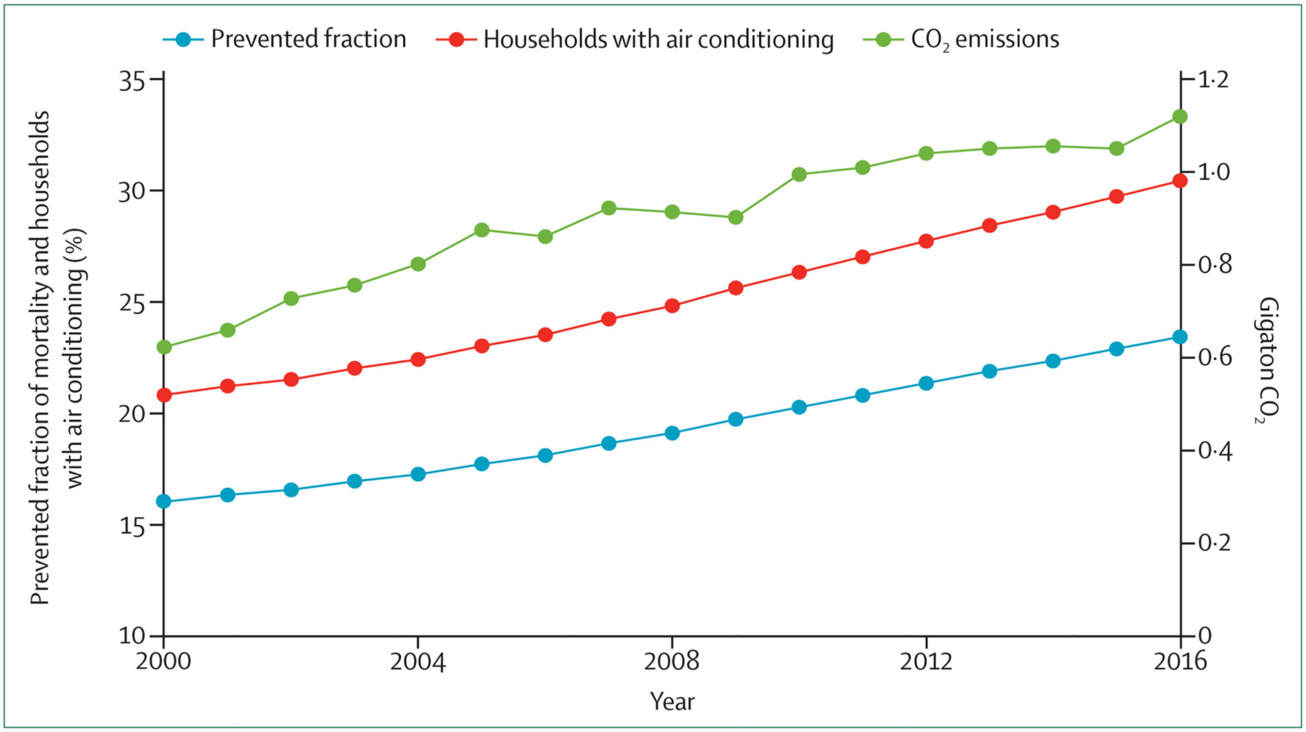

Figure 10. Global proportion of households with air conditioning (red line), prevented fraction of heatwave-related mortality due to air conditioning (blue line), and CO2 emissions from air conditioning (green line) 2000–16

CO_2=carbon dioxide.

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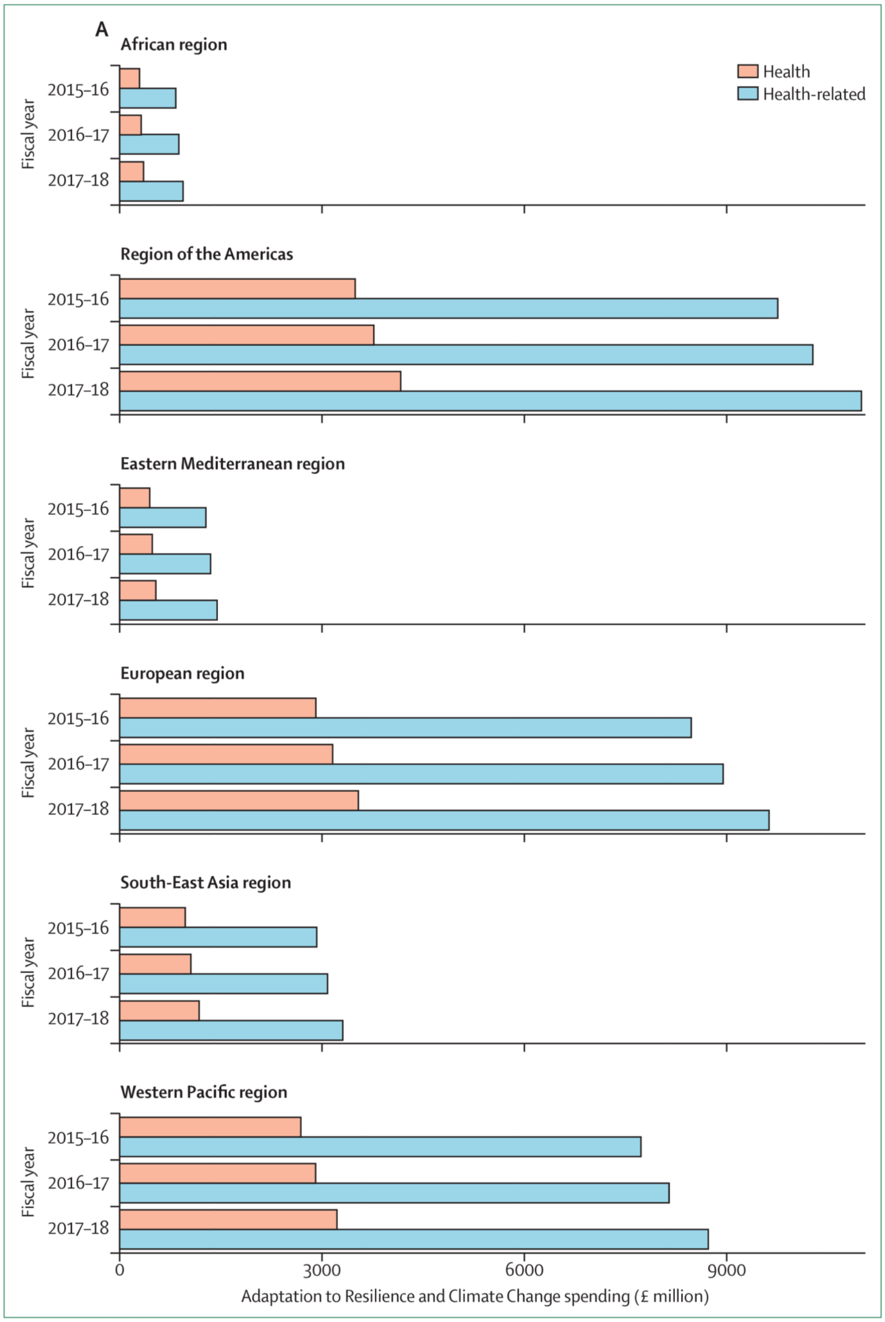

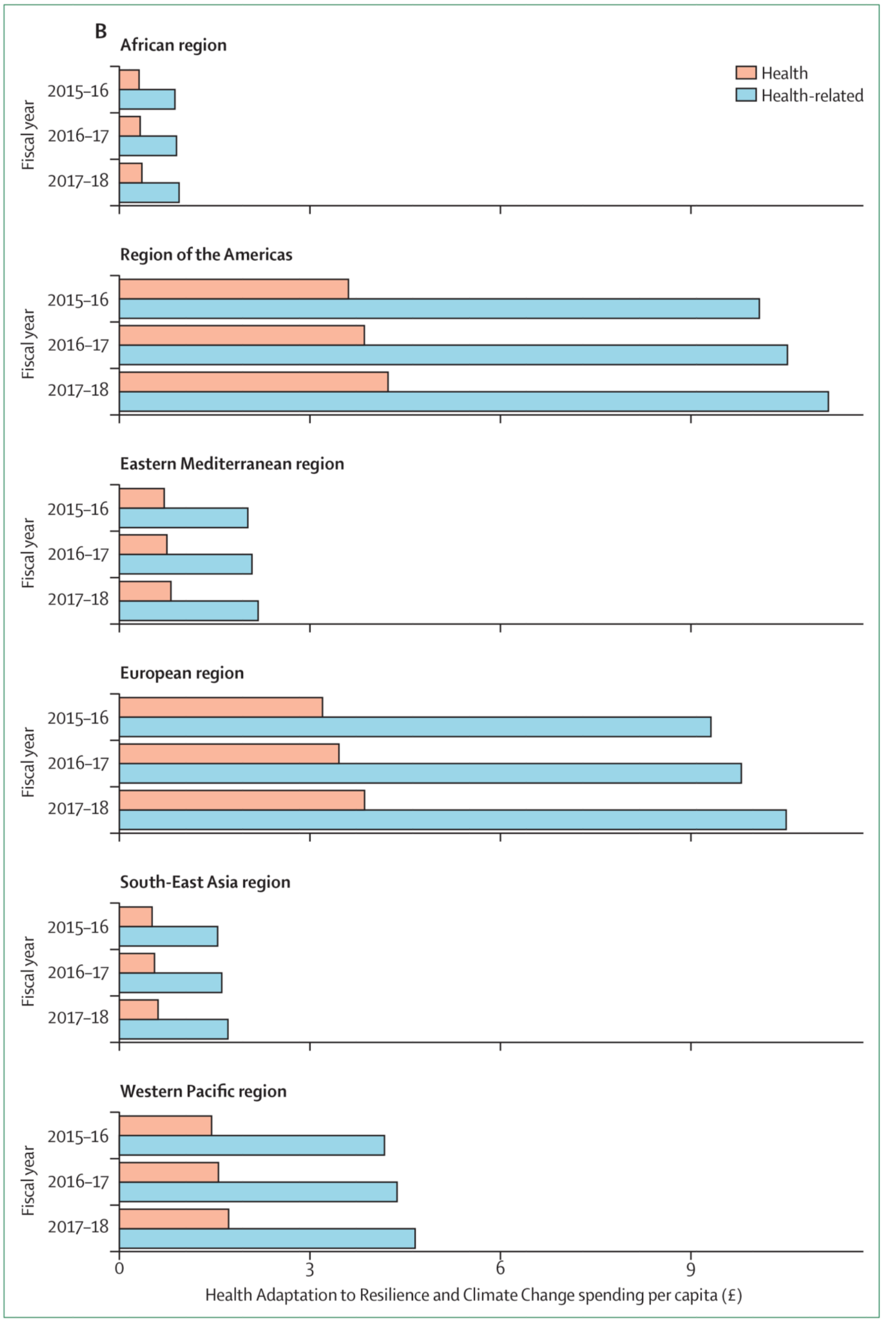

Figure 11. Spending on adaptation for health and health-related activities in WHO-specified regions.

Graphs show Adaptation to Resilience and Climate Change spending (A) and spending per capita (B).

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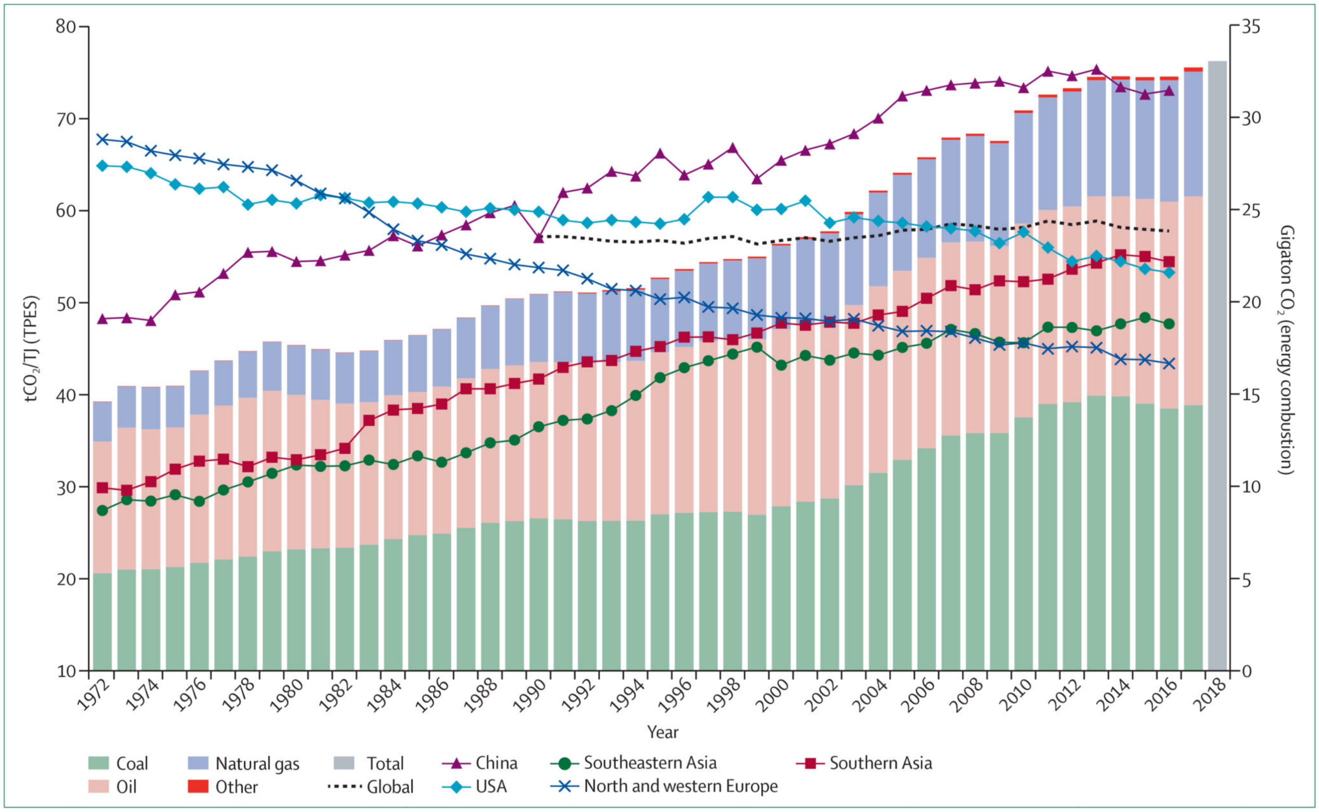

Figure 12. Carbon intensity of TPES for selected regions and countries, and global energy-related CO_2 emissions

Carbon intensity is shown by lines (primary axis) and global emissions by stacked bars (secondary axis). CO_2=carbon dioxide. tCO_2/TJ=total CO_2 per terajoule of energy. TPES=Total Primary Energy Supply.

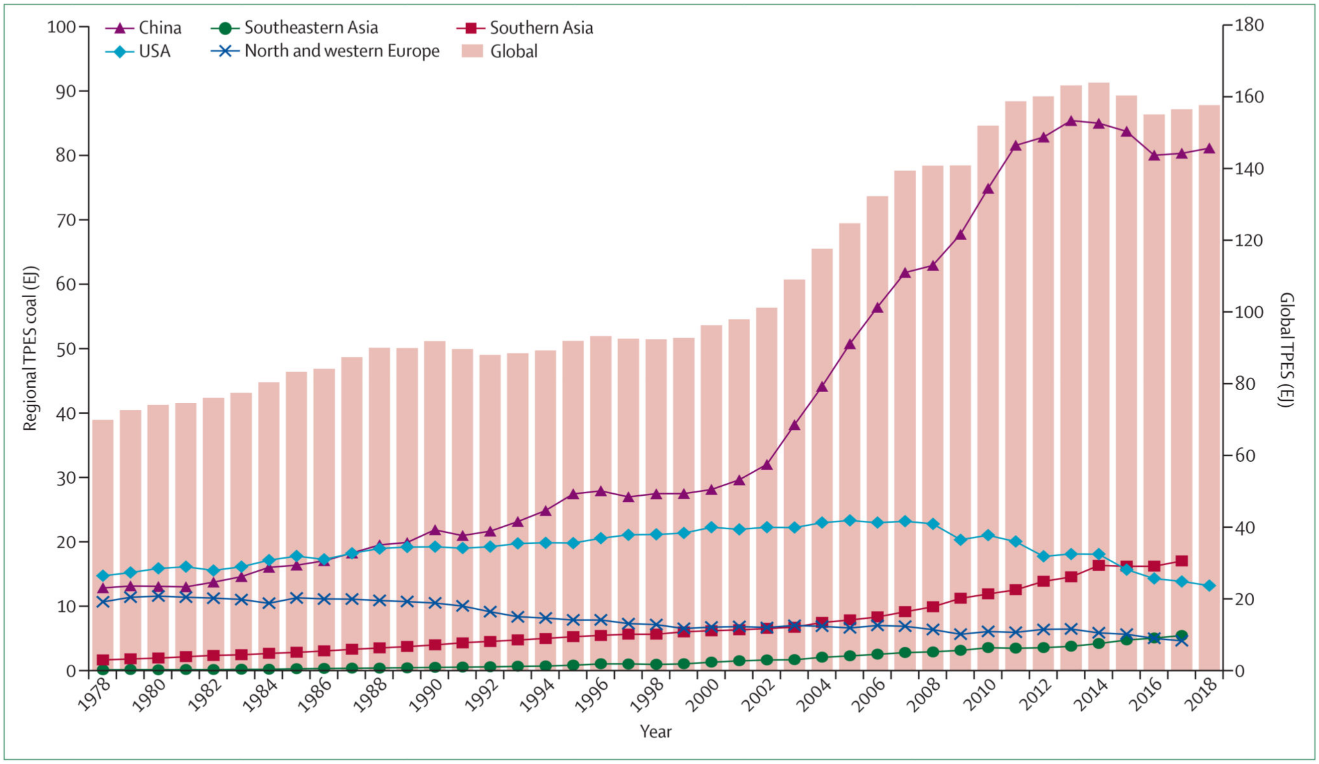

Figure 13. TPES coal in selected countries and regions, and global TPES coal

Regional primary energy supply of coal is shown by the trend lines (primary axis) and total global supply by the bars (secondary axis). EJ=exajoule. TPES=Total Primary Energy Supply.

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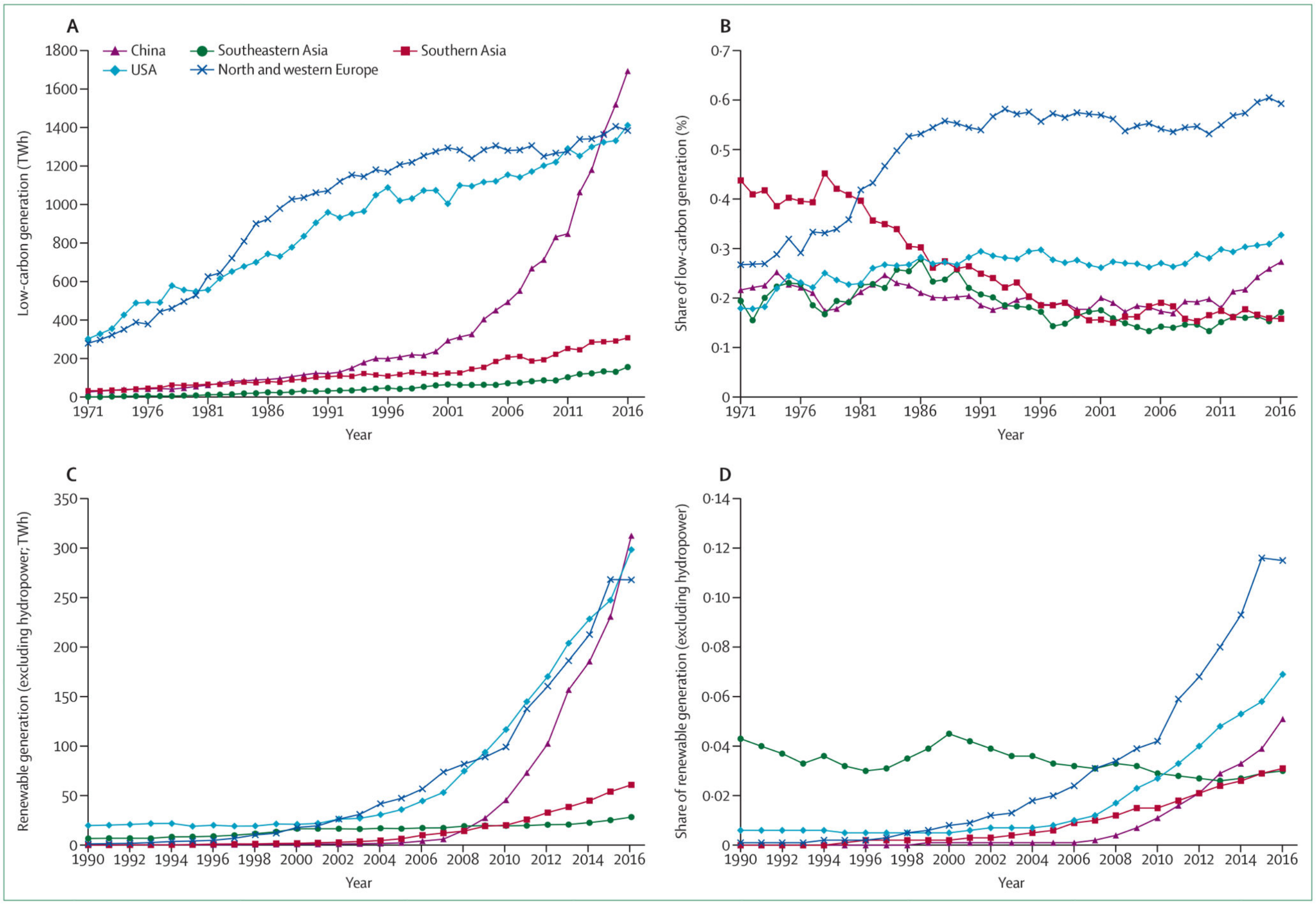

Figure 14. Renewable and low-carbon emission electricity generation

(A) Electricity generated from low-carbon sources. (B) Share of electricity generated from low-carbon sources. (C) Electricity generated from renewable sources (excluding hydropower). (D) Share of electricity generated from renewable sources (excluding hydropower). TWh=terawatt hours.

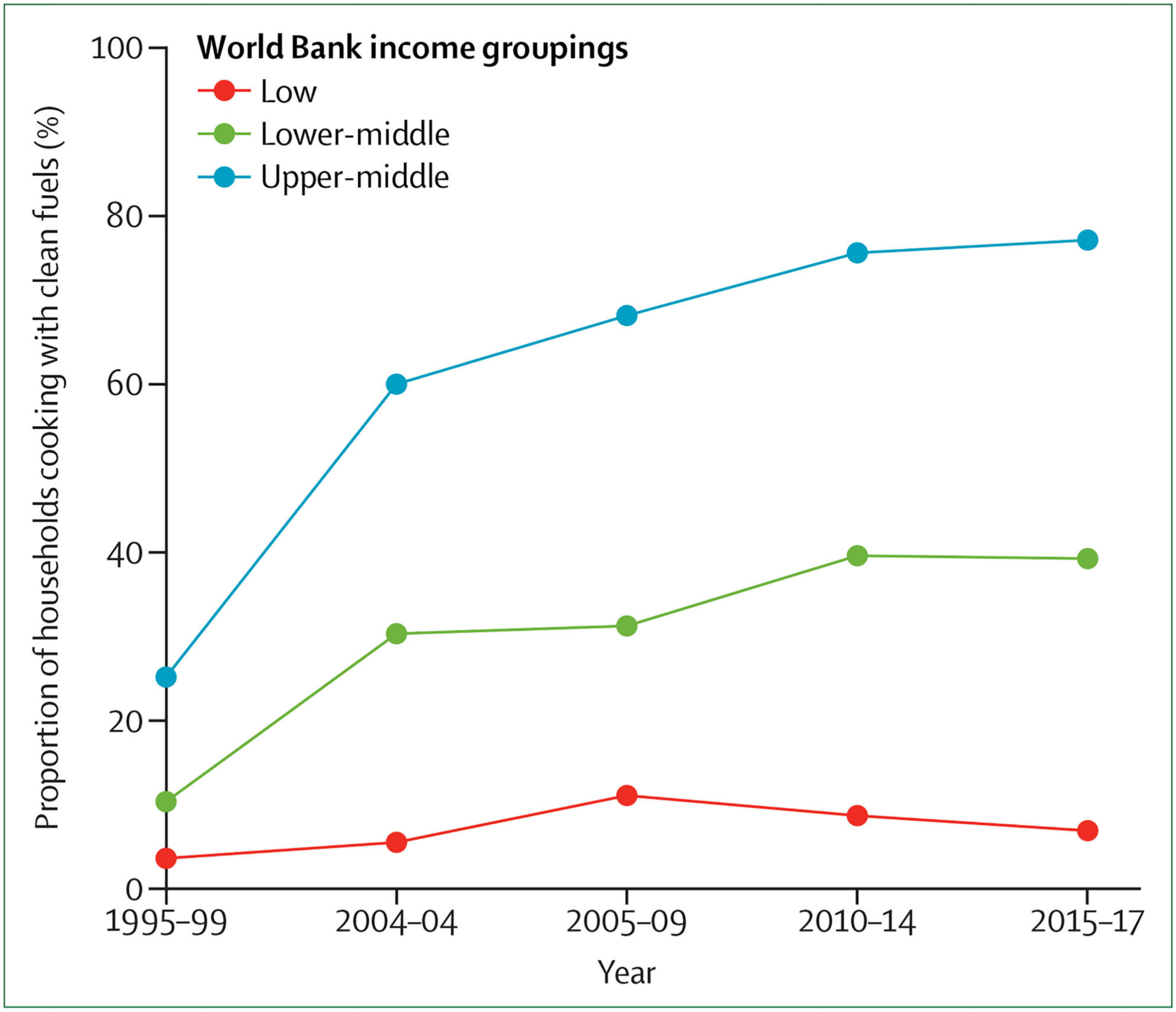

Figure 15. Graph showing proportion of households cooking with clean fuels in World Bank grouped low-income and middle-income countries

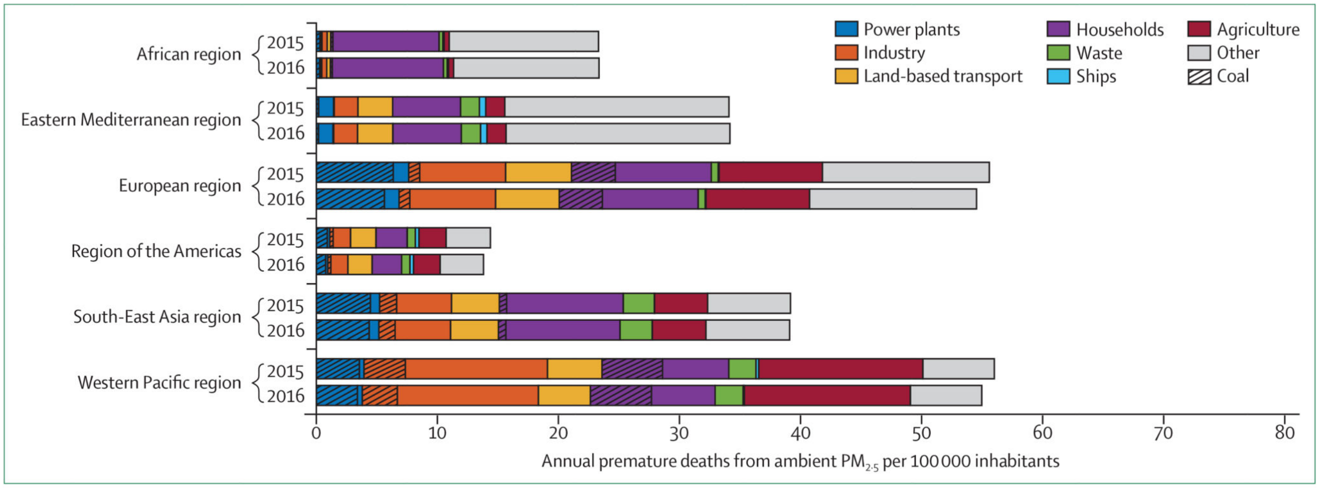

Figure 16. Premature deaths attributable to exposure to ambient fine particulate matter ($PM_{2·5}$) in 2015 and 2016, by key sources of pollution in WHO-specified regions

$PM_{2·5}$=atmospheric particulate matter with a diameter of less than 2·5 μm.

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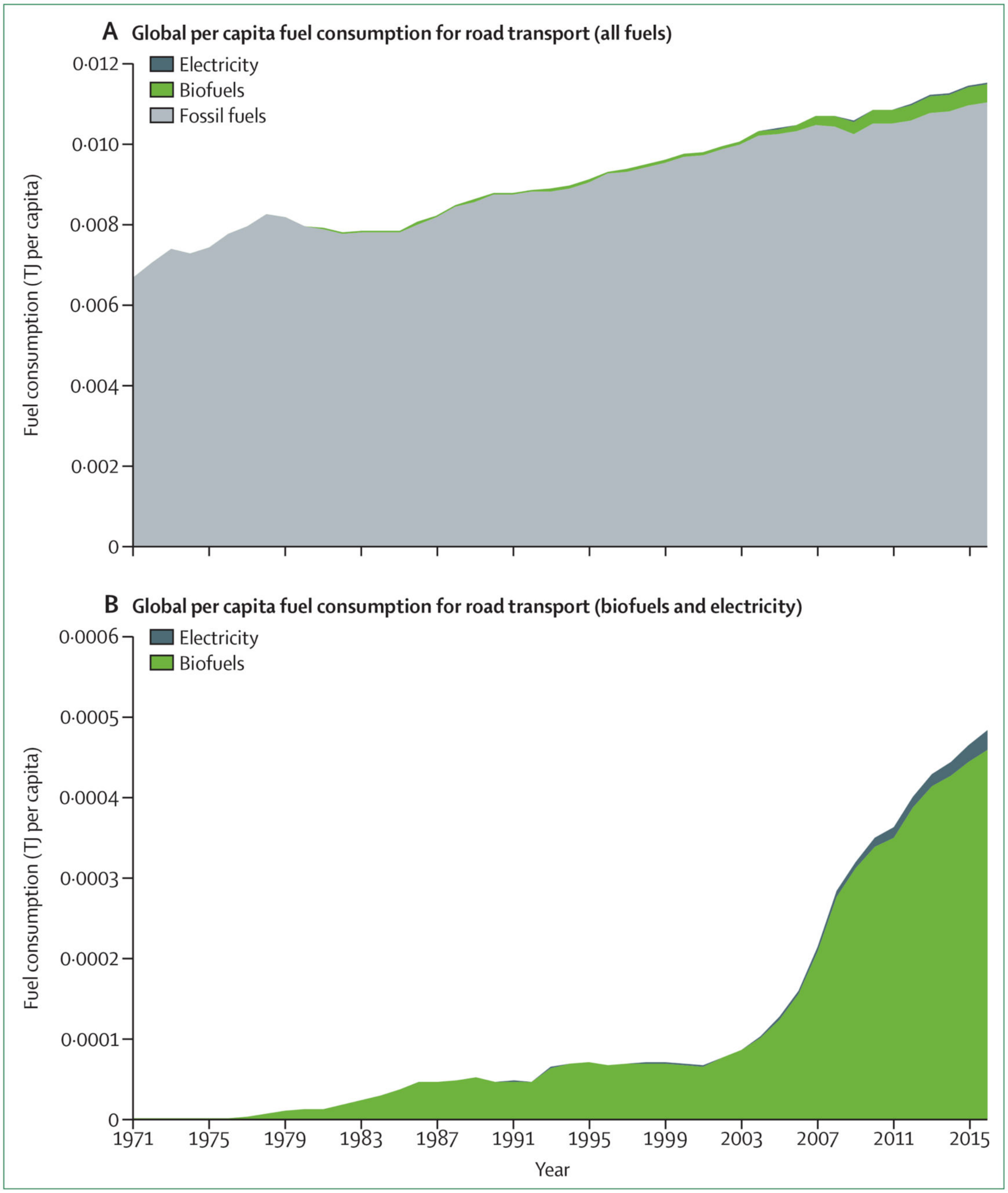

Figure 17. Per-capita fuel use by type (TJ per capita) for road transport

(A) Global per-capita fuel consumption for road transport using all types of fuels. (B) Global per-capita fuel consumption for road transport using biofuels and electricity.

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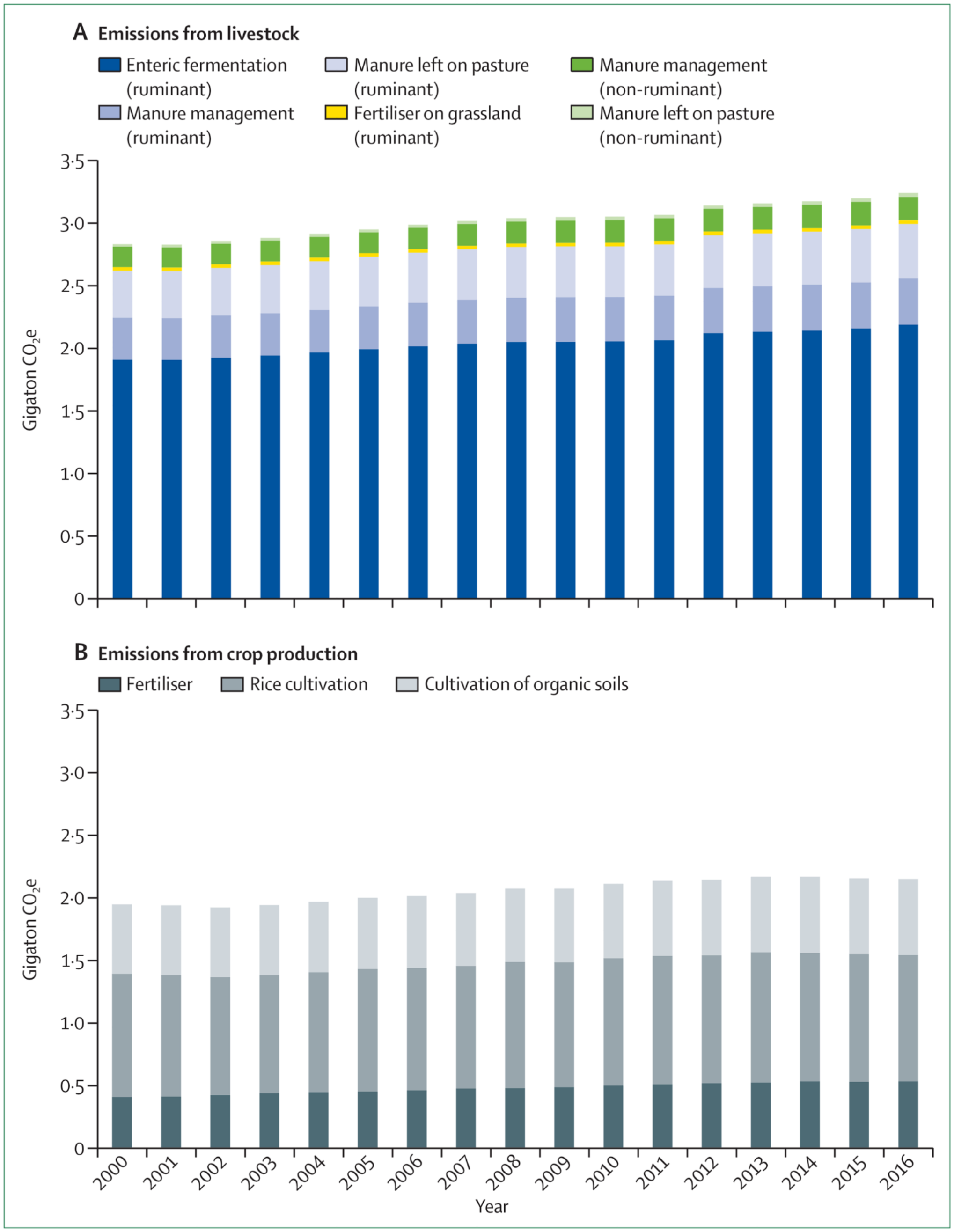

Figure 18. Gigaton CO_2e emissions from 2000 to 2016

(A) CO_2e emissions from livestock. (B) CO_2e emissions from crop production. CO_2e=carbon dioxide equivalent.

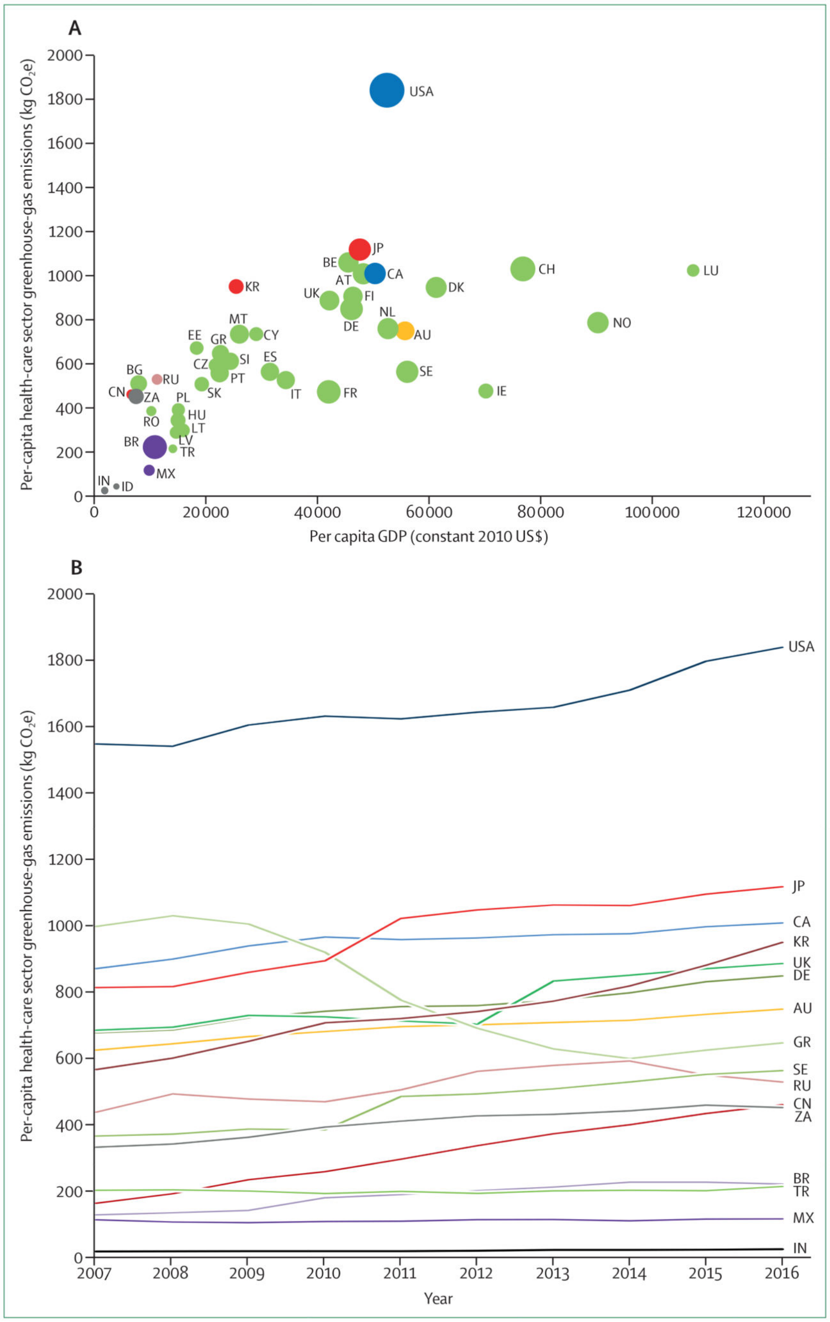

Figure 19. Variations in per capita health-care sector emissions as a function of time, per capita GDP, and the proportion of national spending on health care

(A) Health-care sector emissions as a function of GDP per capita (bubble widths indicate the proportion of national spending on health care). (B) Health-care sector emissions as a function of time. Graphs created using multiregional input-output EXIOBASE model. CO_2e=carbon dioxide equivalent. GDP=gross domestic product. AU=Australia. BR=Brazil. CA=Canada. CN=China. DE=Germany. GR=Greece. IN=India. JP=Japan. KR=South Korea. MX=Mexico. RU=Russia. SE=Sweden. TR=Turkey. ZA=South Africa.

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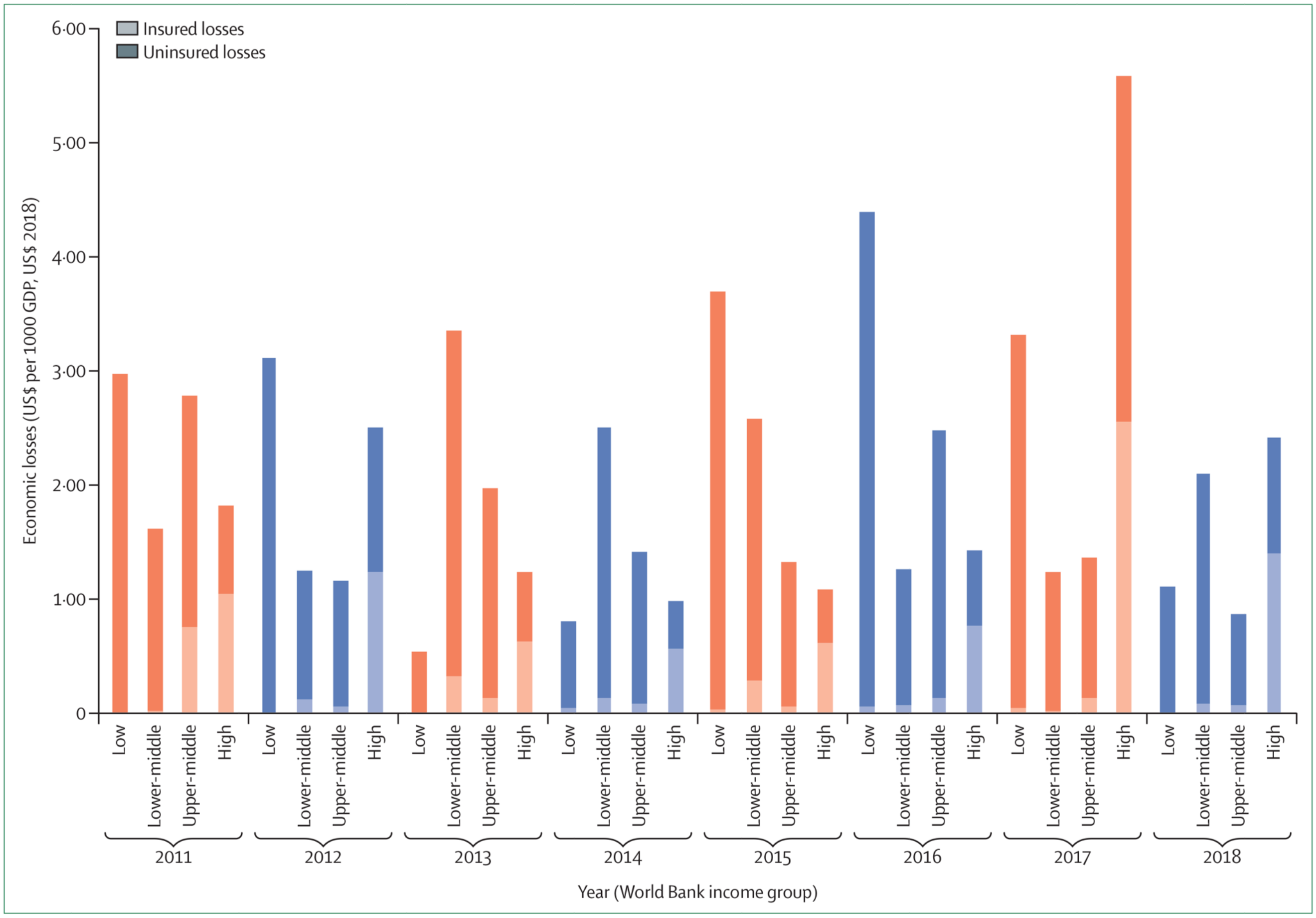

Figure 20. Economic losses from climate-related events relative to GDP

GDP=gross domestic product. US$2018=based on the value of the US dollar in 2018.

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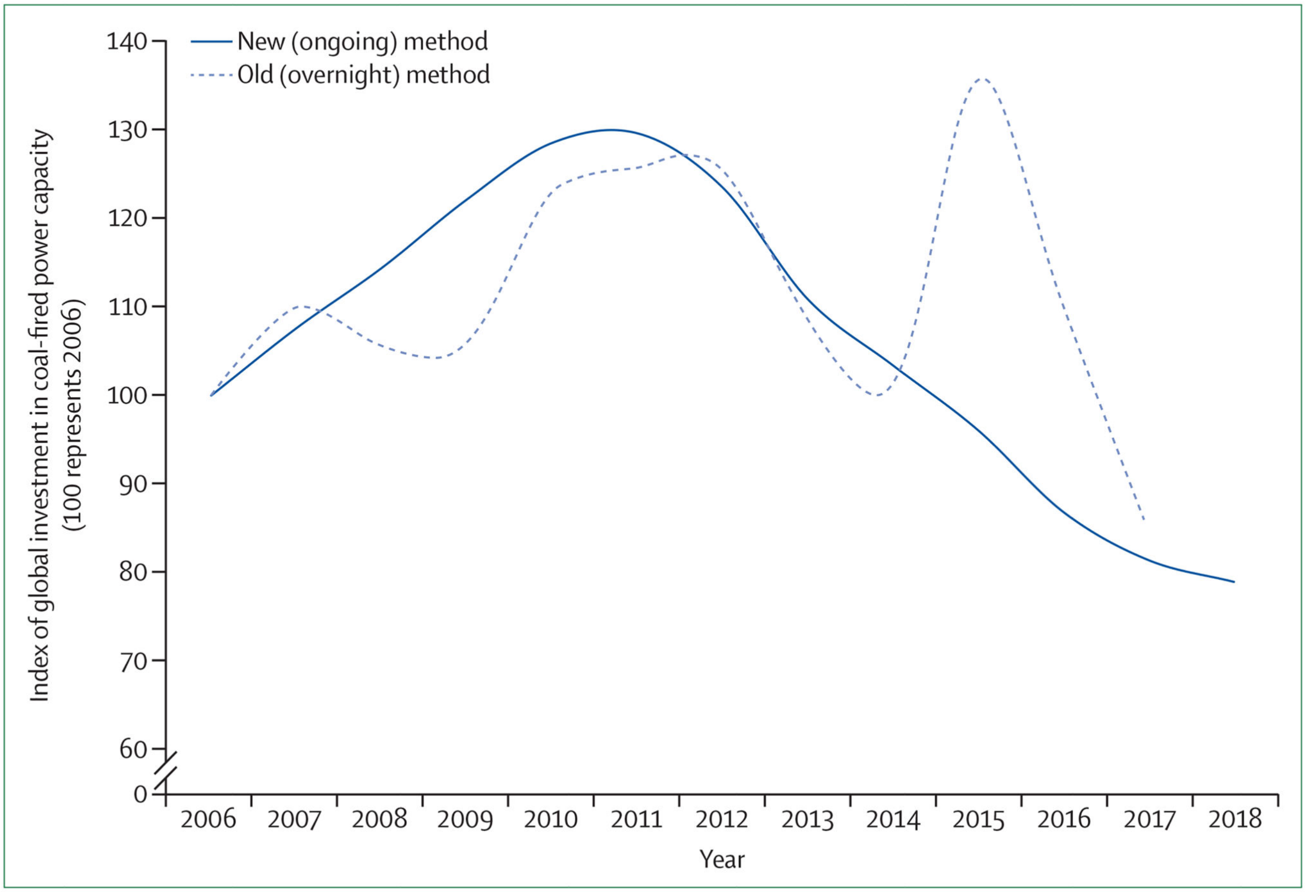

Figure 21. Annual investment in coal-fired capacity from 2006 to 2018

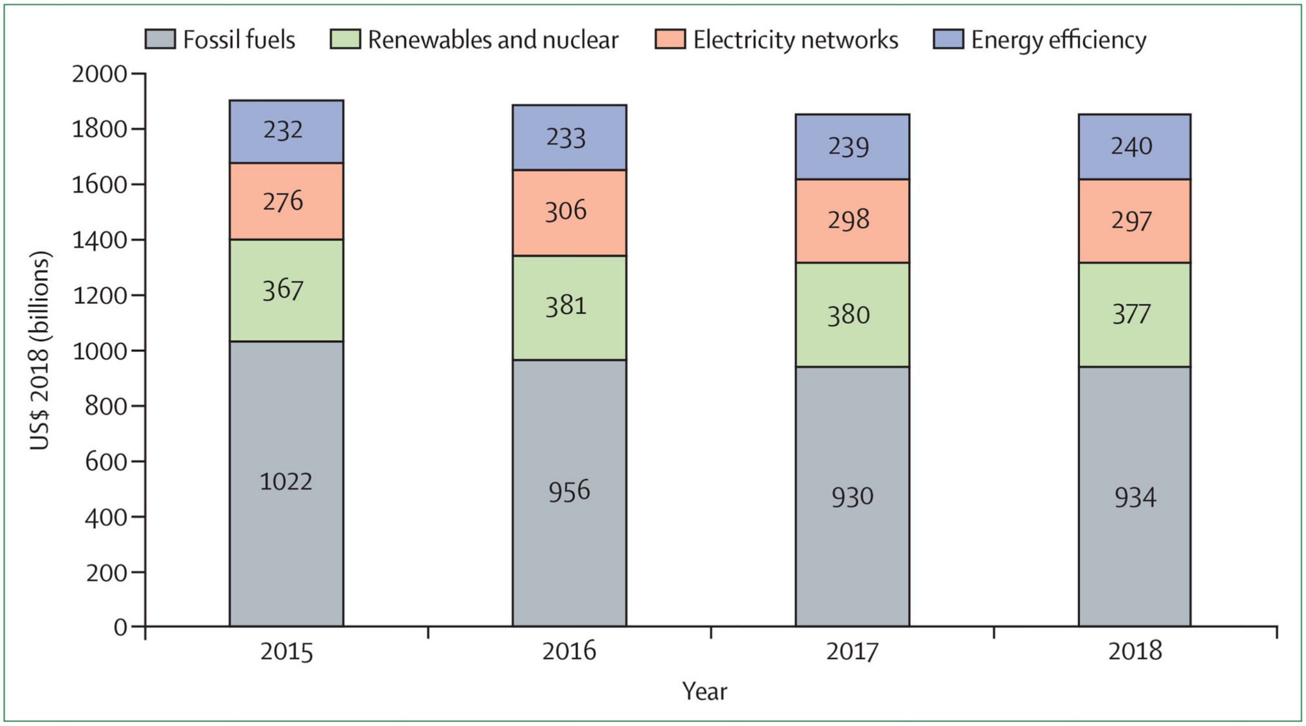

Figure 22. Annual investment in the global energy system

US$ 2018=based on the value of the US dollar in 2018.

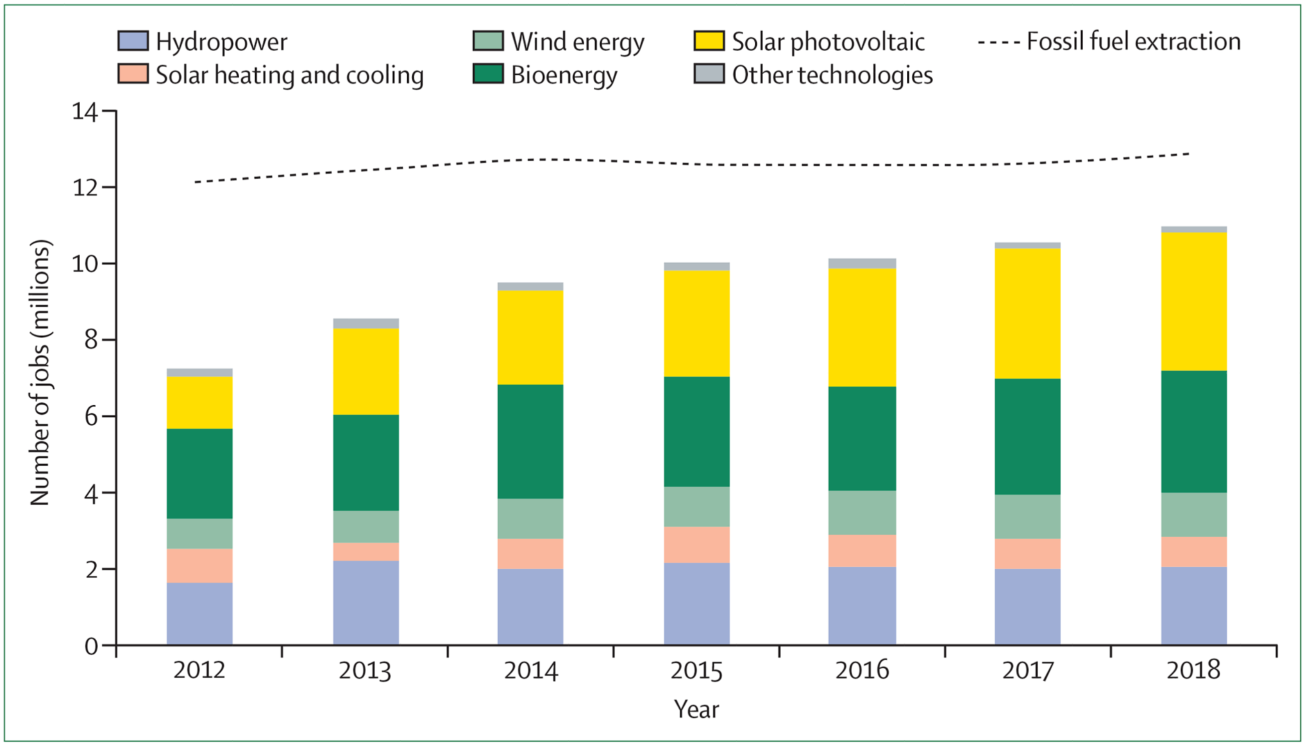

Figure 23. Employment in renewable energy and fossil-fuel extraction sectors
Data from IBISWorld [160,161] and IRENA.[162]

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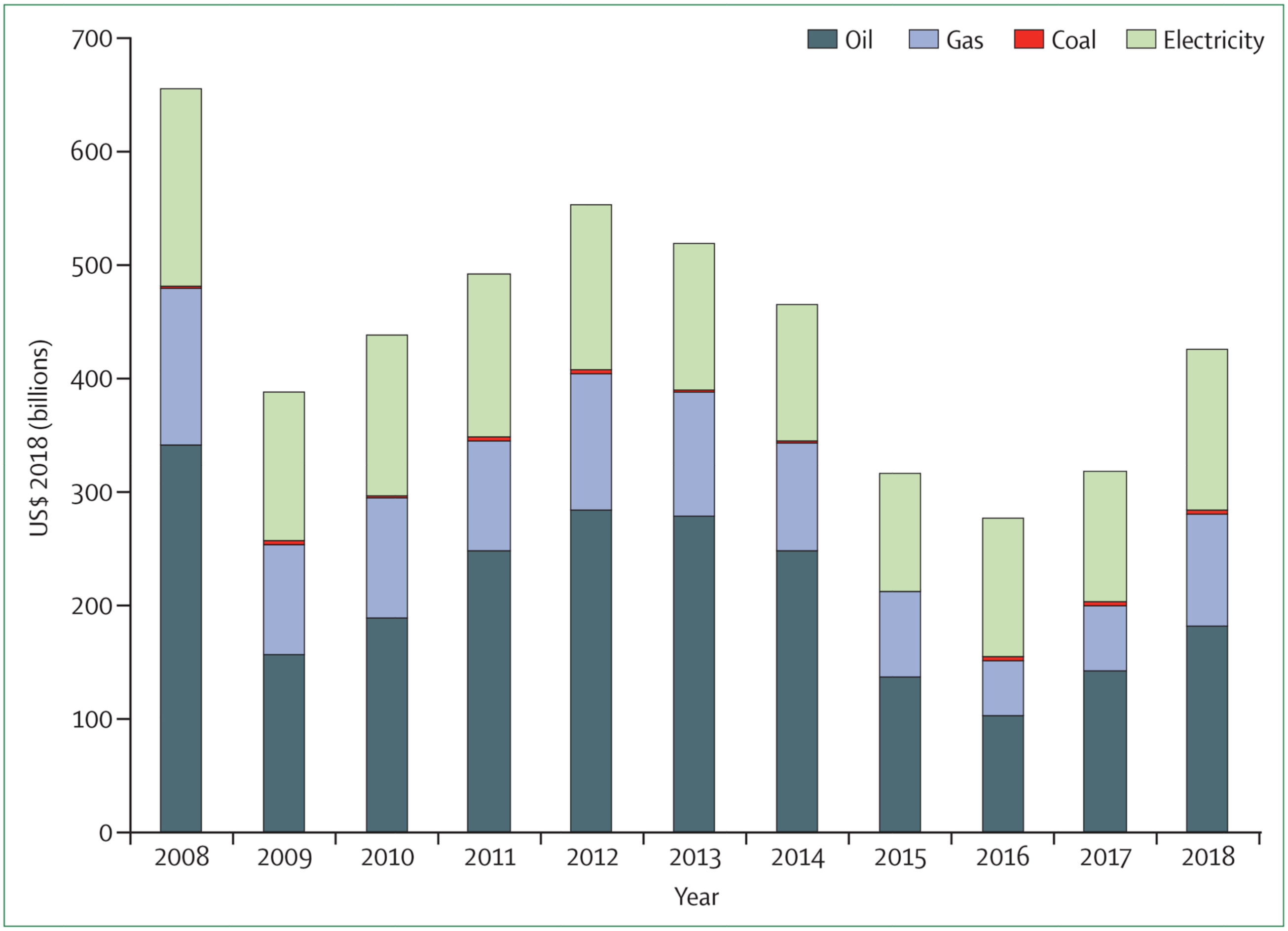

Figure 24. Global fossil-fuel and electricity consumption subsidies in 2008–18

US$ 2018=based on the value of the US dollar in 2018.

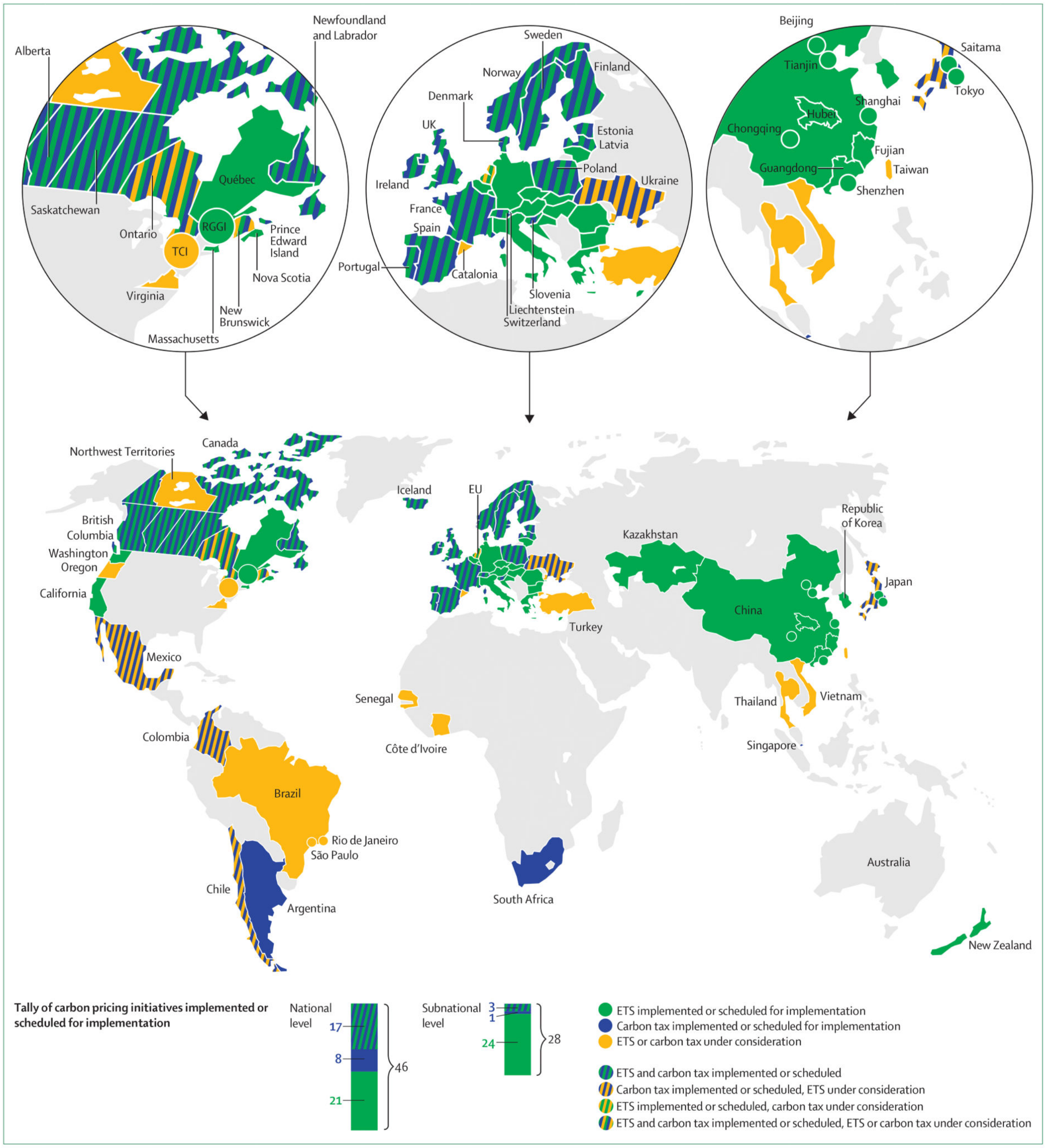

Figure 25. Summary map of regional, national, and sub-national carbon pricing initiatives implemented, scheduled for implementation, and under consideration (ETS and carbon tax)

Adapted from State and Trends of Carbon Pricing 2019,[167] by permission of World Bank Group. The large circles represent cooperation initiatives on carbon pricing between sub-national jurisdictions. The small circles represent carbon pricing initiatives in cities. Carbon pricing initiatives are considered to be scheduled for implementation when they have been formally adopted through legislation and have an official, planned start date. Carbon pricing initiatives are considered to be under consideration if the government has announced its intention to work towards the implementation of a carbon pricing initiative and this has been formally confirmed by official government sources. The carbon pricing initiatives have been classified in ETSs and carbon taxes according to how they operate technically. ETS not only refers to cap-and-trade systems, but also to baseline-and-credit systems as seen in British Columbia. Australia had a carbon tax implemeneted in 2012, which was then removed in 2014. ETS=Emissions Trading Scheme.

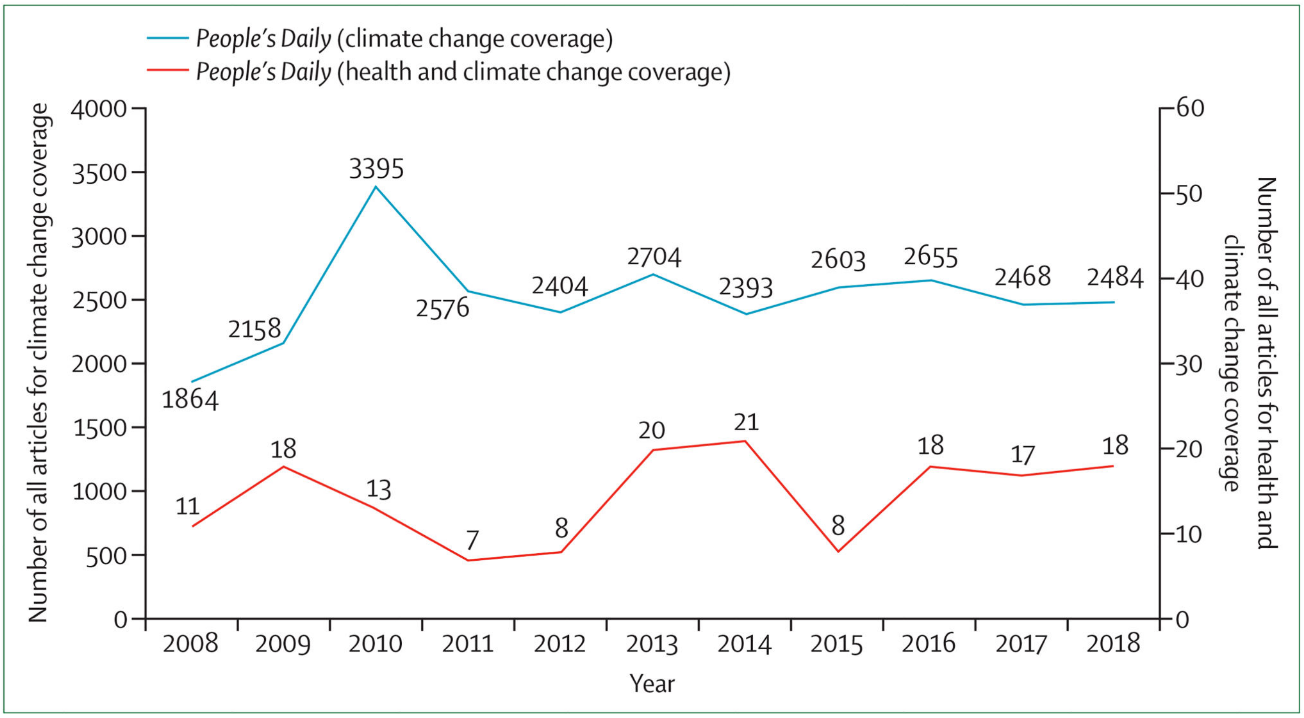

Figure 26. Coverage of climate change and health and climate change in *People's Daily* between 2008 and 2018

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Figure 27. Connectivity graph of Wikipedia articles on health (blue) and climate change (red) visited in 2018

Popularity of articles is indicated by node size; lines represent co-visits in clickstream data.

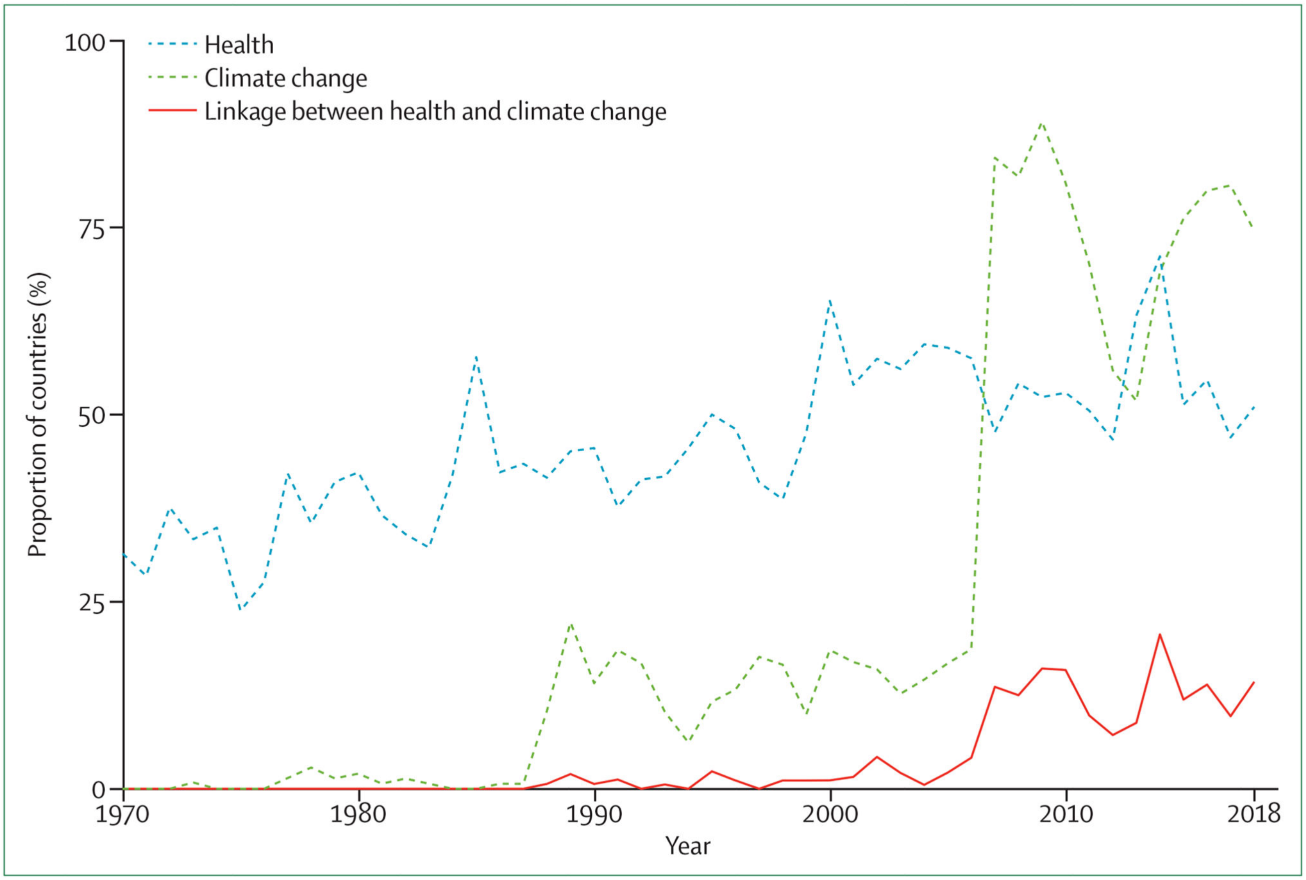

Figure 28. Proportion of countries referring to climate change, health, or the linkage between health and climate change in UN General debates between 1970 and 2018

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Table 1

Carbon pricing—global coverage and weighted average prices per tonnes of carbon dioxide equivalent

	2016	2017	2018	2019
Global emissions coverage *	12·1%	13·1%	13·1%	13·1%
Weighted average carbon price of instruments (prices in US$)	7·79	9·28	11·58	13·08
Global weighted average carbon price (prices in US$)	0·94	1·22	1·51	1·76

* Global emissions coverage is based on 2012 total anthropogenic greenhouse-gas emissions.

Table 2
Carbon pricing revenues and allocation in 2018

	Value (US$)	Proportion of total funds
Mitigation	24·36 billion	56·6%
Adaptation	258·million	0·6%
Revenue recycling	5·50 billion	12·8%
General funds	12·91 billion	30%
Total revenue	43·03 billion	100%