The 2019 Report of The Lancet Countdown on Health and Climate Change

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List of Abbreviations

A&RCC – Adaptation & Resilience to Climate Change
AAP – Ambient Air Pollution
AUM – Assets Under Management
BEV – Battery Electric Vehicle
CDP – Carbon Disclosure Project
CFU – Climate Funds Update
CO_2 – Carbon Dioxide
COP – Conference of the Parties
COPD – Chronic Obstructive Pulmonary Disease
CPI – Consumer Price Indices
CSD – Climate Sensitive Disease
DALYs – Disability Adjusted Life Years
DPSEEA – Driving Force-Pressure-State-Exposure-Effect-Action
ECMWF – European Centre for Medium-Range Weather Forecasts
EEIO – Environmentally-Extended Input-Output
EEZ – Exclusive Economic Zone
EJ – Exajoule
EM-DAT – Emergency Events Database
ERA – European Research Area
ETR – Environmental Tax Reform
ETS – Emissions Trading System
EU – European Union
EU28 – 28 European Union Member States
EV – Electric Vehicle
FAO – Food and Agriculture Organization of the United Nations
FAZ – Frankfurter Allgemeine Zeitung
FISE – Social Inclusion Energy Fund
GBD – Global Burden of Disease
GDP – Gross Domestic Product
GHG – Greenhouse Gas
$GtCO_2$ – Gigatons of Carbon Dioxide
GW – Gigawatt
GWP – Gross World Product
HAB – Harmful Algal Blooms
HFC - Hydrofluorocarbon
HIC – High Income Countries
HNAP – Health component of National Adaptation Plan
ICS – Improved Cook Stove
IEA – International Energy Agency
IHR – International Health Regulations
IPC – Infection Prevention and Control
IPCC - Intergovernmental Panel on Climate Change
IRENA - International Renewable Energy Agency
LMICs – Low and Middle Income Countries
LPG – Liquefied Petroleum Gas

Mt – Megaton
$MtCO_2e$ – Metric Tons of Carbon Dioxide Equivalent
MODIS – Moderate Resolution Imaging Spectroradiometer
MRIO – Multi-Region Input-Output
NAP – National Adaptation Plan
NASA – National Aeronautics and Space Administration
NDCs - Nationally Determined Contributions
NHMSs – National Meteorological and Hydrological Services
NHS – National Health Service
NO_x – Nitrogen Oxides
OECD – Organization for Economic Cooperation and Development
PHEV – Plug-in Hybrid Electric Vehicle
$PM_{2.5}$ – Fine Particulate Matter
PV – Photovoltaic
SDG – Sustainable Development Goal
SDU – Sustainable Development Unit
SHUE – Sustainable Healthy Urban Environments
SO_2 – Sulphur Dioxide
SSS – Sea Surface Salinity
SST – Sea Surface Temperature
tCO_2 – Tons of Carbon Dioxide
tCO2/TJ – Total Carbon Dioxide per Terajoule
TJ – Terajoule
TPES – Total Primary Energy Supply
TWh – Terawatt Hours
UHC – Universal Health Coverage
UN – United Nations
UNFCCC – United Nations Framework Convention on Climate Change
UNGA – United Nations General Assembly
UNGD – United Nations General Debate
V&A – Vulnerability and Adaptation
VC – Vectorial Capacity
WHL – Work Hours Lost
WHO – World Health Organization
WMO – World Meteorological Organization

Executive Summary

The Lancet Countdown is an international, multi-disciplinary collaboration dedicated to monitoring the evolving health profile of climate change, and providing an independent assessment of governments' delivery of their commitments under the Paris Agreement.

The 2019 report presents an annual update of 42 indicators across five key domains: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; finance and economics; and public and political engagement. It represents the findings and consensus of 27 leading academic institutions and UN agencies from every continent. In order to generate the quality and diversity of data required, 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.

The science of public health and climate change describe two possible future scenarios – a world that has responded to this threat, and one that has not. Whilst this can also be described as a continuum, the Lancet Countdown's indicators bring the present-day decisions and implications surrounding these two pathways, into sharp focus.

Without further action, the health of a child born today will be impacted by the world's failure to respond to climate change, at every stage in their life. This new era will come to define the health of an entire generation.

Evidence provided by the Intergovernmental Panel on Climate Change, the International Energy Agency, and the US National Aeronautics and Space Administration is helpful in understanding and contextualising the reason for such a momentous shift. The Paris Agreement lays out a global 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". The world has so-far observed a 1°C temperature rise above pre-industrial levels, with feedback cycles and polar amplification seeing a rise as high as 3°C in North Western Canada.[1,2] Indeed, eight of the ten hottest years on record have occurred in the last decade.[3] Such rapid change is primarily driven by the combustion of fossil fuels, consumed at a rate of 171,000 kg of coal, 11,600,000 litres of gas, and 186,000 litres of oil per second.[4-6] Progress in mitigating this threat is intermittent at best, with CO_2 emissions continuing to rise in 2018.[7] 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 previous downwards trend (Indicator 3.1.2). Correspondingly, the healthcare sector is responsible for some 4.6% of global emissions, steadily rising across most major economies (Indicator 3.6). Global fossil fuel consumption subsidies increased by 50% over the last three years, reaching a high of $429 billion USD in 2018 (Indicator 4.4.1).

Following this path, a child born today will experience a world that is over four degrees warmer than the pre-industrial average, with climate change impacting their health at every stage of life – from infancy and adolescence to adulthood and old age. Downward trends in global yield potential for all major crops tracked since 1960 threatens food production and food security, with infants often 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 hence 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 (the pathogen responsible much 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 $PM_{2.5}$ rising 7.5% from 2015 to 2016 (Indicator 3.3.2) and total global air pollution deaths reaching 7 million.[8]

Later in life, families, agricultural and construction workers, and livelihoods are put at risk from increases in the frequency and severity of extremes of weather, driven by climate change. At the global level, 53% of countries experienced an increase in daily population exposure to wildfires from 2001-2014 to 2015-2018 (Indicator 1.2.1). Perhaps unsurprisingly, India and China sustained the largest increases, with an increase of over 15 million and 10.5 million exposures over this time period. The economic cost per person affected by wildfires is over 48 times that of flooding.[9] In low-income countries, 99% of economic losses from extreme weather events are uninsured, placing a particularly high burden on individuals and households (Indicator 4.1). Temperature rises and heatwaves are limiting the labour capacity of populations at increasing rates. In 2018, 45 billion potential work hours were lost globally compared to a 2000 baseline, and Southern parts of the United States lost as much as 15-20% of potential daylight work hours during the hottest month of 2018 (Indicator 1.1.4).

Elderly populations aged over 65 years are particularly vulnerable to the health effects of climate change, and especially to extremes of heat. From 1990 to 2018, populations in every region has become more vulnerable to heat and heatwave, 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). Finally, whilst they are difficult to quantify, the systemic risks of climate change, such as those seen in migration, poverty exacerbation, violent conflict, and mental illness affect people of all ages and all nationalities.

Much of the data up to present day suggests that this first pathway is more closely aligned with the current global trajectory.

And yet, a second path is apparent. It is clear that such an unprecedented challenge requires an unprecedented response which accelerates the pace of change, transforming the health of that same child born today, right the way through their life.

In a world that matches the ambition of the Paris Agreement, this child would see the phase-out of all coal in the UK and Canada by their 6th 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. These changes and many more could result in cleaner air, safer cities, and more nutritious food. They would see renewed investment in health systems and vital infrastructure, as well as greater care for the broader determinants of health.

Considering the evidence available in the 2019 indicators, there are signs that the beginning of such a transition may be unfolding. Despite a small uptick in coal use in 2018, in key countries such as China, it continued to fall as a share of electricity generation (Indicator 3.2.1). 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 grew by an enormous 20.6% between 2015 and 2016, and now represents 1.5% of China's total transportation fuel use (Indicator 3.4). In a number of cases, the savings from a healthier and more productive workforce with fewer healthcare expenses will cover the initial investment costs of these interventions. Similarly, more resilient cities and health systems are beginning to emerge. Almost 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). 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 is in part funded by growing revenues from carbon pricing mechanisms, which saw a 50% increase in funds raised between 2016 and 2017, up to $33 billion USD (Indicator 4.4.3).

Taken as a whole, current progress is inadequate, and 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. There are too many missed opportunities to improve public health, and leadership in recognising these links at the UN General Assembly is too often left to Small Island Developing States (Indicator 5.3). Indeed, it is those who will be affected most by climate change that have led the wave of school climate strikes across the world. The scale and scope of the transformation to a low-carbon economy needs to accelerate if the second of these two pathways are to become a reality.

Delivering such an unprecedented transition will require bold, new approaches to research, policymaking, and business. It will take the work of the 7.5 billion people currently alive, to ensure that the health of a child born today, isn't defined by a changing climate.

Introduction

The stability of human health and wellbeing, local communities, health systems, and governments all depend on how they interface with the global climate.[2,3] A global average temperature rise of 1°C since a pre-industrial baseline[4,5] has already revealed profound impacts, with more severe storms and floods, prolonged heatwaves and droughts, new and emerging infectious diseases,[6-8]and compounding threats to global and local food security. Left unabated, climate change will come to define the health profile of coming generations, will overwhelm hospitals and health services around the world, and undermine efforts to achieve the United Nations (UN) Sustainable Development Goals (SDGs) and efforts to achieve universal health coverage (UHC).[9,10]

The Intergovernmental Panel on Climate Change's (IPCC) recent Special Report on Global Warming of 1.5°C makes the scale of the response required clear, with a stark reminder that meeting this ambitious goal requires global annual emissions to halve by 2030 and reach net-zero by 2050, whilst recognising that no further level of warming at the current rate is considered 'safe'.[5] 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 only one of these pathways – cleaner air through more sustainable transport and power generation systems – confirms 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 world-wide.[11] This complements recent assessments from outside the health sector, which estimate that a robust response to climate change could yield over US$26 trillion, and 65 million new low-carbon jobs, by 2030 compared to a business-as-usual scenario.[12]

Monitoring this transition from threat to opportunity, and demonstrating the benefits of realising the Paris Agreement, is precisely why *the Lancet Countdown: Tracking Progress on Health and Climate Change* was formed. As an international, independent research collaboration, the partnership brings together some 27 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 42 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).

Working Group	Indicator	
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
		1.2.1: 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 under-nutrition	1.5.1: Terrestrial food security and under-nutrition
		1.5.2: Marine food security and under-nutrition
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: Adaptation financing	2.4.1: Spending on adaptation for health and health-related activities
		2.4.2: Health adaptation funding from global climate financing mechanisms
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: Zero-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 healthcare sector	
Finance and Economics	4.1: Economic losses due to climate-related extreme events	
	4.2: Economic value of change in mortality due to air pollution	
	4.3: Investing in a low-carbon economy	4.3.1: Investment in new coal capacity
		4.3.2: Investments in zero-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 United Nations General Assembly	
	5.4: Engagement in health and climate change in the corporate sector	

Panel 1: The Lancet Countdown Indicators

Strengthening a global monitoring system for health and climate change

Commencing its work in 2012 and first publishing in 2015, this collaboration initially sought to understand and assess the science and pathways linking climate change to public health. In 2016, the Lancet Countdown launched a global consultation process, actively seeking input from experts and policymakers on which aspects of these pathways could and should be tracked as part of a global monitoring process. The final set of indicators were selected, based on: 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 policymakers.[13]

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 continuously improved and updated. In every case, a full description of these changes is provided in the appendix.

The 2019 report presents 12 months of work refining the metrics and analysis. In addition to updating each indicator by one year, key developments include:

- Strengthened methodologies and datasets 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; and qualitative validation of engagement from the media and national governments in health and climate change;
- Expanded geographical and temporal coverage 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.
- Constructed new indicators that capture: exposure to wildfires; the transmission suitability for cholera; the benefits and harms of air conditioning; emissions from livestock and crop production; global healthcare system emissions; and individual online engagement in health and climate change.

For the second consecutive year, these changes represent significant updates to a majority of indicators – a pace which will only accelerate as additional 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 new input and participation from experts and academic institutions willing to build on the analysis published in this report.

The year in health and climate change

The 2019 report of the Lancet Countdown is accompanied by a detailed appendix, which discusses the data, methods, strengths and limitations of each indicator and which is intended as an essential companion to the main report, rather than a more traditional addendum.

The additional year of data presented in the 2019 report points to a number of worsening human symptoms of climate change. Over 220 million additional exposures to extremes of heat occurred in 2018 compared to a 1986-2005 average, more than any number previously on record (Indicator 1.1.3). This occurred at a time when vulnerability to these extremes is rising 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, this resulted in losses in labour capacity, with a number of the Southern states in the United States 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 wildfires, with 106 countries experiencing a marked increase in the daily population exposures to wildfires when compared to baseline (Indicator 1.2.1). In the case of infectious disease, nine out of the last ten most suitable years for the transmission of dengue fever have occurred since 2000, and 2018 was the second most suitable year on record for the transmission of diarrhoeal disease and wound infections from *Vibrio* bacteria (Indicator 1.4.1).

Despite this, the carbon intensity of the global energy system remains flat since 1990 (Indicator 3.1.1), and access to clean fuels for household services is stagnating (Indicator 3.2). Perhaps of greatest concern, total primary energy supply from coal increased by 1.7% from 2016 to 2018, reversing a previously observed downwards trend (Indicator 3.1.2), and 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 $429 billion in 2018, a greater than 33% rise from 2017 (Indicator 4.4.1), and air pollution related deaths rose by around 200,000 additional deaths from 2015 to 2016 (Indicator 3.3.2), resulting in economic losses of **XX** in Europe alone (Indicator 4.2). More directly related to health and healthcare delivery, healthcare emissions now represent 4.6% of global emissions and continue to rise across most major economies (Indicator 3.6).

Whilst these already apparent health impacts and lack of coordinated global response portray a bleak picture, they also mask important trends that lie behind the data. Encouraging trends of reduced investment in new coal capacity and a fall in coal as a share of total electricity generation continue (Indicators 4.3.1 and 3.1.2). Strong growth in renewables continues, accounting for 45% of total growth in 2018 (Indicator 3.1.3). Indeed, low-carbon electricity reached an impressive 32% of total global electricity in 2016 (Indicator 3.1.3). At the same time, the world is beginning to adapt, with almost 50% of countries, and 69% of cities surveyed, reporting the completion or undertaking of a climate change risk assessment or adaptation plan (Indicator 2.1.2 and Indicator 2.1.3). In the health sector, the Royal College of General Practitioners and the UK’s Faculty for Public Health divesting their fossil fuels investments (Indicator 4.3.4), and 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 Lancet Countdown’s 2019 report are deeply concerning, and suggestive of a world that is failing to reduce its greenhouse gas emissions and is too slow in responding to climate change. Nevertheless, the continuing expansion of renewable energy, increased investment in health system adaptation, improvements in sustainable transport, and growth in public engagement suggest ongoing reason for cautious optimism. At a time when the UN Framework Convention on Climate Change (UNFCCC) is preparing to review commitments under the Paris Agreement in 2020, greatly accelerated ambition and action in these sectors may provide a pathway to meet the world’s commitment to remaining “well below 2°C”.[14]

Section 1: Climate Change Impacts, Exposures, and Vulnerabilities

Climate change and human health are interconnected in a myriad of complex ways.[8] Building on the Lancet Countdown's previous work, section 1 of the 2019 report continues to track quantitative metrics along a pathway of population vulnerability, exposure, and health outcome that are indeed indicative of the cost to human health of climate change, and thus the urgent need for climate change mitigation. The impacts tracked here in turn motivate and guide climate change adaptation (section 2) and mitigation (section 3) interventions.

The work in section 1 spans exposure-oriented indicators that are closer to the climate signal, such as exposure to extreme weather events (Indicator 1.2.1), changes in crop yield potential (Indicator 1.5.1), and labour productivity (Indicator 1.1.4), through to indicators closer to health outcomes, such as those related to infectious diseases (Indicator 1.4.1).

Changes in warming and weather events are not evenly distributed across the globe, and some populations are more vulnerable than others to these changes. This is reflected through indicators that, for example, focus on particularly vulnerable populations (such as Indicator 1.1.1) and by disaggregating some data at the regional level (such as Indicators 1.1.1 and 1.3).

Whilst it is certainly true that the effects of climate change vary by geography and that these will not always be negative, it is also true that these so-called 'positives' are often short-term in nature, and quickly overwhelmed and outweighed by other exposures. One such example is seen in Australia, where any benefit that may 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.

For 2019, a new metric, tracking exposure to wildfires (Indicator 1.2.1) has been added, as has an expansion of climate suitability for transmission of infectious diseases (Indicator 1.4.1) to now include cholera. These indicators portray a world which is rapidly warming, where environmental and social systems are already feeling the effects of climate change, and human health is being affected as a result.

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 are well documented and understood, and include heat stress and heat stroke, acute kidney injury, and the exacerbation of congestive heart failure,[15] as well as increased risk of interpersonal[16] and collective violence[17]. In the 2019 Lancet Countdown report, four indicators are related to heat, 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 elderly populations in every region of the world. Whilst Europe remains the most vulnerable, the Western Pacific, South East Asia and African regions have all seen an increase in vulnerability to extremes of heat of over 10% since 1990.*

Certain populations are more vulnerable to heat than others. The elderly, especially those with pre-existing medical conditions (such as diabetes and cardiovascular , respiratory, and renal disease) are particularly at risk.[18] Outdoor workers, while younger and healthier overall, are also vulnerable due to heightened exposure. This indicator presents a heat vulnerability index, with the data and methods unchanged from previous years.

Vulnerability to extremes of heat continues to rise among elderly populations in every region of the world (Figure 1). The highest increase from 1990 to 2017 has been seen in the Western Pacific (33.1% to 36.6%), 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 elderly population, high rates of urbanisation, and high prevalence of cardiovascular and other chronic diseases.

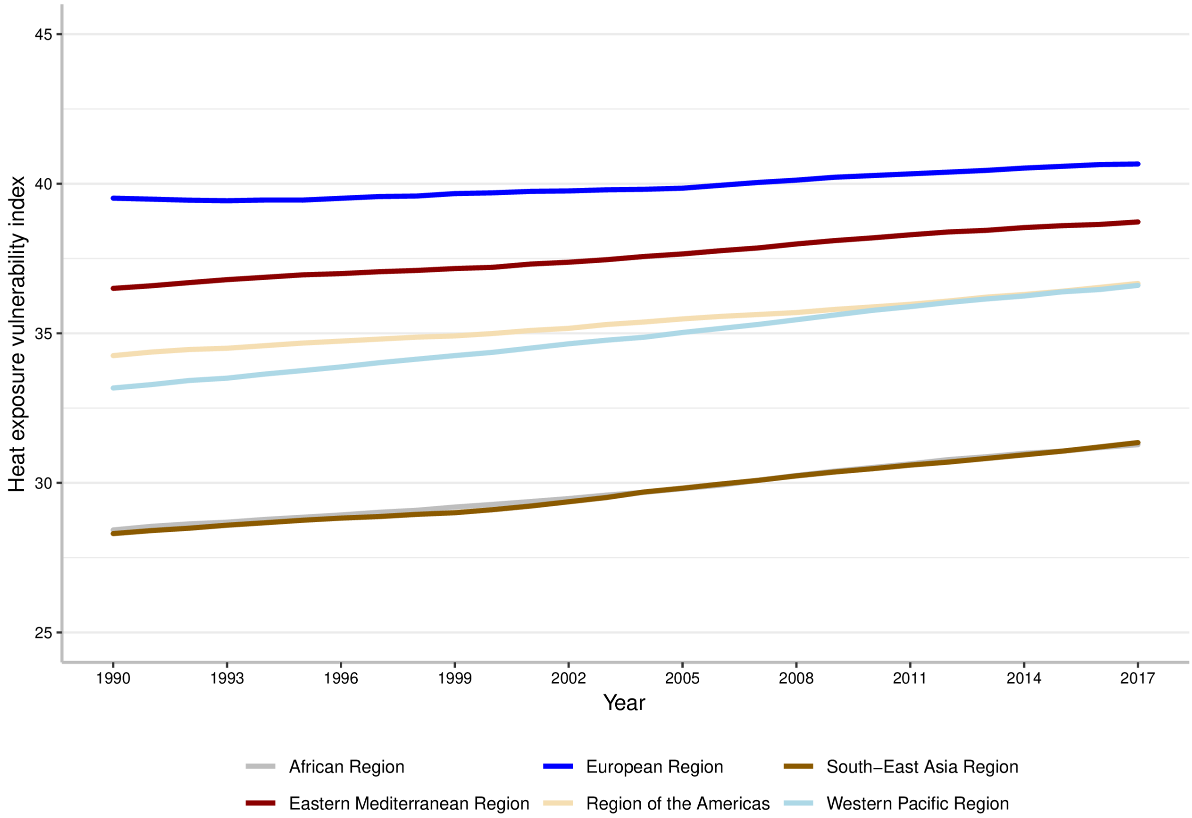


Figure 1: Trends in heat-related vulnerability for populations over 65 years by WHO Region

Indicator 1.1.2: Health and exposure to warming

Headline finding: *The mean global summer temperature change experienced by humans continues to increase significantly faster than the mean global summer temperature change experience across the whole planet. In 2018, a 0.8°C mean change relative to the 1986–2005 baseline was experienced by the world population, compared to a 0.2°C global mean change over the same period.*

This indicator compares the population-weighed temperature change from a 1986-2005 baseline with the global average temperature change over the same period, using weather data from the European Centre for Medium-Range Weather Forecasts (ECMWF),[19] ERA-Interim project and population data from the NASA Socioeconomic Data and Applications Center (SEDAC) Gridded Population of the World (GPWv4)[20] (see appendix). The 2019 report improves on previous methods, using higher resolution climate and population data(0.5˚ grid instead of 0.75˚ grid).

Figure 2 presents the trend in global and population-weighted temperature change. The population weighted temperatures (normalised for population growth) continue to grow at a significantly faster pace than the global average, increasing the human health risk; this increase is broadly evenly distributed across the globe. The global average population-weighted temperature has risen by 0.8ºC from the 1986-2005 baseline to 2018, compared with a global average temperature rise of 0.2°C over the same period.

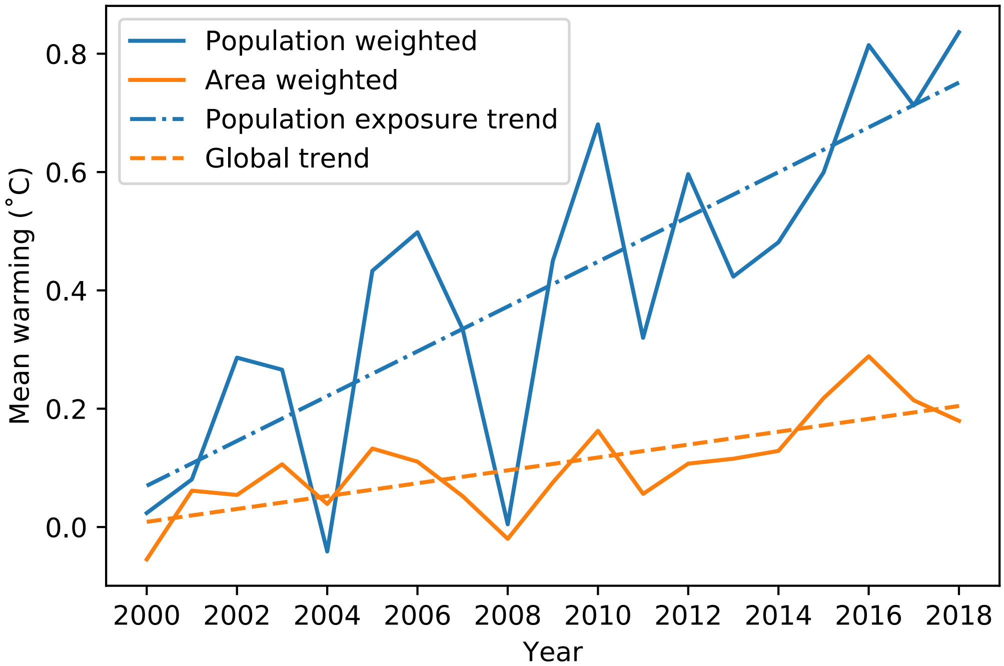


Figure 2 : Mean summer warming relative to the 1986–2005 average

Indicator 1.1.3: Exposure of vulnerable populations to heatwaves

Headline finding: *In 2018, 220 million heatwave exposures were observed, breaking the previous record of 209 million exposures in 2015. Japan alone experienced 32 million heatwave exposures, the equivalent of almost every person aged 65 and above experiencing a heatwave in 2018.*

Heatwaves were identified in the 2015 Lancet Commission as posing significant health risks, particularly in vulnerable populations, resulting in excess deaths and hospital admissions.[18] The definition of a heatwaves, and methods used here remain unchanged from previous reports (See Appendix). For the 2019 report, demographic data from the NASA SEDAC GPWv4,[20] with each heatwave exposure event being one heatwave experienced by one person (see appendix). This indicator was also improved with a higher resolution (0.5˚ grid instead of 0.75˚ grid).

Figure 3 presents the change in heatwave exposure events relative to the recent past average. In 2018 there were 220 million heatwave exposures, 11 million more than the previous record set in 2015. This is due to a series of heatwaves across India (45 million exposures); in central and northern Europe (31 million exposures in the EU); and northeast Asia, where the heatwave affected Japan the Korean peninsula, and Northern China, with 32 million exposures in Japan alone, the equivalent of almost every person aged 65 and above in Japan experiencing a heatwave in 2018.[21]

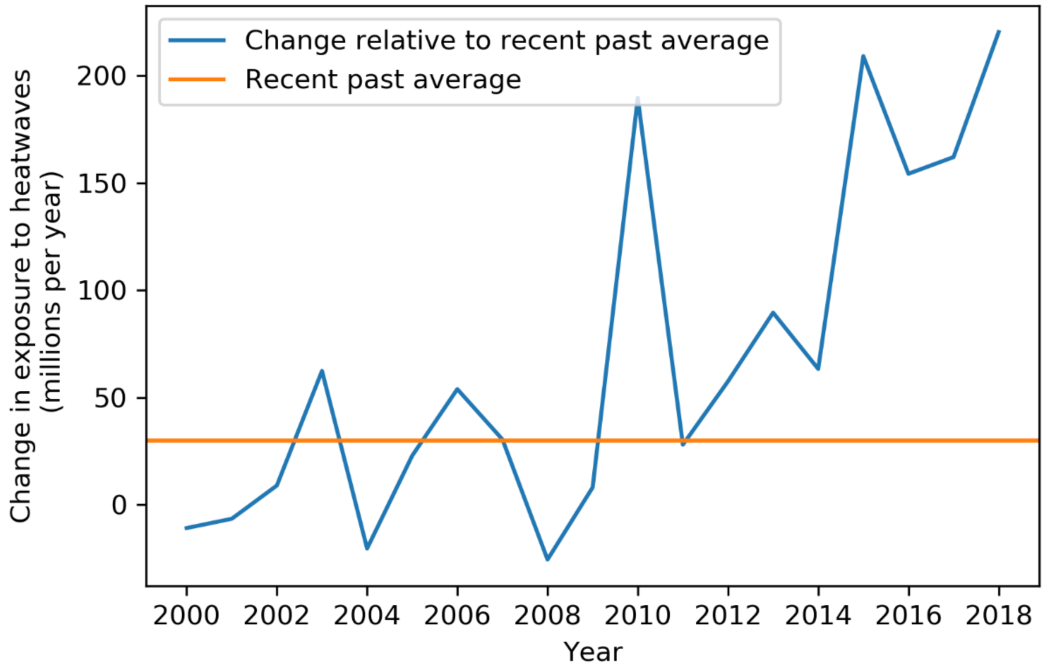


Figure 3: Change in the number of heatwave exposure events (with one exposure event being one heatwave experienced by one person) compared with the historical average number of events (1986–2005 average)

Indicator 1.1.4: Change in labour capacity

Headline finding: *higher temperatures continue to affect people's ability to work. In 2018 there were 45 billion additional work hours lost compared with 2000 due to extremes of heat.*

This indicator highlights the important impact of climate change on labour capacity in vulnerable populations.[22] People's ability to work is affected by both 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%.[23] Reduced labour productivity may be the first symptom of the health effects of heat, and, if not addressed, may lead to more severe health effects, such as heat exhaustion and heat stroke.

This indicator assesses labour capacity loss by assigning work-fraction loss functions to different activity sectors in accordance with the power (metabolic rate) typically expended by a worker performing that activity. Unsafe work hours are calculated as a function of the WBGT and the internal heat generated by work activity within three sectors: service (200W), manufacturing (300W) and agriculture (400W), and analysed on an hourly basis by 0.5˚ grid cell.[24] This is then coupled with the proportion of the population working within each of these three sectors to calculate potential work hours lost (WHL).[20,25] This indicator has been improved to include the impact of sunlight of the work hours lost by calculating the increase in WBGT using solar radiation data available from the ERA database.

The global atmospheric temperature and humidity in 2018 were slightly more favourable for work than in 2017, but the upward trend of work hours lost since 2000 remains clear (Figure 4). In 2018, 133.6 billion of potential work hours were lost, 45 billion hours more than in 2000. **Error! Reference source not found.** presents a map of the equivalent potential full-time work lost in the sun and the shade**.** Of note, for 300W work in the shade (typical for manufacturing), over 10% potential daily work hours are lost in densely populated regions such as South Asia. For 400W work in the sun (typical for agriculture and construction), even workers in the Southern parts of the USA (below a latitude of 34ºN, with Texas, Louisiana, Mississippi, Alabama, Georgia, and Florida particularly affected), lost 15-20% of potential daylight work hours in the hottest month in 2018.

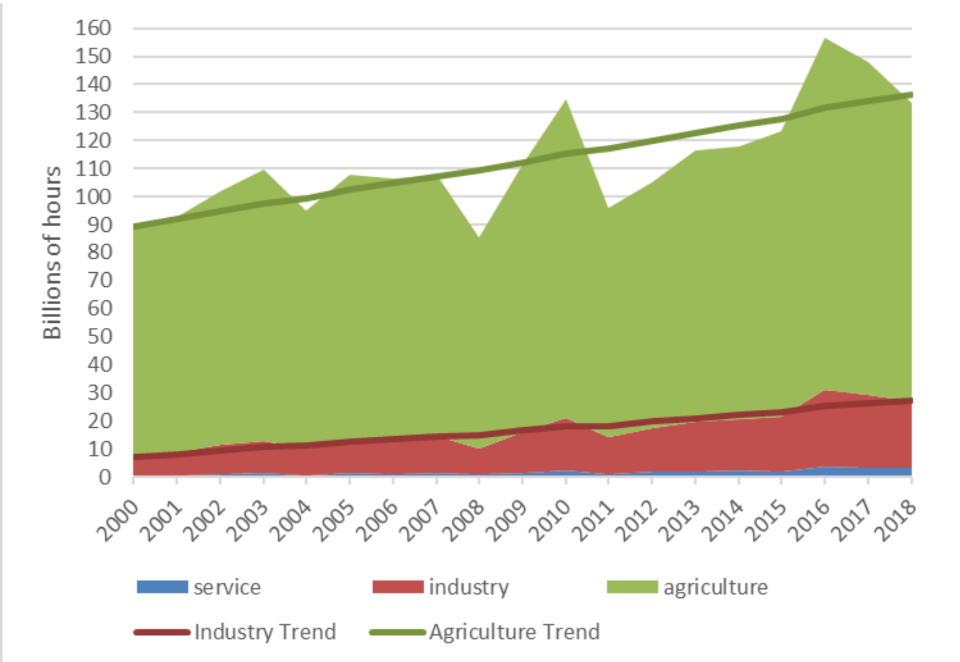


Figure 4: Potential global work hours lost by sector 2000-2018

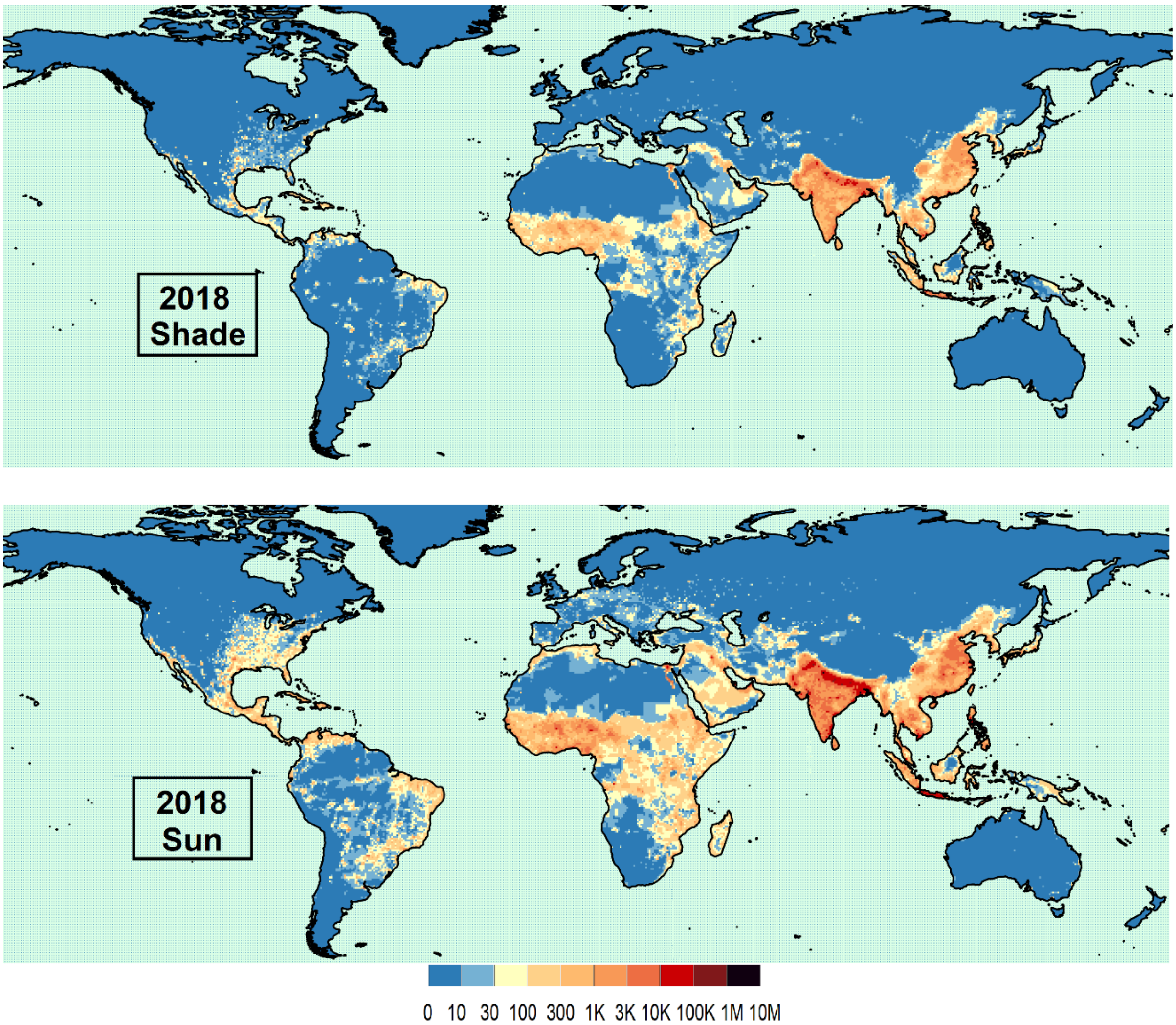


Figure 5: Potential full-time work lost assuming all work in the shade or all work in the sun (12 hours a day, 365 days a year) based on the percent of people working in agriculture (400W), industry (300W) and services (200W) in each grid cell.

Indicator 1.2: Health and extreme weather events

Indicator 1.2.1: Wildfires

Headline finding: *106 out of 196 countries tracked saw an increase in daily population exposure to wildfires in 2015-2018 compared to 2001-2004, with India alone experiencing an increase of 15 million daily population exposures to wildfire. Wildfires not only pose a threat to public health, but also result in major economic and social burdens in both higher and lower-income countries.*

The health impacts of wildfires range from direct thermal injuries and death, to the exacerbation of acute and chronic respiratory and cardiovascular symptoms due to a rise in ambient particulate matter.[26] Additionally, the global economic burden per person affected by wildfires is over twice that of earthquakes and over 48 times that of floods.[27] Furthermore, recent climatic changes including increasing temperature and earlier snowmelt contribute to hotter, drier conditions that increase risk of wildfires.

Wildfires remain an important component of many ecosystems, although they can be ecologically harmful through human ignition or where forest management practices do not fully account for it including support for periodic, natural burning.

This new indicator represents the difference between the average person days exposed to wildfire in each country during the most recent four years, as compared a 2001 – 2004 baseline period (the earliest period for which data is available).

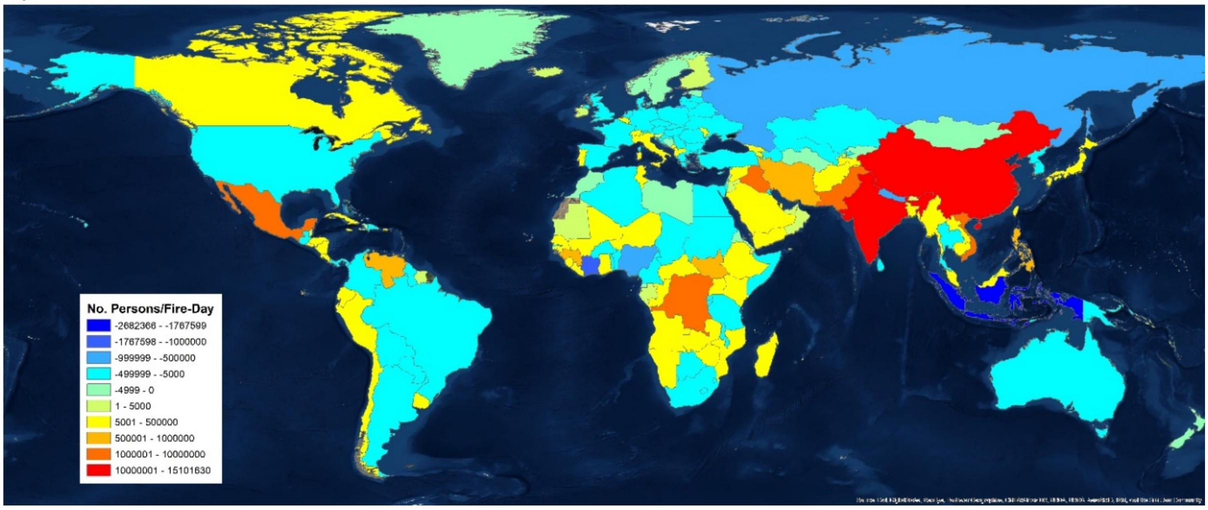
It was developed using Collection 6 active fire product from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra and Aqua satellites.[28] Fire point locations were matched to a political border shapefile from the GBD, and consequently joined with population count per squared kilometre, taken from NASA SEDAC GPWv4.[20] The result is an annual sum of people experiencing a fire event per day. The mean number of person-days exposed to wildfire was taken for years 2001-2004 (the earliest period available) and compared with the mean number from 2015-2018.

Overall, this indicator reports a mean increase of 169,802 person-days exposed to wildfire per year over the period studied, however the change experienced in some countries is far greater than the global increase. India, China, the Democratic Republic of Congo, Mexico, and Iraq sustained the largest increase in the number of persons impacted by wildfire-days, with a maximum difference of nearly 15,102,000 person-days in India followed by

10,454,000 person-days in China (Figure 6). Countries such as Indonesia, Russia and Nepal saw significant reductions in the number of people affected.

Results from this indicator imply that wildfire is not just an issue for countries where slash-and-burn agricultural practices persist, such as Botswana, Indonesia, and Brazil, but is also an issue for densely populated middle- and high-income countries including China, India, Mexico, and Japan.

A)



B)

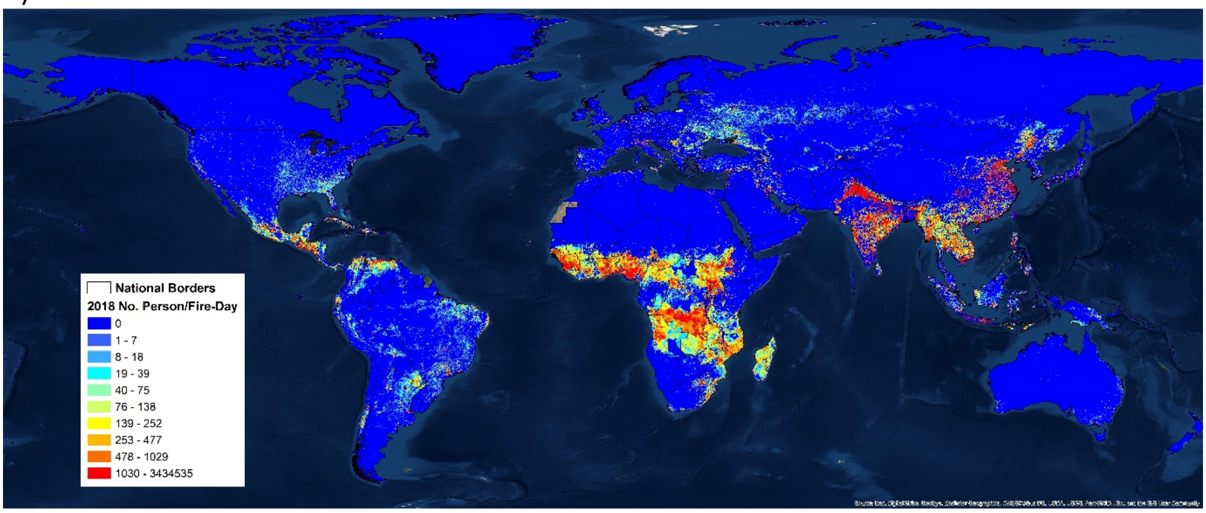


Figure 6: Human exposure to fire. A) Average change in annual person days exposed to wildfires between 2001-2004 and 2015-2018; B) Person days exposed to fire in 2018.

Indicator 1.2.2: Flood and drought

Headline Finding: *Extremes of precipitation, resulting in flood and drought have profound impacts on human health and wellbeing, with South American and South East Asian populations experiencing long-term increases in both phenomena.*

This indicator tracks exposure to extremes of precipitation, using weather and population data used in previous reports, and described in full in the appendix. [19,13] 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- and water-borne disease, and mental health sequalae.[29] Figure 7 provides a global map of extremes of rainfall as a proxy for flood, and demonstrates South America and South East Asia experiencing particularly consequential increases.

Conversely, 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.[29] The change in the mean number of severe droughts)highlight increased exposure in large areas of South America, Northern and Southern Africa, and South East Asia, with many areas experiencing a full 12 months of drought throughout the year.

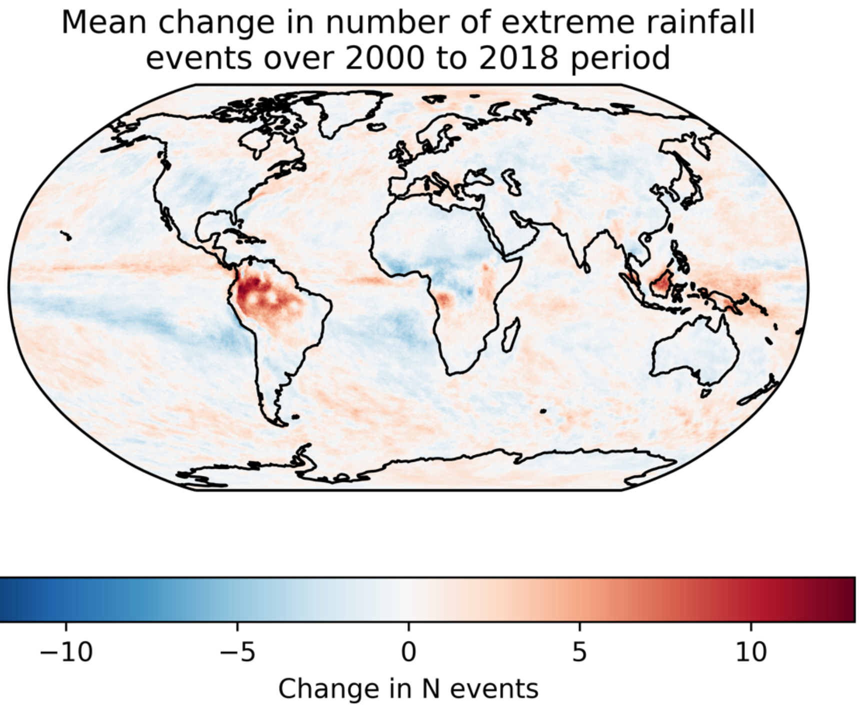


Figure 7. Mean change in number of extreme rainfall events per year over the 2000-2018 period (change calculated relative to mean of 1986-2005)

Indicator 1.2.3: Lethality of weather-related disasters

***Headline Finding:** To date, there has been a statistically significant long-term upward trend in the number of flood and storm related disasters in Africa, Asia, Europe 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 lethality and number of people affected by weather-related disasters. 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.[30] For the 2019 report, disasters have been separated into two groupings: flood and storm related disasters; and heatwave and drought related disasters. Further detail of these methods and data are presented in the appendix.

For the heatwave, drought and extreme temperature related disasters, no statistically significant global trend was identified, reflecting 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. The trends for Africa, which demonstrated a statistically significant increase in the number of people affected, is presented in Figure 8, below.

The relative stability of the lethality and numbers of people affected due to these disasters could be possibly linked to improved disaster preparedness (including improved early warning systems) as well as increased investments in healthcare services, and will be discussed further in section 2.[31-33] Importantly, work from the 2015 Lancet Commission demonstrate that a business-as-usual trajectory is expected to result in an additional 2 billion flood-exposure events per year by 2090, overwhelming health systems and public infrastructure.[8]

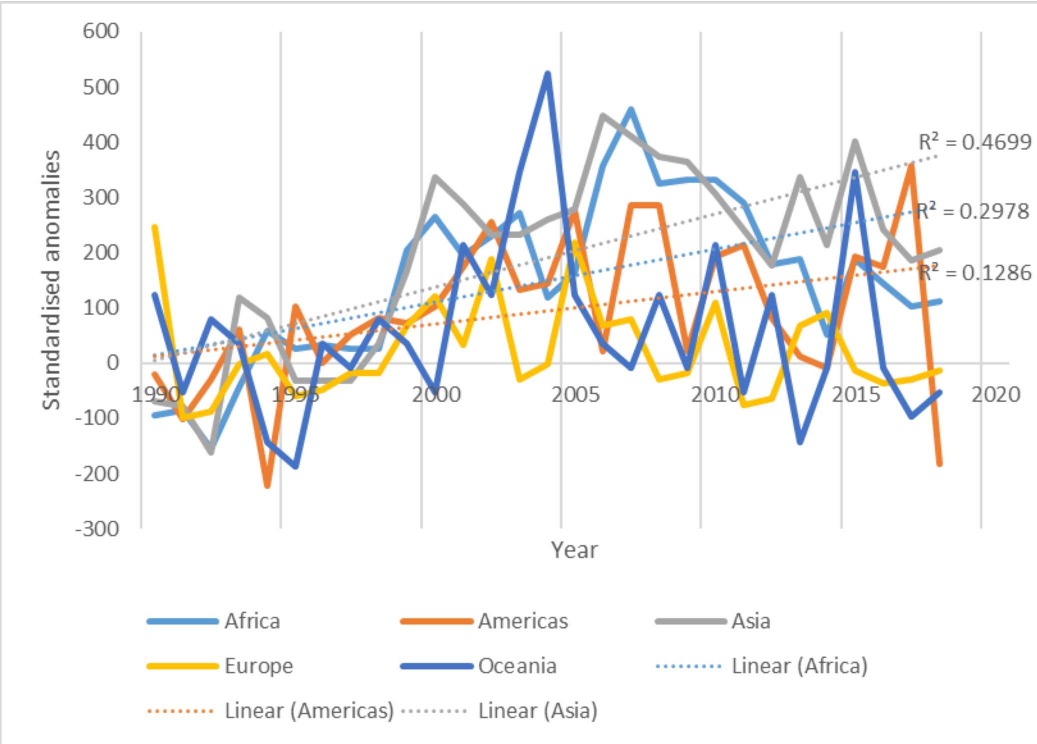


Figure 8: Time series of occurrences flood and storm related disasters. Significant increases in occurrences of these disasters against the base period of 1990-1999 have occurred in Asia, Africa and the Americas. Standardized anomalies are calculated by taking the annual value from the average value from 1990-2018, normalised by the standardized value from 1990-2018 The regression lines and R^2 values present the relationship between time and the frequency of occurrences in Africa, the Americas and Asia.

Indicator 1.3: Global health trends in climate-sensitive diseases

Headline finding: *Whilst large improvements are occurring in mortality due to diarrhoeal diseases, malnutrition, and malaria, mortality due to dengue and malignant melanoma is rising in regions most affected by these diseases.*

As described in the preceding indicators, climate change affects a wide range of disease processes. Whilst those indicators track change in exposure, suitability and vulnerability to these disease outcomes, this indicator tracks mortality to climate-sensitive diseases using GBD data, which has been updated for the year 2017 (see appendix).[34] Mortality due to earthquake and volcano events is removed from 'forces of nature' to give estimates for weather-related events.

Mortality from all climate-related causes is rising in the Western Pacific and South East Asia and remains flat in Europe. Death from diarrhoeal diseases and protein-energy malnutrition continue to decline in regions most affected (Africa, South East Asia and Eastern Mediterranean) and malaria mortality has had a strong decrease since the 2000s in Africa. However, mortality from dengue fever and malignant melanoma continues to rise, with South East Asia seeing the strongest increase in dengue fever mortality.

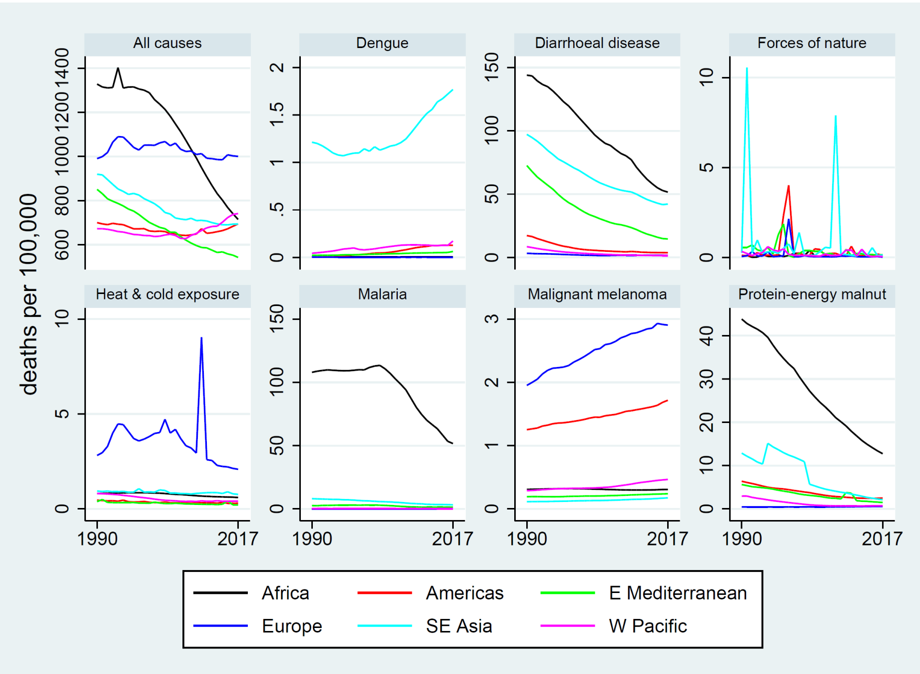


Figure 9: Deaths per 100,000 population by WHO regions and disease. Data taken from IHME GBD 2017 [34]

Indicator 1.4: Climate-sensitive infectious diseases

Indicator 1.4.1: Climate suitability for infectious disease transmission

Headline Finding: *Due to a changing climate, environmental conditions are increasingly suitable for the transmission of numerous infectious diseases. Suitability for disease transmission has increased for dengue, malaria,* Vibrio cholerae *and other pathogenic* Vibrio *species. The number of suitable days per year in the Baltic for pathogenic* Vibrio *reached 107 in 2018, the highest since records began and double the early 1980s baseline.*

Climate change can affect the distribution and risk of many infectious diseases.[29] The 2019 Lancet Countdown report, updates its analysis of dengue virus, malaria and *Vibrio* with the most recently available data. Each trend is presented, as well as an additional analysis for cholera transmission risk.

The methodology used to track climate suitability is similar for each of these pathogens. For the mosquito-borne infectious diseases, suitability for transmission is affected by factors such as temperature, humidity and precipitation. For dengue, vectorial capacity (VC) is calculated, which expresses the average daily rate of subsequent cases in a susceptible population resulting from one infected case, 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.[35] For malaria, the number of months suitable for transmission of *Plasmodium falciparum* and *P. vivax* malaria parasites is calculated based on temperature, precipitation and humidity. Climate suitability for both of 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, septicemia, and cholera. *Vibrio* species are found in brackish marine waters and cases of infections are influenced by sea surface salinity (SSS), sea surface temperature (SST), and chlorophyll-a concentrations.[36-38] Climate suitability for *Vibrio* species was estimated based on SSS and SST globally and focally for two regions in which *Vibrio* (excluding *V. cholerae*) infections are most frequently observed. For pathogenic *Vibrio* species (excluding *V. cholerae*), an average of the five most recent years for which data is available is compared with a 1980s baseline, whereas the new *V. cholerae* specific analysis compares the most recent three years with a 2003-2005 baseline (based on data availability). Full detail on methods can be found in the appendix.

Climate suitability for transmission is rising for each of the pathogens studied in the 2019 Lancet Countdown report. VC for both dengue vectors was the second highest year on record in 2017, with the 2012-2017 average 7.2% and 9.8% above baseline for *Aedes aegypti* and *Aedes albopictus*, respectively (Figure 10). This continues the upward trend of climate suitability for transmission of dengue, with nine of the ten most suitable years occurring since 2000. Malaria suitability continues to increase in highland areas of Africa, with the 2012-2017 average 25.6% above baseline. The percentage of coastal area suitable for *Vibrio* infections in the 2010s has increased at northern latitudes (40-70° N) by 3.8% compared to a 1980s baseline, with 2018 the second most suitable year on record (5.0% above the baseline) (Figure 11). The area of coastline suitable for *Vibrio* has increased by 31.0% and 29.0% for the Baltic and US Northeast respectively. Additionally, the number of days per year suitable for Vibrio in the Baltic reached 107 in 2018, which is double the early 1980s baseline and the highest on record. Globally, suitability for coastal *V. cholerae* has increased by 9.9%, driven by regional increases in Asia, Europe, Middle East, North America, and Northern and Western Africa.

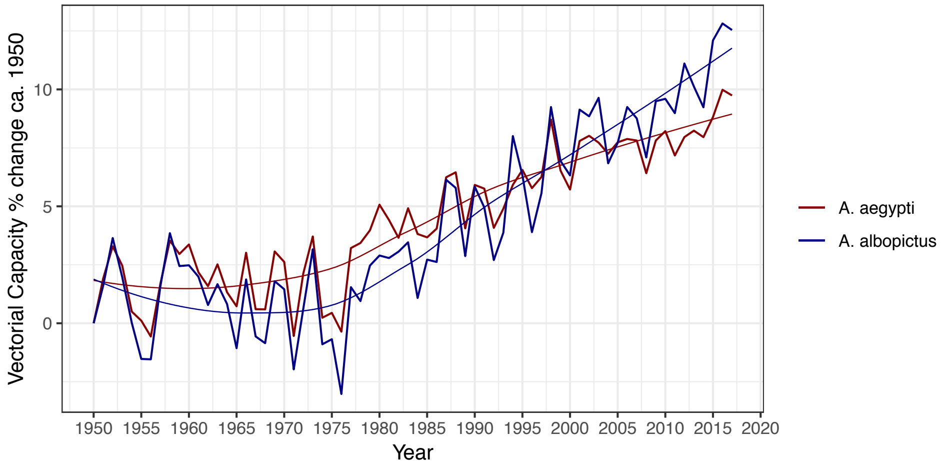


Figure 10: Changes in global vectorial capacity for the dengue virus vectors Aedes aegypti and Aedes albopictus 1950-2017.

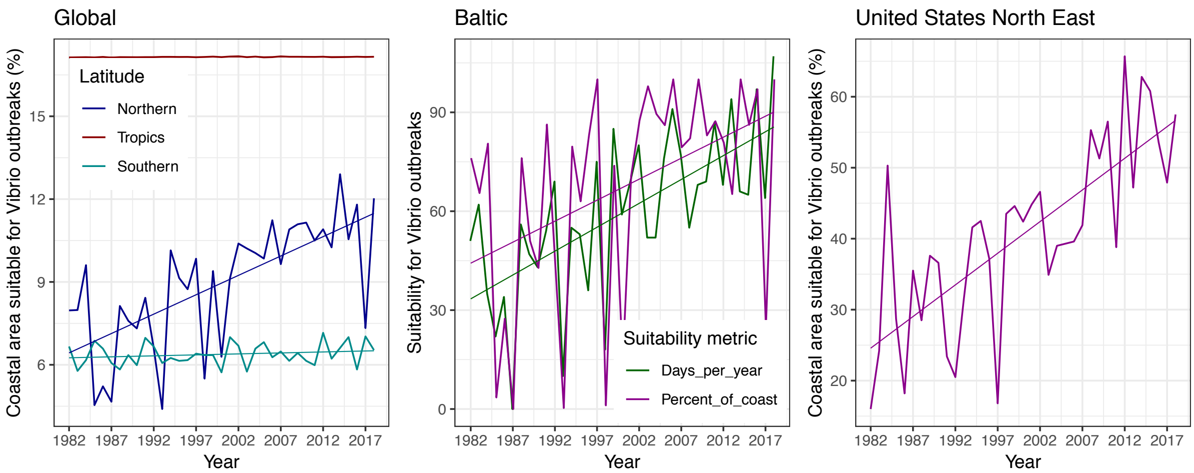


Figure 11: Change in suitability for pathogenic Vibrio outbreaks as a result of changing sea surface temperatures a) globally, divided into three latitudinal bands (northern latitudes = 40-70°N; tropical latitudes = 25°S-40°N; and southern latitudes = 25-40°S); b) the Baltic and c) United States North East coast.

Indicator 1.4.2: Vulnerability to mosquito-borne diseases

***Headline finding:** Climate change induced risk of mosquito-borne diseases may be offset by improvements in public health systems. Dramatic investments in public health have resulted in a 31% fall in global vulnerability observed from 2010–2017. 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.*

The indicator above describes the influence of climate over the transmission of numerous vector-borne diseases. Importantly, population vulnerability to this phenomenon is modulated by human, social, financial, and physical factors as well as to the adaptive capacity of a community.[39,40].[3941]

County-level data from the WHO International Health Regulations (IHR) core capacities for the years 2010 to 2017,[42] are used as a proxy for adaptive capacity. *Aedes aegypti* vulnerability is defined by abundance and VC as described in Indicator 1.6.1. This index estimates the population-level risk of exposure to *Aedes* mosquitoes, accounting for the public health core capacity to cope with the potential impacts. A full account of the methods can be found in the appendix. A contraction of the vulnerability to dengue is observed from 2010 to 2017 in the tropical and sub-tropical areas of South America, Africa and Asia. However, this decrease in vulnerability has levelled off in recent years, 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:** All major crops tracked – maize, wheat, rice, and soybean – demonstrate ongoing downward trends in global crop yield potential.*

There is increasing evidence that crop production is threatened in complex ways by changes in the incidence of pests and pathogens;[43] increasing water scarcity;[44] and increased frequency and strength of extreme weather conditions that can damage or even wipe out harvests. Currently, global food production continues to increase. In many countries yield gaps are still being closed through improvements such as better nutrient and water management,[45] and expansion of agricultural area continues in many lower-income countries.[46] Yet, the global number of undernourished people appears to have been increasing since 2014.[47] [48] Moreover, globally, crop yield potential for maize, winter wheat, and soybean is demonstrating a downwards trend (Figure 12), challenging efforts to achieve SDG 2 to end hunger by 2030.[48]

Crop yield potential was tracked for wheat, rice, and soybean, in addition to maize. Change in crop growth duration is used as a proxy here, which compares total season accumulated thermal time (ATT) with a 1981-2010 baseline reference period.[49] This updated methodology and proxy is described in full, in the appendix, alongside a full description of the CRU database used.[44] Crop yield potential for maize, winter wheat, and soybean all demonstrate a downwards trend (Figure 12). For spring wheat and rice, the data suggest no reduction in yield potential in recent years. This data resonate with a meta-analysis of the literature by Zhao et al. (2017),[50] which suggests that global yields of these four key crops are reduced by 6%, 3.2%, 7.4% and 3.1% globally for each 1°Cincrease in global mean temperatures.

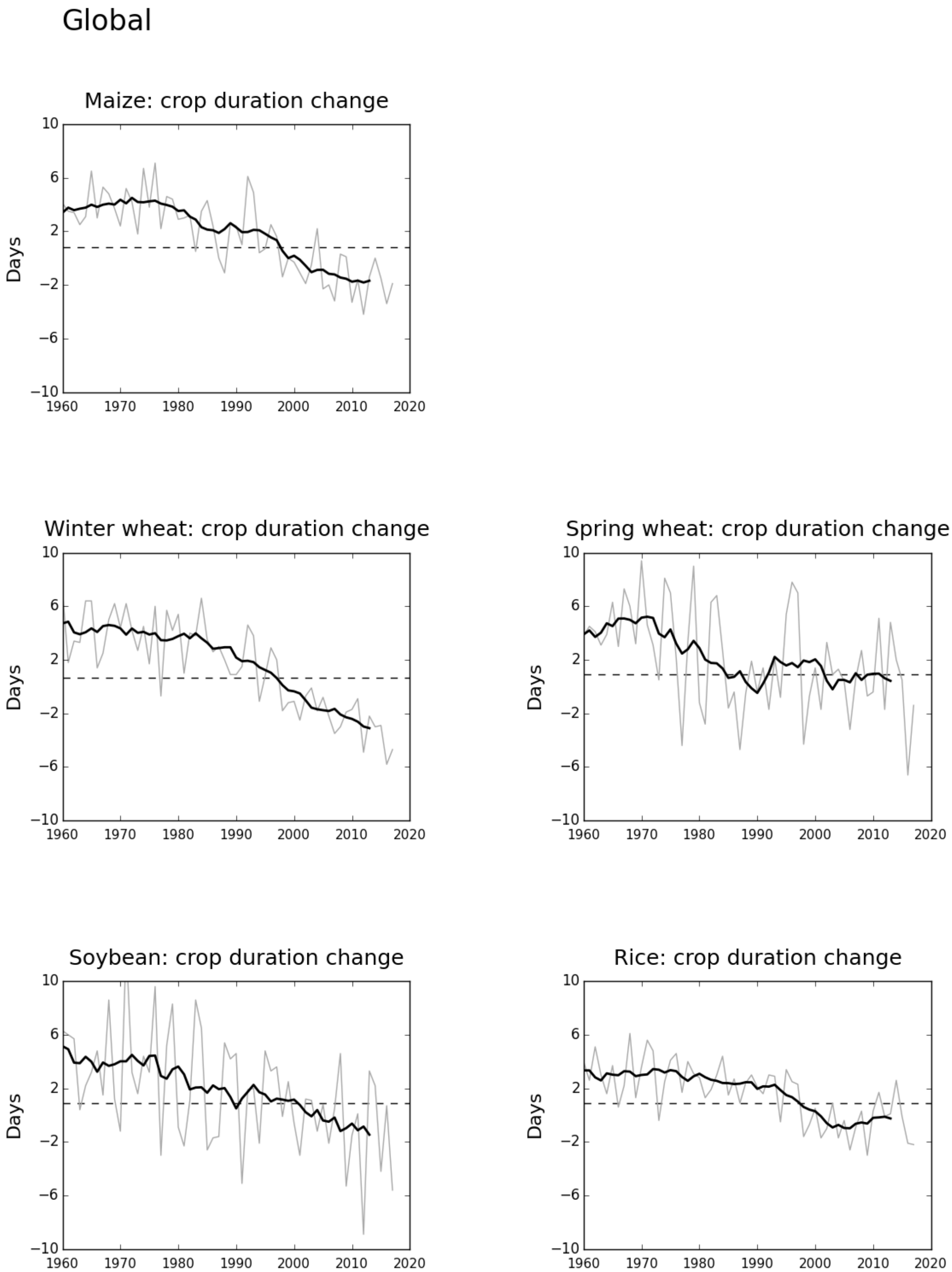


Figure 12: Change in crop growth duration for five crops, 1981-2010 baseline

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, to a maximum of 3.5°C , undermining marine food security.*

Fish are an important part of diets for populations around the world, providing 3.2 billion people with almost 20% of their animal protein intake, with a greater reliance on fish sources of protein often in LMICs, particularly small island developing states (SIDS).[51] Climate change threatens fisheries and aquaculture in a number of ways, including through SST rise, intensity, frequency, and seasonality extreme events, sea level rise, and ocean acidification.[52] Acute disturbances such as thermal stress lead to impaired recovery of the coral reefs, which threatens marine fish populations and therefore marine primary productivity, a key source of omega3 fatty acids for many populations.[53]

This indicator tracks SST in territorial waters, selected for their geographical coverage and importance to marine food security, using data sourced from FAO, NASA and NOAA with all methods described in full in the appendix.[54-56] This has been further developed and now includes 64 territorial waters (including countries where data is available) located in 16 FAO fishing areas This indicator is complemented by monitoring of coral bleaching due to thermal stress (abiotic indicators), and per-capita capture-based fish consumption (biotic indicator) (see appendix).

Conclusion

The indicators presented in this section provide evidence of the exposures, vulnerabilities and impacts of climate change on health. Continued work on attribution remains an important consideration here. For example, in earlier reports, migration was addressed, where questions of attribution to climate change remain particularly challenging.[10,13]

Irrespective of how climate change migrants are counted,[57] many factors contribute to health risks faced by migration. Health impacts depend on both pre-existing conditions (e.g. mental health and nutritional status, desire or not to migrate, and existing health systems) along with interventions (e.g. healthcare access, provision of food and shelter, and changing health-related resources).

Similarly, in 2018 the links between climate change and mental health were highlighted.[10] Mental health may variously be affected negatively by heatwaves, loss of property and livelihoods due to floods, or climate-induced migration. However, though there are known links between climate and mental health, those links are many and varied and highly socially and culturally mediated. Attempting to operationalise such an idea as a single-number indicator linking climate change and mental health outcomes proves equally unsatisfactory and remains elusive, yet quantifying these impacts is of clear importance.[58]

Section 2: Adaptation, planning, and resilience for health

As knowledge regarding the health consequences of climate change continues to strengthen, so too does the urgent need to redouble efforts to protect people from these adverse effects, particularly given the lack of dramatic material progress on mitigation. Without a timely and scaled-up response, health systems will be placed under increasing and overwhelming pressure, and it is now clear that adaptation is required, even with the most ambitious mitigation action.[40] An adaptation gap is apparent, signalled in some of the impacts discussed above, and the rapid introduction of better-developed and funded adaptation initiatives across all sectors is therefore essential in closing this divide. The health sector was highlighted as one of the top three priority areas for adaptation, identified in an analysis of Intended Nationally Determined Contributions prepared for the Paris Agreement.[59]

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.[60-62] Beyond this, evaluating the success of any interventions tracked is ever more difficult, given that the goals of adaptation inherently long-term, and no counterfactual is readily available. Rising to this challenge, the work in this section has expanded substantially, from the initial three indicators proposed in 2016,[63] to the eight presented here. The structure of these indicators, and this section, builds on the WHO Operational Framework for developing climate resilient health systems,[64] 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)
- Adaptation financing (Indicators 2.4.1 and 2.4.2)

True to an iterative approach, many of the indicators here have been further developed. Metrics evaluating national health adaptation planning and vulnerability mapping provide a dramatic increase in the number of country respondents, from 40 to 100 (Indicators 2.1.1 and 2.1.2). Additional information on implementation and government funding is included alongside qualitative analysis, to strengthen the validation of these self-reported surveys. A new indicator focuses 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 as a whole.

A number of 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 may indeed be subject to reporting bias (unconscious or otherwise) and local verification is difficult, [61] however the datasets here – from the WHO and the CDP – are by far the best available information on national- and city-level health-specific adaptation globally.

Indicator 2.1: Adaptation planning and assessment

Indicator 2.1.1: National adaptation plans for health

***Headline finding**: Recognition of climate change health adaptation needs is widespread and planning is underway. In 2018, almost half of countries surveyed reported having a national health and climate change plan in place.*

Over the past decade, there has been a steady increase in countries scaling up health adaptation projects to build climate resilience.[65] The lessons learned from these experiences have highlighted the benefit of strengthening health policy and planning to achieve timely and effective climate adaptation and mitigation in the health and health determining sectors.

This indicator, based on data from the 2018 WHO Health and Climate Country Survey,[66] 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 100 countries reporting in the 2018 survey compared with 40 countries reporting in the previous survey presented in previous Lancet Countdown reports.[13]

Global coverage of national adaptation plans for health is growing, with nearly]49 out of 100 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 (Figure 13), however challenges to full implementation remain, with less than 20% of countries reporting that action is being taken on a majority of their key priorities. National funding for implementation of health and climate change plans was identified as a central constraint across all income categories with approximately 4 in 10 countries reporting to have at least partial funding for the implementation of their main health adaptation and mitigation priorities (Figure 13).

A further analysis of approximately 40 strategies/plans, collected as part of the survey, highlights three key issues. First, approximately 40% of the documents that were received were published over 5 years ago. Additionally, although a broad range of climate-sensitive disease (CSD) priorities were identified across most of the documents, many did not elaborate on these climate-related health risks and less than half provided sufficient detail on the current and future burden of CSDs, vulnerable populations, or other relevant information. Finally, only a small number of plans are directly linked to the National Adaptation Plan (NAP) process as part of the UNFCCC. Opportunities therefore 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 (HNAPS),[64] thereby situating health within national climate processes and potentially strengthening access to international climate finance for health adaptation.

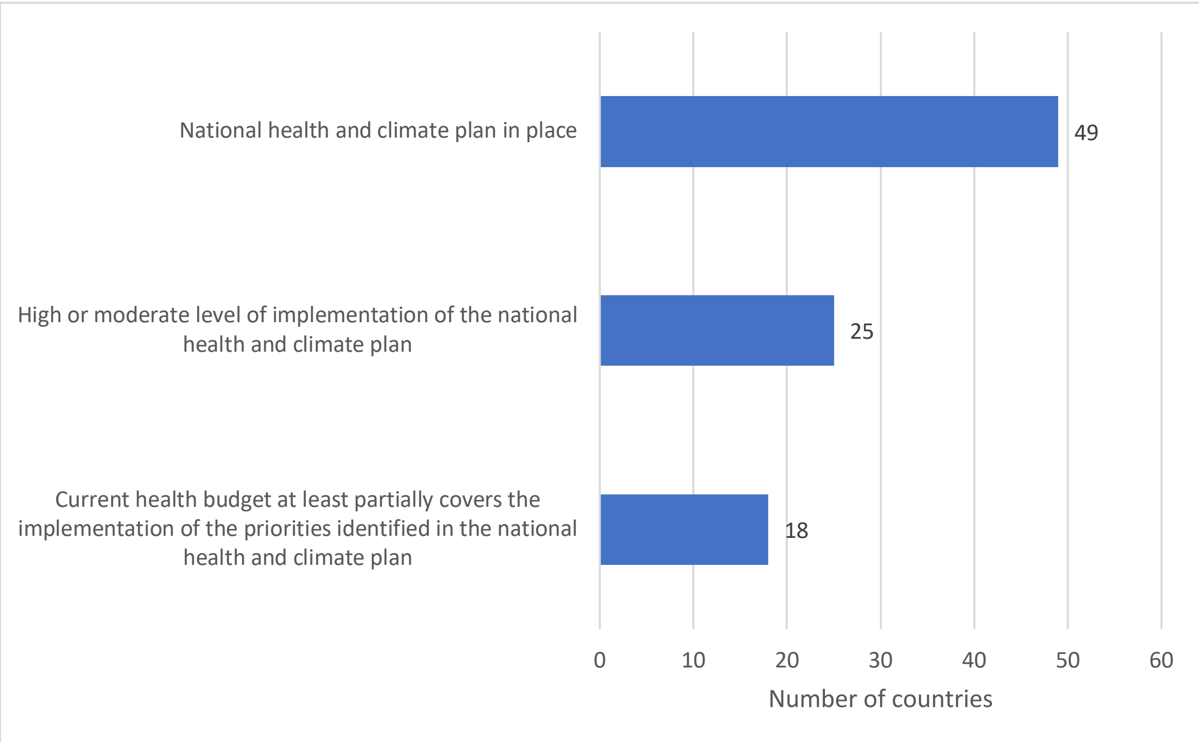


Figure 13: Number of countries with a national health and climate change plan by World Bank Group country income grouping (n=100).

Indicator 2.1.2: National assessments of climate change impacts, vulnerability, and adaptation for health

***Headline finding:** Of 100 countries surveyed in 2018, 51 indicated that a national assessment of health vulnerability to climate change had been conducted. However, of these, less than 40% reported that assessment findings had influenced the allocation of human and financial resources.*

An adequate health adaptation response requires an assessment of which populations and geographical areas are most vulnerable to different kinds of health effects, and the corresponding capacity of health services. A health vulnerability and adaptation (health V&A) assessment serves as a baseline analysis against which changes in disease risks and protective measures can be monitored and can serve to strengthen the case for investment in health protection.[67] As above, data for this indicator is sourced from the 2018 WHO health and climate change country survey.[66] Additional information on the survey methods and data can be found in the appendix.

An increasing number of countries are undertaking national V&A assessments, with over 60% of countries indicating that these assessments are having at least some influence over policy prioritization (Figure 14). However, funding remains an issue, with less than 40% of countries reporting that assessment findings have strongly or somewhat influenced the allocation of human and financial resources.

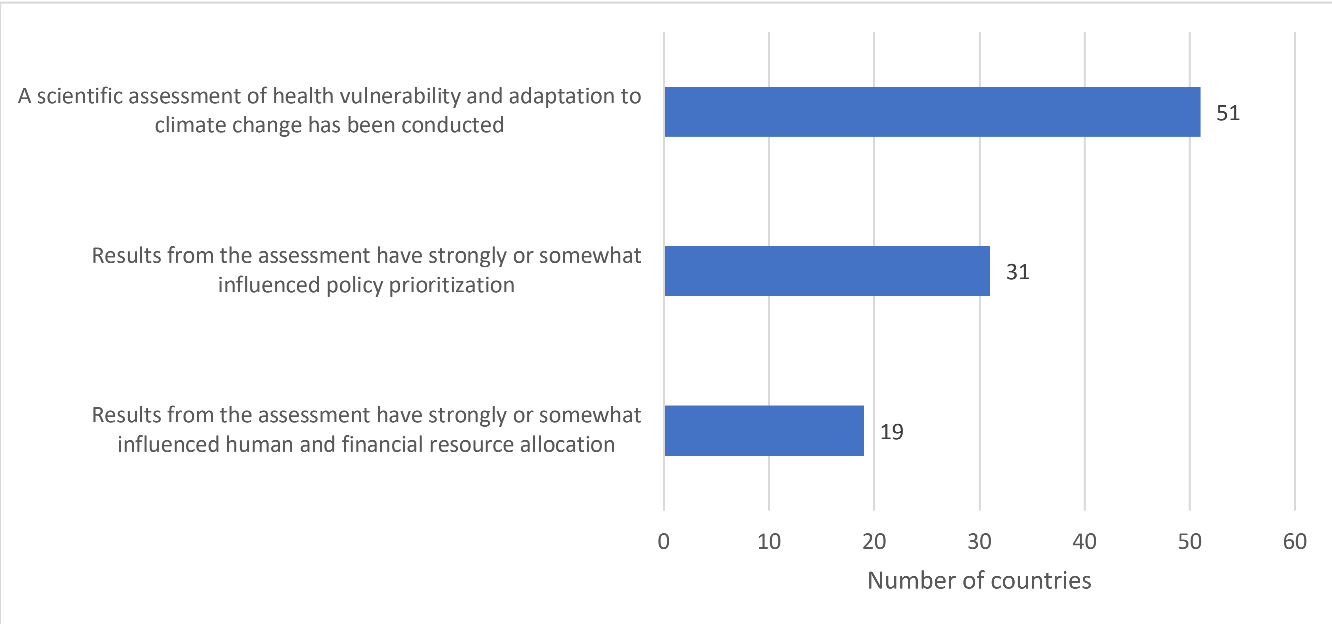


Figure 14: Number of countries that have conducted a scientific assessment of health vulnerability and adaptation to climate change (n=100)

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 government forming a crucial component of any health adaptation response. For this indicator, the

Lancet Countdown works with the Carbon Disclosure Project (CDP) to include data from their annual global survey of cities.[68] Two components of this data is analysed: the number of global cities that have undertaken a climate change risk or vulnerability assessment; and these cities' perceived vulnerability of critical health infrastructure to climate change. In 2018, 489 cities participated in the survey, with the majority (61%) of the cities coming from high-income countries.

Figure 15 presents the proportion of cities that have undertaken a risk or vulnerability assessment, by income group. Just over half (52%) of all responding cities have undertaken an assessment and a quarter either have an assessment in progress (17%) or intend to undertake an assessment in the future (7%). This represents a small, but steady increase from 2017.[10] The health impacts of climate change are of increasing concern for cities, with (54%) of responding cities noting that critical assets and/or services related to public health would be impacted by climate change, compared with 51% in 2017.[10]

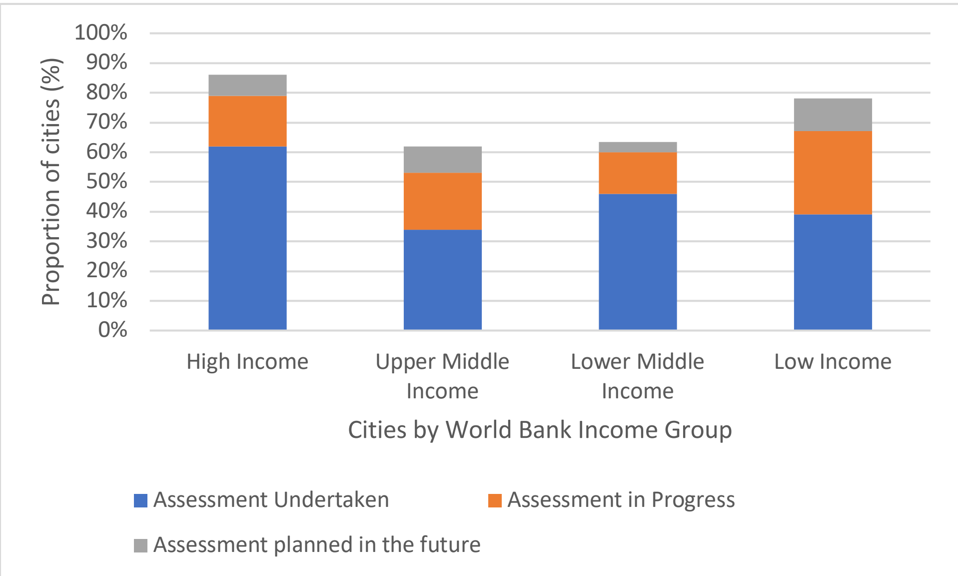


Figure 15: Proportion of cities that have conducted climate change risk assessments, by World Bank Group

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.*

A key component of health adaptation involves meteorological and hydrological services with health services to monitor and prepare for environmental risks to health such as those tracked in section 1.[64] This indicator tracks national climate information services for health using data reported by national meteorological and hydrological services to the World Meteorological Organization (WMO) Country Profile Database integrated questionnaire.

Of the 70 national meteorological and hydrological services of WMO Member States reported to provide climate services to the health sector, 15 more than previously. 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. 47 respondents provided additional detail, with a number of services working with the health sector and creating products accessible to the health sector. However, application to policymaking remains low, with only 4 out of the 47 Member States reporting that climate services are guiding health sector's policy decisions and investments plans.

Indicator 2.3: Adaptation delivery and implementation

Indicator 2.3.2: Air conditioning – benefits and harms

Headline finding: *use of air conditioning as an adaptation measure is a double-edged sword: on the one hand, 23% of the reduction in heat-related mortality in 2016 can be attributed to it; 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 heat-related mortality;[69] 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.[70] Electricity generated for air conditioning use contributes to both CO_2 and $PM_{2.5}$ emissions, and waste heat from air conditioning can paradoxically increase night time temperatures by more than 1°C.[71] Hydrofluorocarbon (HFC) refrigerants used for air conditioning can escape into the atmosphere where they act as powerful greenhouse gases (GHGs). In baseline scenarios, these HFC emissions will rise to 1-2 $GtCO_2eq$ per year by 2050.[72,73] Consequently, a nuanced approach to heat adaptation must be deployed, which protects vulnerable populations across the world from heat-related morbidity and mortality whilst minimising the health and other co-harms of air pollution, the urban heat island effect, and worsening climate change.

This new indicator includes four components: the proportion of households using air conditioning; the prevented fraction of heat-related mortality attributable to air conditioning use; CO_2 emissions attributable to air conditioning use; and premature mortality from air conditioning attributable $PM_{2.5}$. Unpublished data for air conditioning use, electricity consumption, and GHG emissions was provided by the International Energy Agency (IEA). The prevented fraction,[74] the percent reduction in heat-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 heat-related mortality of 0.23 for having household air conditioning compared with not having household air conditioning,[69] and the proportion of the population with household air conditioning. The air pollution source attribution methods discussed in section 3 (Indicator 3.5.2) 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 30% (Figure 16). In 2016, this proportion was 4% in India, 14% in the European Union, 58% in China, and ≥90% in the United States and Japan. Correspondingly, the global prevented fraction of heat-related mortality increased from 16% in 2000 to 23% in 2016, ranging from <10% in India, Indonesia, and South Africa to ≥66% in the United States, Japan, and Korea.

These trends have also been associated with significant harms. In 2016, air conditioning accounted for 10% of global electricity consumption and 18.5% of electricity used in buildings.[75] Under the IEA's baseline scenario, these figures will increase in 2050 to 16% and 30%, respectively.[75] CO_2 emissions from air conditioning use tripled from 0.35 gigatons in 1990 to 1.1 gigatons in 2016 (Figure 16), and are projected to rise to 2 gigatons in 2050 in the International Energy Agency's baseline scenario.[75] In 2016 the number of premature deaths due to $PM_{2.5}$ exposure attributable to air conditioning was 3459 in in India, 3236 in China, 1088 in the European Union, and 789 in the United States.

Fortunately, there is a path forward that provides for adaptation against heat-related mortality for those who need it, without the associated harms of GHGs 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 building design through strong, enforced building codes.[75] Traditional building designs in tropical and sub-tropical regions reduce thermal stresses by providing shade, thermal mass, insulation, and ventilation.[75] There is great potential to reduce the harms of air conditioning by increasing its efficiency,[75] by generating electricity from non-fossil-fuel sources, and by implementing the Kigali Amendment to the Montreal Protocol to phase-down HFCs.[76]

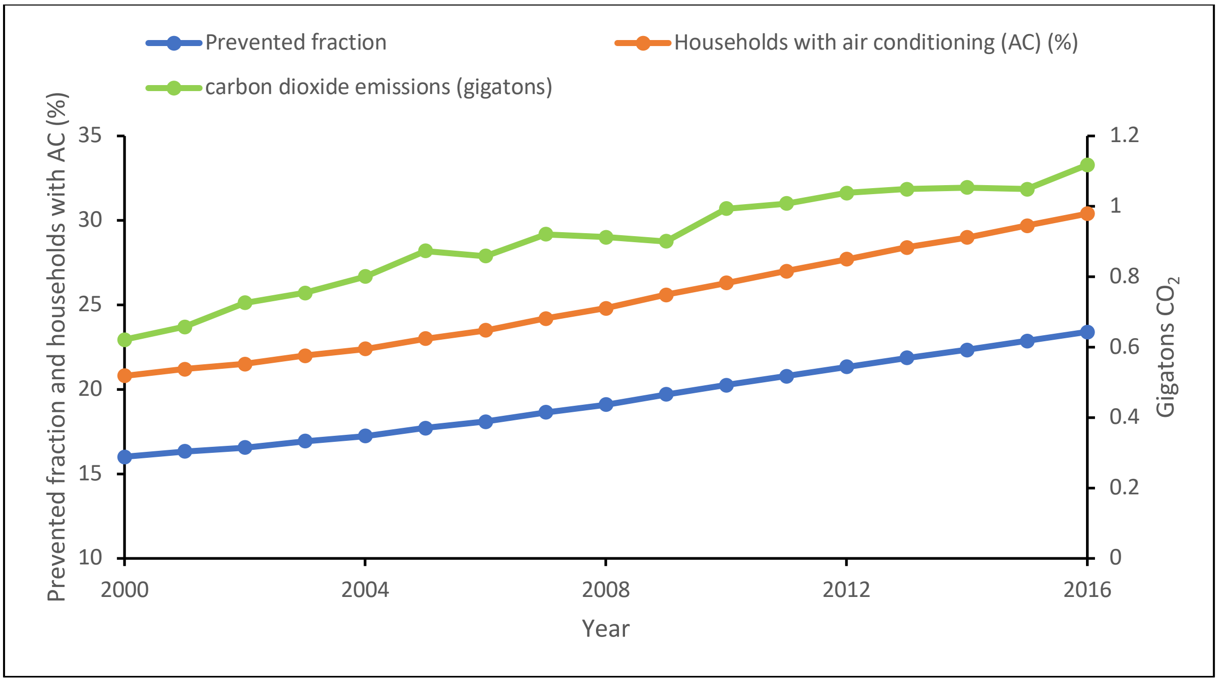


Figure 16: Global proportion of households with air conditioning, prevented fraction of heat-related mortality due to air conditioning, and CO_2 emissions from air conditioning.

Indicator 2.4: Adaptation financing

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 5% (£13 billion) of all adaptation spending, and health-related spending was estimated at 13.5% (£35 billion). 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 (A&RCC) dataset produced by kMatrix,[77] as described in the 2017 and 2018 reports.[10,13] Data in this year's indicator covers 191 countries and territories that have data reported in the A&RCC dataset. Per capita values are based on 183 countries with population estimates from the International Monetary Fund (IMF) World Economic Outlook.[78] "Health adaptation" focuses on national spending specifically within the formal healthcare sector, whereas "health-related adaptation" follows spending related to the health industry, disaster preparedness, and agriculture.

Spending on adaptation to climate change in health and healthcare increased by 11.2% in 2017/18, compared to 2016/17 data. This percentage increase is, notably, larger than the change in adaptation spending as a whole (an increase of 6.5% on last year). At the country level, growth of health adaptation spending ranges from 17.5% (United Kingdom) to 10.0% (Latvia). There are lower increases and lower variation in the health-related values, from 11.1% (United Kingdom) to 6.8% (Kazakhstan). Importantly, health still represents a small proportion of total adaptation spend, having grown from 4.6% in 2015/2016 to 5.0% in 2017/2018.

Grouped by WHO Region, the highest percentage change for health adaptation spending is in Europe (12.06%), and the highest per capita spending is in the Americas (£4.23 for health, £11.2 for health-related) (Figure 17). By comparison, in the African, Eastern Mediterranean and South East Asian regions, per capita health adaptation spending is less than £1.

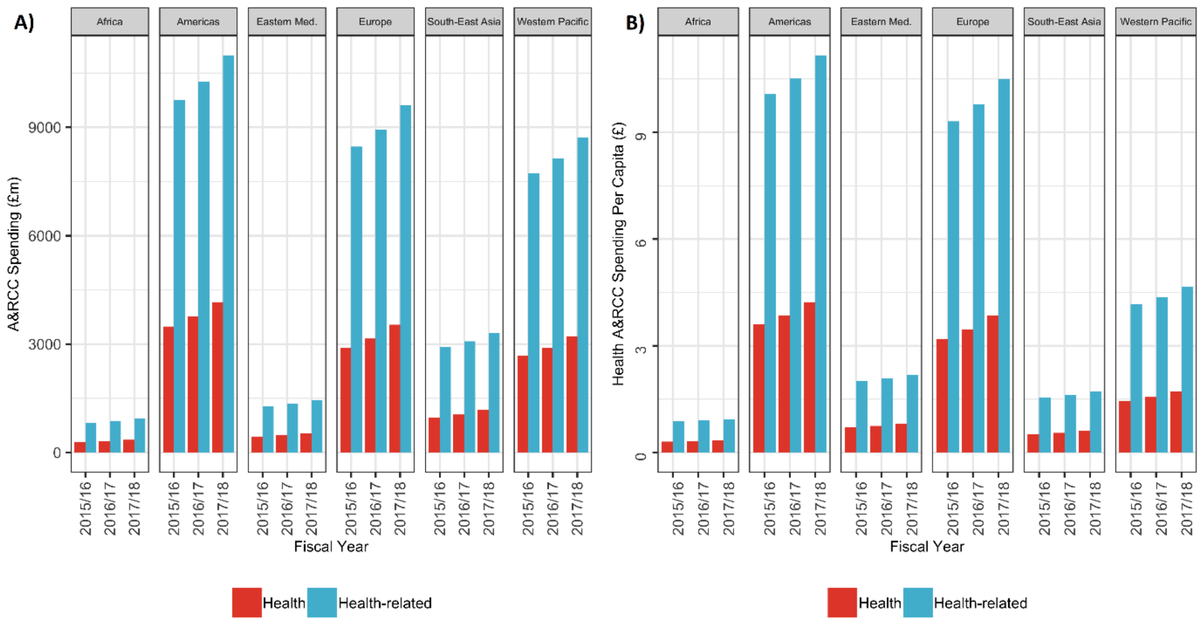


Figure 17: Adaptation Spending for Financial Years 2015/16 to 2017/18. A) Total health and health-related A&RCC spending (£m), B) Health and health-related A&RCC per capita (£). Plots are disaggregated by WHO Region. 'Eastern Med.' denotes the Eastern Mediterranean.

Conclusion

Whilst 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 inadequate in the face of unmitigated climate change. The number of countries with national adaptation plans for health and the number of countries and cities that have assessed health risk and vulnerabilities have increased, along with the spending on health adaptation. Thorough consideration of the best adaptation options is required before implementation goes ahead. For example, the health benefits of adaptation measure such as air conditioning may be counteracted by the harms they cause through a contribution to heat generation, climate change and air pollution (Indicator 2.3.2).

As identified in the findings of this section and in the UN Environment Adaptation reports, further work is required, both in terms of the planning and implementation of adaptation for health.[79,80] The Lancet Countdown will continue to invest in its capacity to track health adaptation by building on existing methods, sourcing new data, and developing a guiding framework and the systematic identification of indicator gaps.

Section 3: Mitigation Actions and Health Co-Benefits

As section 1 highlighted, the health impacts of climate change are already occurring, and require an urgent response, both in terms of health adaptation (section 2) and also, importantly, in mitigation in order to minimise future climate change.

In keeping with the Paris Agreement's commitment of "well below 2°C", and to pursue a 1.5°C target, it is necessary for global emissions to peak as soon as possible (some studies suggest 2020) and then follow a steep decline to 2050.[5] However, current mitigation actions and commitments are not consistent with this goal. Indeed, at 53.5 $GtCO_2e$, total global GHG emissions for 2017 were the highest ever recorded.[81] Current commitments under the Paris Agreement are far from sufficient, with 2030 emissions estimated to be lowered by only 6 GtCO2e - half the reduction required to achieve a 2˚C scenario and one fifth for a 1.5˚C scenario.[79]

Discussions of GHG emissions reductions must be more directly coupled with the positive economic and health benefits that they bring. Mitigation actions improve health in the long term, through avoided climate change, but also in the near term through numerous pathways such as, reductions in risk of respiratory and cardiovascular disease attributable to air pollution,[82] reductions in the risk of diseases related to physical inactivity and obesity due to increased cycling and walking,[83] and a suite of improvements that result from healthier diets.[84]

Section 3 of the 2019 Report of the Lancet Countdown tracks mitigation and its health consequences, by sector:

- 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)
- Health (Indicator 3.6)

Crucially, it adds two new indicators of great importance to health – 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 healthcare systems.

The major sectors of global GHG emissions are electricity and thermal power generation, transport, industry, and buildings. Overall CO_2 emissions from fossil fuels have risen by 2.6% from 2016 to 2018 (Indicator 3.1.1). Concerningly, coal phase-out has reversed, with a 1.7% increase from 2016 to 2018 seen in total primary energy supply (Indicator 3.1.2). Growth in renewables continues apace and comprised 45% of total growth in electricity generation. Currently, modern renewables represent 5.5% of global electricity generation (Indicator 3.1.3), but are predicted to reach 30% by 2023.[85]The implication for air pollution of both of these trends is important. With continued demand for fossil fuels and an increase in coal consumption, ambient air pollution from the energy sector has also grown, with an additional 200,000 deaths attributable to the growth in emissions in 2016 compared with 2015 (Indicator 3.3.2).

The transport sector is an equally entrenched emitter (Indicator 3.4), with GHG emissions and fuel use maintaining a modest growth trajectory of 0.7% per capita CO2e in 2016. While there has been a dramatic increase in electric vehicle (EV) use, they continue to represent a small proportion of the global fleet. Yet countries such as China have positioned EVs as the future of driving with electricity in transport reaching 1.5 % of total fuel use.

Feeding the global population is a critically 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 are an important area for climate change mitigation. Global agricultural GHG emissions (Indicator 3.5) have increased between 2000 to 2016 by 14% for livestock and 10% for crops.

The health sector is on the frontline of climate change, and plays a vital role in any response. It is also a major contributor to GHG 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 flat, at the same level as in 1990. However, GHG emissions from fossil fuel combustion has 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 through to 2050.*

In the 2019 Report of the Lancet Countdown, this indicator includes data to 2016, supplemented with additional statistics for 2017[86] and 2018.[87] It tracks the carbon intensity of the energy system, monitoring the CO_2 emitted per terajoule of primary energy supplied. Key improvements in this analysis are seen in the disaggregation of fuel type, the extension of data back to 1970, and the inclusion of new projections forward to 2050. A full description of the data and methods is provided in the appendix.

Global emissions of CO_2 from fossil fuel combustion, having been flat between 2014-16, have increased since that period, reaching a new high of 33.1 $GtCO_2$ in 2018.[87] (Figure 18). This 2.6% increase over the last two years is due to continued growth in energy demand, most of which is met by fossil fuels.

The carbon intensity of the energy system will need to reduce to near zero by 2050. In the last 15 years, carbon intensity has largely plateaued, as the growth of low carbon energy has been insufficient to displace fossil fuels in order to start to bend the intensity curve downwards. However, recent IEA data suggests that carbon intensity may be starting to reduce due to gas displacing coal (Figure 18).[87]

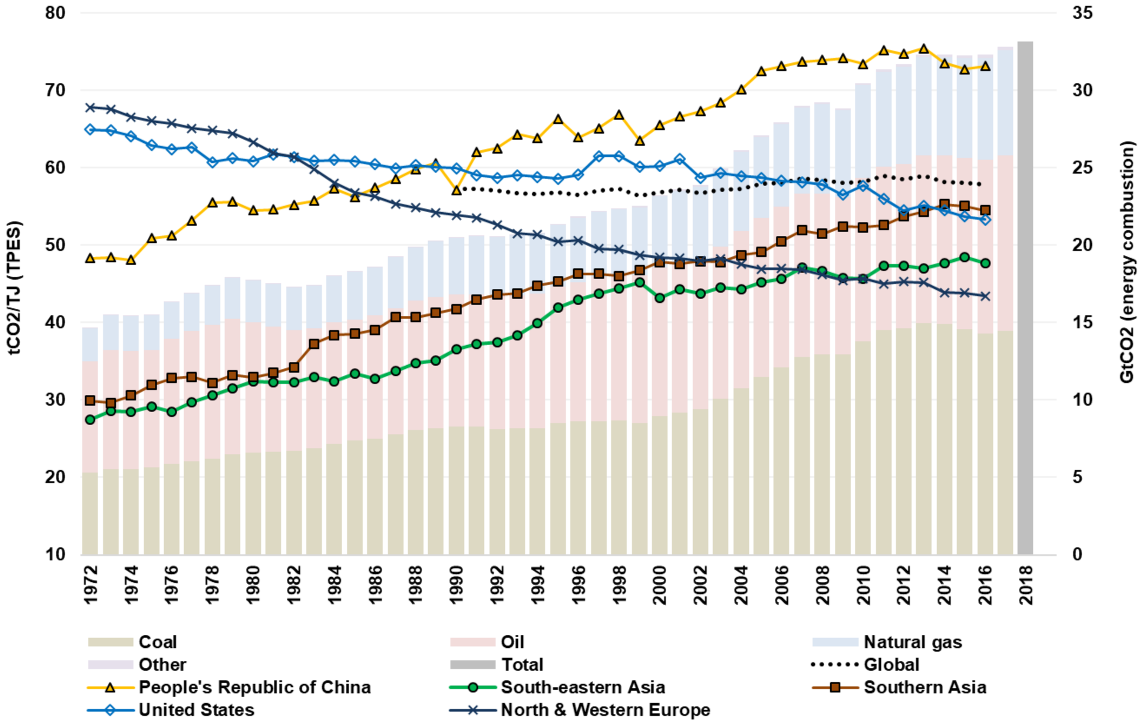


Figure 18: Carbon intensity of Total Primary Energy Supply (TPES) for selected region and countries, and global CO_2 emissions by fuel type, 1972-2018. Carbon intensity is shown by lines (primary axis) and global emissions by stacked bars (secondary axis). This carbon intensity metric estimates the tonnes of CO_2 for each unit of total primary energy supplied (tCO2/TJ). For reference, carbon intensity of fuels (tCO$_2$/TJ) are as follows: coal 95-100, oil 70-75, and natural gas 56.

Indicator 3.1.2: Coal phase-out

***Headline Finding:** From 2016 to 2018, TPES from coal has increased by 1.7%, driven by growth in China and other Asian countries.*

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.[82] 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.[88] In this year's Lancet Countdown report, this indicator tracks total primary energy supply from coal, plus projections for coal phase-out, using the scenarios that informed the IPCC Special Report on Global Warming of 1.5°C.[5]

Coal has returned to a growth trajectory from 2016 to 2018 (Figure 19), however, due to the overall growth in global energy demand, the share of coal in primary energy supply continues to fall**Error! Reference source not found.**). 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 to gas, the next highest at 23%). Most of this growth is in Asia, notably China, India and South East Asia.

Rapidly decreasing coal use to zero is critical to meeting the commitments embodied in the Paris Agreement. For example, an 80% reduction in coal use from 2017 to 2050 (a 5.6% annual reduction rate) is consistent with a 1.5°C trajectory.

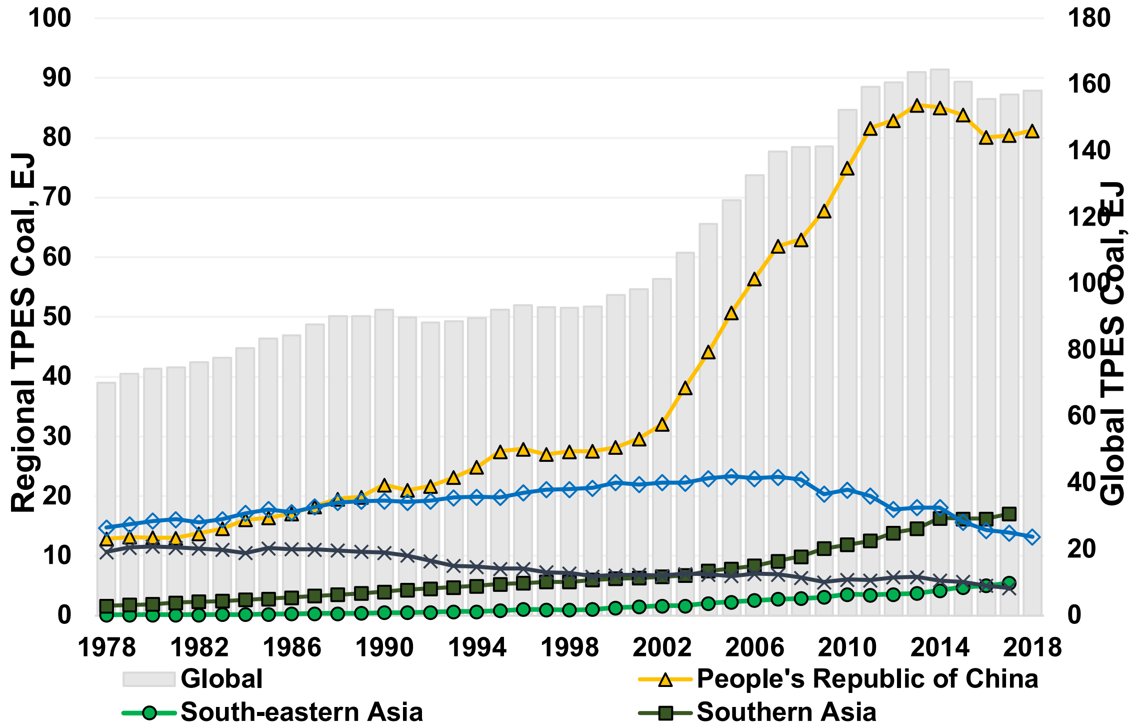


Figure 19: Total Primary Energy Supply (TPES) coal use in selected countries and regions, and global TPES coal, 1978-2018. Regional primary energy supply of coal is shown by the trend lines (primary axis) and total global supply by the bars (secondary axis). Data are shown to at least 2017, and extended to 2018 for selected regions and global supply (where data allows)

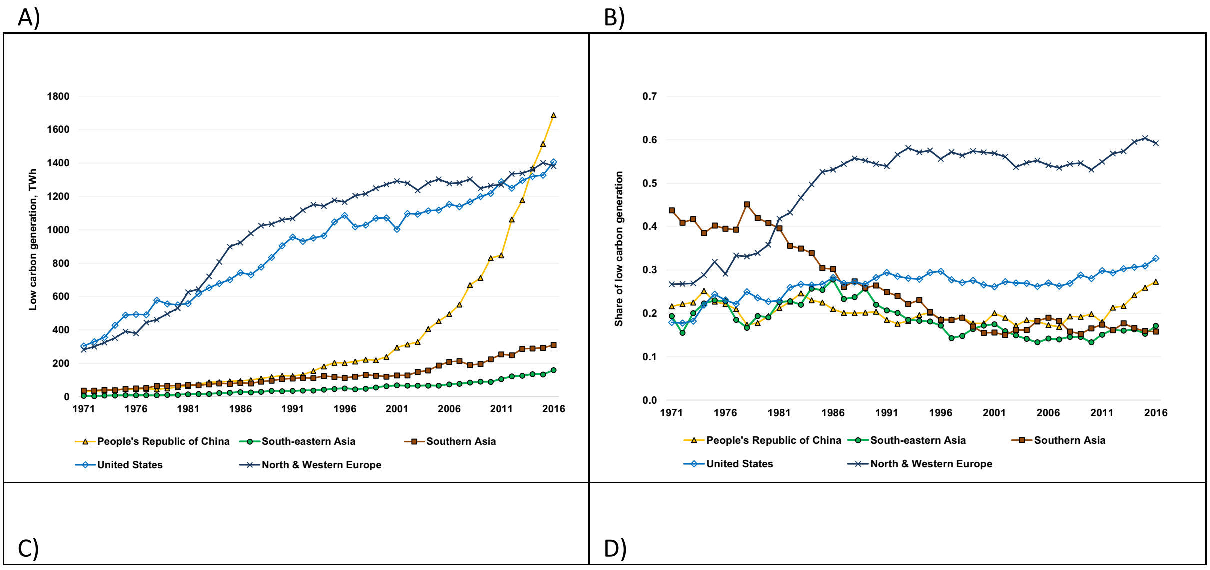
Indicator 3.1.3: Zero-carbon emission electricity

***Headline Finding:** In 2018, renewable energy continues to account for a large share (45%) of growth in electricity generation, with 27% coming from wind and solar.*

With the power generation sector accounting for 38% of total energy-related CO_2 emissions, that renewables displace fossil fuels is crucial. This indicator tracks total low carbon electricity generation (which includes nuclear and all renewables, including hydro) and new renewable electricity generation (excluding hydro), using the World Extended Energy Balances dataset from the IEA.[87] Renewable electricity generation was also projected using the scenarios that informed the IPCC Special Report on Global Warming of 1.5°C.[5] A full description of the datasets, methods, and these projections is provided in the appendix.

In 2016, low-carbon electricity globally accounted for 32% of total global electricity generation (Figure 20). As costs continue to fall, solar generation continues to grow at an unprecedented rate of around 30% per annum (whilst still only accounting for 2% of total global generation).[89]

An assessment of 1.5°C compliant scenarios highlights that generation from new renewables sources (solar, wind, geothermal, wave and tidal) need to increase by 9.7% per annum, to a level in 2050 that is larger than the total global electricity generation today. Since 1990, the annual growth rate of electricity generation from these renewable sources was over 14%, a very promising trend, but one that must be maintained for a further three decades.



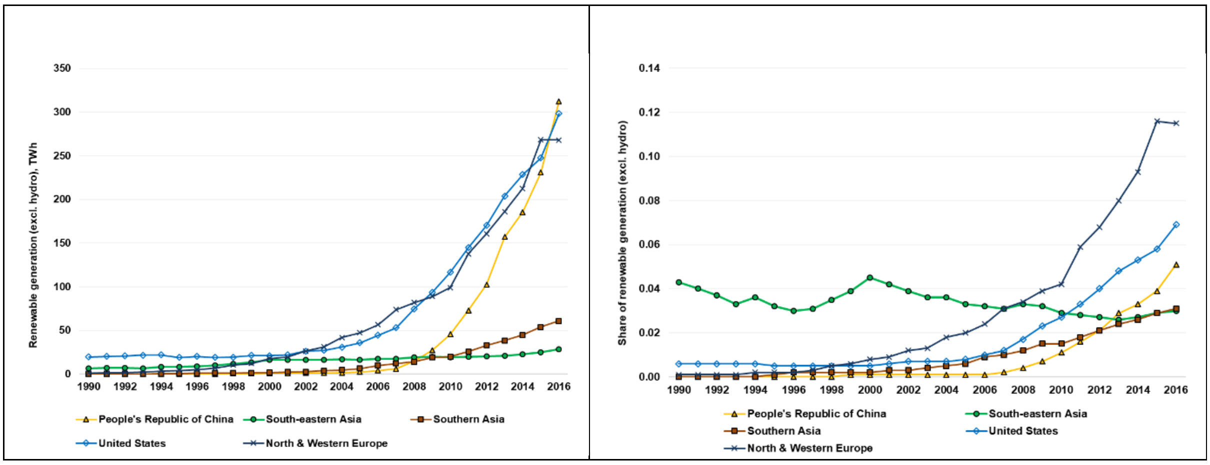


Figure 20: Renewable and zero-carbon emission electricity generation (excluding bioenergy), 1990-2016. A) Electricity generated from zero carbon sources, TWh; B) Proportion of electricity generated from zero carbon sources; C) Electricity generated from renewable sources (excl. hydro), TWh; D) Proportion of electricity generated from renewable sources (excluding hydro).

Indicator 3.2: Access and use of clean energy

Headline Finding: *Over 1 billion people still remain without access to electricity, and almost 3 billion people live without access to clean fuels and technologies for cooking, yet the consumption of zero emission energy in the residential sector remains at just 24% in 2016 and a rate of growth of 2% per year since 2000.*

Universal access to affordable, reliable, sustainable and modern energy for all is a key determinant of economic and social development and is Goal 7 of the SDGs.[90] Access to energy is also central to health and well-being, as economic and social development contribute to improved health outcomes and the most basic operating procedures in health care facilities require energy use for water, temperature control, lighting, ventilation, and clinical processes.[91]

This indicator analyses aggregated data on access to energy from the IEA, IRENA, UN Statistics Division, WBG and WHO.[91] and data on the proportion of clean energy from the IEA.[92] Access to energy is defined by the IEA as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average".[93] Full details of the methods and data for this indicator are consistent with previous reports, and are provided in the appendix.

Access to electricity has risen from 83% in 2010 to 87% in 2016, although approximately 1 billion people remain without access to electricity, with much of these populations living in rural areas in sub-Saharan Africa and South Asia. Access to clean cooking has improved by just 1% since 2010, with 41%(just less than 3 billion) remaining in access-deficit.[94] In 2016, the global proportion of clean energy use in the residential sector was approximately 24%, up from 17% in 2010 (Figure 21).[92] However, solid biomass which contributes to respiratory and cardiovascular disease attributable to household air pollution,[95] is currently estimated to account for 36% of total residential sector energy use. Panel 2 presents a case study on indoor exposure to $PM_{2.5}$, the mortality attributable to this exposure, and CO_2e emissions in slum housing in Viwandani, Nairobi, Kenya.

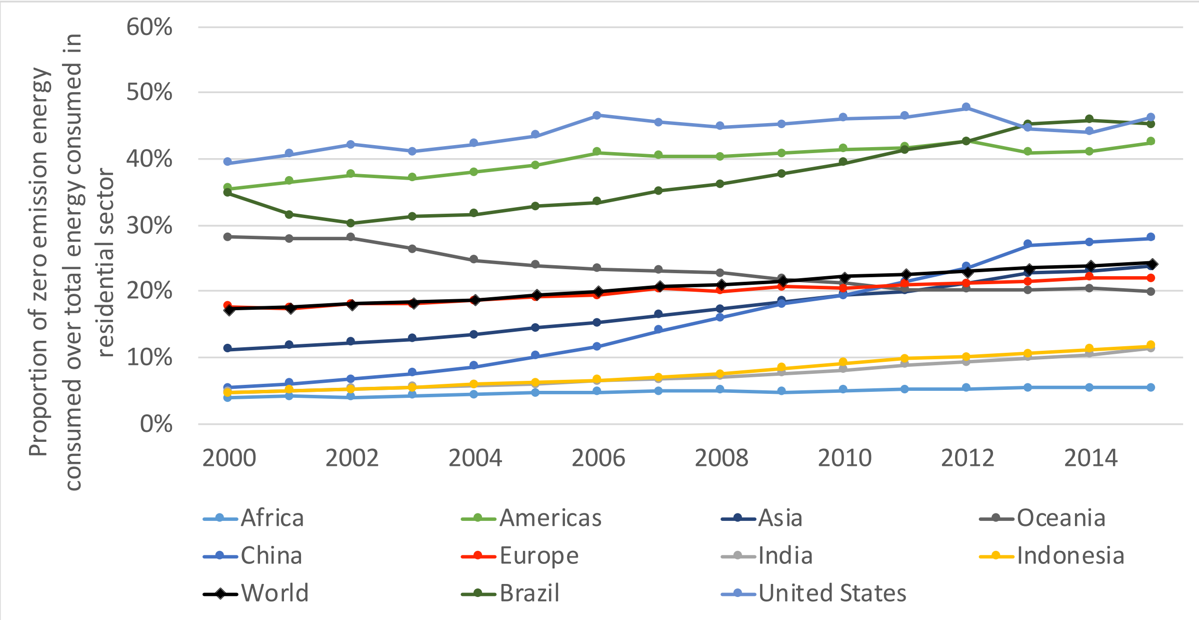


Figure 21: Proportion of zero emission energy consumption in the global residential sector, 2000-2016. Proportion is measured as fuels with no emissions at point of use (not generation) and include electricity, geothermal, and solar thermal energy over total residential sector consumption. Electricity comprises 75% of total clean energy use in 2016.

Around 3 billion people worldwide cook with solid fuels and kerosene worldwide,[96] causing an estimated 3.8 million deaths attributable to indoor air pollution.[97] In addition to cooking, other sources of indoor air pollution include the infiltration of outdoor air pollution indoors and emissions from other indoor activities such as heating, lighting, and smoking.

This case study focuses on indoor exposure to $PM_{2.5}$, the mortality attributable to this exposure, and CO_2e emissions in slum housing in Viwandani, Nairobi, Kenya. Cooking is done with solid fuels (14.6%), kerosene (72.9%), or electricity (12.5%). Most dwellings lack 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 year-round; 8-hour average ambient outdoor pollution levels are around 67μg/m^3.[98]

Current indoor exposure and space heating estimates were estimated using EnergyPlus,[99] calibrated to monitored indoor levels in dwellings using different fuel types and ventilation behaviours.[100] Two scenarios were modelled, involving the following changes in exposure and heating energy consumption:

1) Electrification of all existing stoves, lamps, and heaters using the current electrical network, which was assumed to reduce outdoor pollution by 40% based on the estimated contribution of residential combustion to annual mean air pollution in Nairobi from the GAINS model.[101]
2) Electrification as in (1), but with low energy lighting, and heaters installation extended to all dwellings. Additionally, upgrades to dwelling energy efficiency and airtightness in-line with local sustainable design guidelines.[102]

CO_2e emissions for the various fuels were taken from GAINS and Klimont et al (2017).[103] Air pollution exposure for different age groups was estimated using a time-weighted average of time spent indoors and outdoors based on information from local experts. Associated annual premature mortality due to $PM_{2.5}$ exposure was calculated by applying the GBD's integrated exposure–response functions (IERs)[104] to estimate cause-specific deaths for the local population, taking account of the fraction attributable to indoor air pollution.

Mean 24-hour exposures in Viwandani are estimated to average 53 μg/m3, causing around 7 attributable premature deaths (2.4% of all deaths) per year. The fuels used produce an estimated 595 kg of CO_2e per household year. Following electrification, exposures were estimated to average 31 μg/m^3, associated mortality decreases 19%, and households produce an estimated average of 210 kg CO_2e yearly. Improving the building envelopes reduced exposures to 25 μg/m^3, attributable mortality by 25%, but CO_2e increased to 211 kg per household-year, due to the increased coverage of electrical space heating. Such wholesale changes, however, do not reduce indoor exposures to less than the WHO-recommended limit of 10 μg/m^3. Therefore, reduction of indoor pollution to adequate levels will also necessitate significant reductions in outdoor ambient levels and/or the application of additional technologies such as air filtration systems.

Panel 2: Household air pollution conditions in Nairobi, Kenya

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 and has been shown to be responsible for several million premature deaths every year.[82,105,106] 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, traffic, and household heating and cooking, and therefore $PM_{2.5}$ emissions share many of the same sources as GHG emissions.[107]

Indicators 3.3.1 and 3.3.2 report on source contributions to ambient air pollution and its health impacts, drawing from calculations with the GAINS model[108] which calculates emissions of all precursors of $PM_{2.5}$ on a detailed breakdown of economic sectors and fuels used. Underlying activity data are based on statistics reported by the IIEA[109] (see appendix for detailed methodology). The latest complete statistics to date are for the year 2016.

Indicator 3.3.1: Exposure to air pollution in cities

Headline finding: *Urban citizens are continuing to be exposed to high levels of air pollution, especially in developing countries. A major share of the pollution is associated with energy use, particularly residential combustion.*

The world is becoming increasingly urbanised, with 70% urbanisation expected for 2050.[110] Due to the concentration of population and emissions, many cities have become hot spots of air pollution. Only few cities worldwide reach $PM_{2.5}$ concentration levels below the WHO guideline of $10 \mu g/m^3$ annual mean, while many cities exceed this standard several times.[111] The highest measured concentrations in recent years have been reported in South and East Asia, while big data gaps exist in other world regions. Particularly concerning is the fact that these high concentration levels have been further increasing or stagnant in many regions of the developing world. A positive exception to this trend is China, where many highly polluted cities have experienced strong improvements in air quality in recent years due to drastic emission control efforts. Cities in Europe and the US have seen slowly decreasing $PM_{2.5}$ levels thanks to effective implementation of air pollution control legislation.

This analysis estimates of source contributions to ambient $PM_{2.5}$ concentration levels in urban areas worldwide (more than 4,500 cities over 100,000 inhabitants), with results aggregated to the WHO world regions.

Figure 22 shows the estimated $PM_{2.5}$ levels and their source attribution for the year 2015. In most regions, residential fuel combustion of solid fuels for cooking and heating is the dominant source. While coal is prominent in some countries, the majority of the burden comes from the use of biomass in traditional stoves, which is often associated with net GHG emissions as well due to unsustainable harvesting.

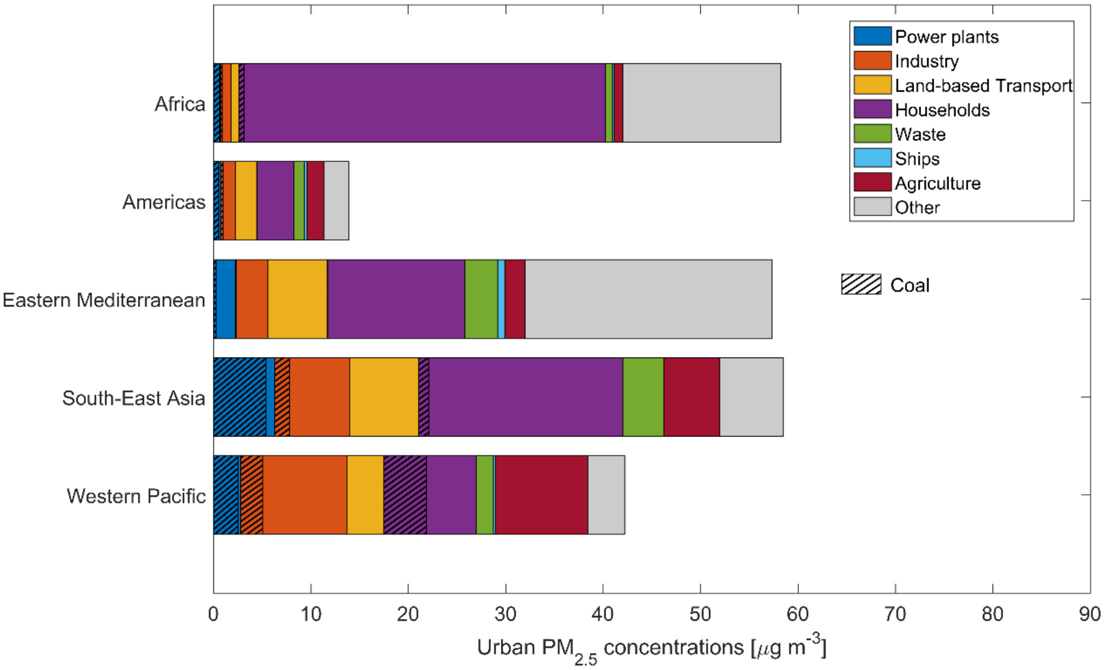


Figure 22: Source contributions to ambient PM2.5 levels in urban areas, averaged by WHO region, for the year 2015.

Indicator 3.3.2: Premature mortality from ambient air pollution by sector

Headline finding: *Globally the deaths attributable to air pollution continue to rise. From 2015 to 2016 there were 200,000 additional deaths due to ambient $PM_{2.5}$ pollution.*

Knowing 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 health impacts on a global level, quantifying contributions from individual economic sectors and highlighting coal combustion across sectors.

Results for 2016 are higher than the estimates for 2015, with an overall number of deaths attributable to ambient $PM_{2.5}$ estimated at 3.1 million in 2016 compared to 2.9 million in 2015. The dominant contribution varies between and within world regions; in Africa household cooking is the overwhelming source while in other regions industry, traffic, electricity generation, and agriculture play bigger roles (Figure 23). Between 2015 and 2016, some decreases are seen in Europe related to coal power plants (Figure 24); however, worldwide almost half a million cases continue to be related to coal burning.

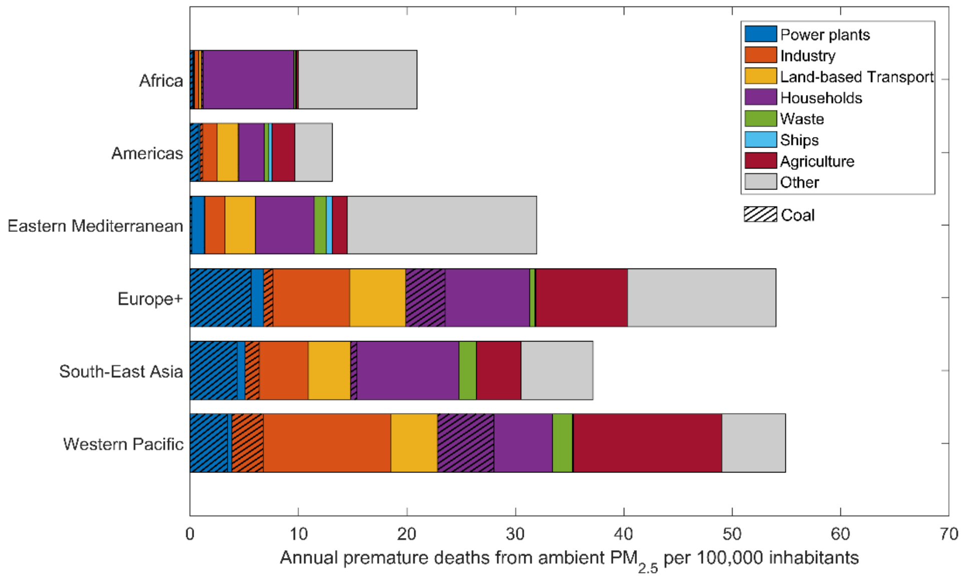


Figure 23: Premature deaths attributable to ambient PM2.5 in 2016, by economic source sectors of pollutant emissions. Coal as a fuel is highlighted by hatching.

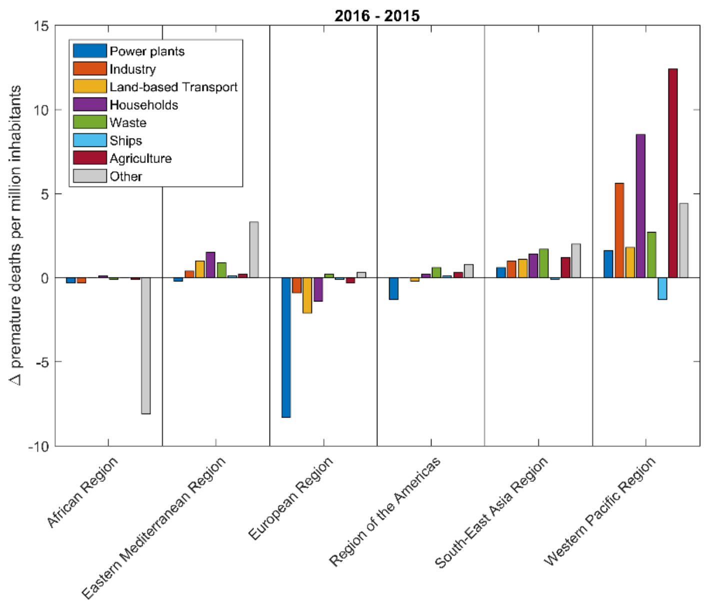


Figure 24: Differences in attributable mortality from ambient $PM_{2.5}$ exposure, 2015 to 2016, differentiated by emission source sector.

Indicator 3.4: Sustainable and healthy transport

***Headline Finding:** Global road transport fuel use increased 0.7% from 2015 to 2016 on a per capita basis. Fossil fuels continue to dominate, but their growth is being tempered somewhat by rapid increases in biofuels and electricity.*

As with electricity generation, transition to cleaner fuels for transport is important for climate change mitigation and will have the added benefit of reducing mortality from air pollution.[83] Fuels used for transport currently produce more than half the nitrogen oxides emitted globally and a significant proportion of particulate matter, posing a significant threat to human health particularly in urban areas (Indicator 3.3).[112] Additionally, the health benefits of increasing uptake of active forms of travel (walking and cycling) have been demonstrated through a large number of epidemiological and modelling analyses.[31,83,113-115] Encouraging active travel, in particular cycling, has become increasingly central to transport planning, and there is growing evidence that bikeway infrastructure, if appropriately designed and implemented, can increase rates of cycling.[116]

Global trends in levels of 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.[117,118] 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; fossil fuels grew by 0.5% compared to 3.3% growth in biofuels and 20.6% growth in electricity. In China, electricity now represents 1.5% of total transportation fuels use. This is more than any other country and an 80% higher share than that seen in Norway (0.85%). A growing number of countries and cities have announced plans to ban vehicles powered by fossil fuels and auto-maker Volkswagen has announced that it will stop developing engines that run on petrol or diesel after 2026.[119]

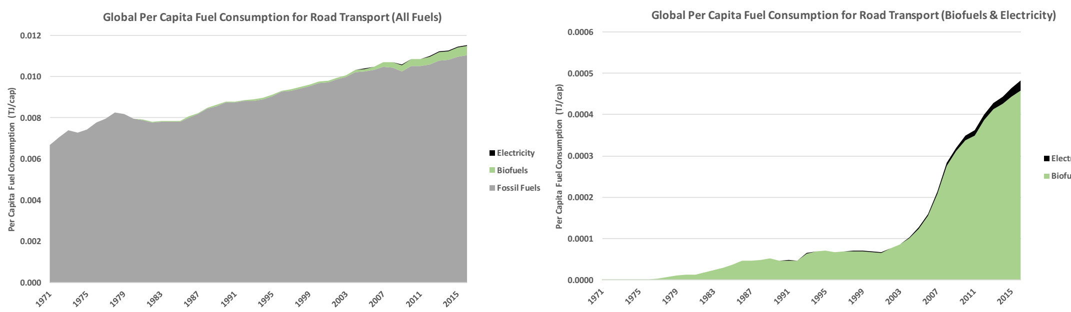


Figure 25: Per capita fuel use by type (TJ/person) for road transport with all fuels (left) and non-fossil fuels only (right).

Some cities have made considerable progress towards improving levels of cycling. Notable is Vitoria-Gasteiz in Spain, where cycling mode share has increased from close to zero to almost 15% in less than a decade. 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 as well as communication on the health benefits of cycling.[120] The search for a more comprehensive metric of active transport remains elusive, principally limited by scarcity of data access in this field.

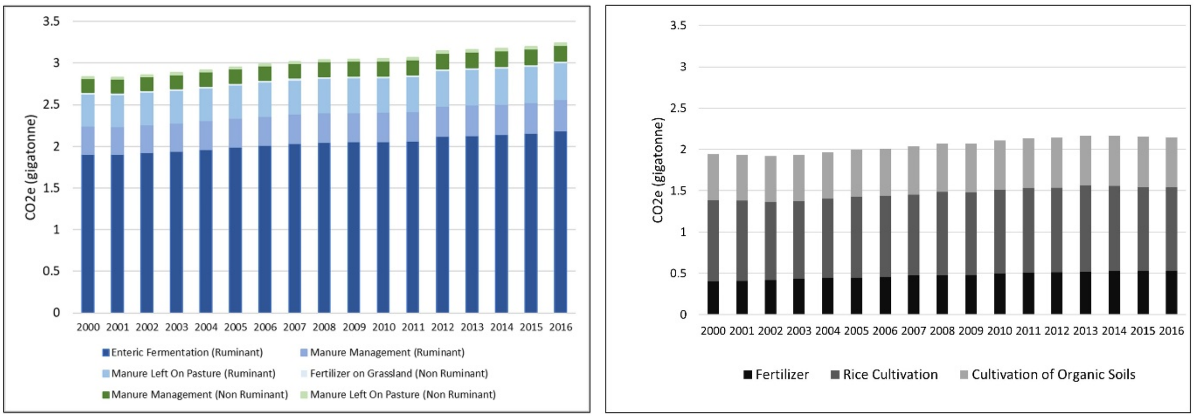
Indicator 3.5: Emissions from livestock and crop production

Headline finding: *Total emissions from livestock and crop production have increased by 14% and 10% from 2000 to 2016, with 93% of livestock emissions attributed to ruminants.*

Current dietary trends are contributing to both non-communicable diseases and GHG emissions, as well as other impacts on the planet, including biodiversity loss and impacts on water and land use.[84] In particular, excess red meat consumption contributes to both the risk of cardiovascular disease and type 2 diabetes as well as GHG emissions.[121] To this end, whilst total emissions from crops and livestock will need to decline significantly 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. Importantly, the nuance and complexity of any such indicator must be stressed, and it is clear that there is no 'one-diet-fits-all' solution.

For the 2019 Lancet Countdown report, this indicator focuses on production of emissions from livestock and crop production.. The new analysis added here provides a novel method of understanding the emissions profile of some of the most concerning groups – for example, ruminant livestock. A full description of the methods and data is provided in the appendix.

Overall emissions from livestock have increased by 14% since 2000 to over 3 billion tonnes of CO_2e in 2016 (Figure 26). Ruminants contribute 93% of total livestock emissions, with non-dairy cattle contributing 62-65% of this. However, the largest increase in emissions from 2000 to 2016 has come from poultry (rising from 33.6 million tonnes CO_2e in 2000 to 52.1 million in 2016), which has an increase in emissions of 55%, more than double that of non-dairy cattle.



(a) Emissions from Livestock (b) Emissions from Crop Production

Figure 26: Global livestock (a) and crop (b) GHG emissions annually from 2000-2016, by process.

Total emissions from crop production have increased by 10% since 2000, to around 2 billion tonnes of CO_2e in 2016. Rice cultivation, which causes methane production, contributes around half of these emissions (47-50%), with cultivation of organic soils and fertiliser contributing 27-29% and 21-25% respectively.

Indicator 3.6: Healthcare sector emissions

Headline Finding: *Global health care sector GHG emissions were approximately 4.6% of the global total.*

Section 2 makes clear that the healthcare sector is central in managing the health damages of a changing climate, but is also a significant contributor of GHG emissions, both directly and indirectly through purchased goods and services. Recent national-level studies for the US,[122] Canada,[123] and Australia[124] have used environmentally-extended input-output (EEIO) modelling, finding that health care sector emissions represent between 4-10% of total GHG emissions in those countries. EEIO models have been in wide use since the 1970s,[125] and underpin consumption-based accounting of emissions performed at national and global scales.[126] An important advantage of using EEIO modelling is that estimates of healthcare sector emissions are performed on a life cycle basis.

National-level studies cannot easily be compared due to differences in how emissions inventories, monetary input-output tables, and health expenditure data are collected in each country. In addition, some portion 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 standardized, international measure of health care sector GHG emissions was created using multiple MRIO models (EXIOBASE, WIOD) 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.

Figure 27 shows variations in per capita healthcare-related GHG emissions as a function of time, affluence, and the proportion of national economic output spent on health care. Per capita, US emissions per capita in the US are significantly higher than those of any other country, and have risen steadily over the study period 2007-2016. However, other countries have increased even more significantly, albeit from a lower base, including China (CN, 180%), South Korea (KR, 75%) and Japan (JP, 37%). In contrast, Greece's health care GHG emissions showed a marked decrease (GR,-35%), likely reflecting economic hardships in that country. Results using the WIOD MRIO model show similar trends but slightly lower absolute GHG emissions. The lowest per capita emissions modelled were for India (IN) and Indonesia (ID), at less than 1/40th those for the United States. Comparison of emissions per capita and Gross Domestic Product (GDP) per capita show a levelling off trend of health-care emissions versus affluence, again with the exception of the US.

Overall, healthcare is responsible for approximately 2250 Mt CO2e in 2016, or 4.6% of the global total (excluding land use change emissions). A parallel global analysis using a different MRIO model (EORA) just looking at CO_2 (excluding other GHGs) for 36 countries determined a healthcare contribution of 4.4% to the global total for the countries considered,[127] corroborating the results presented here.

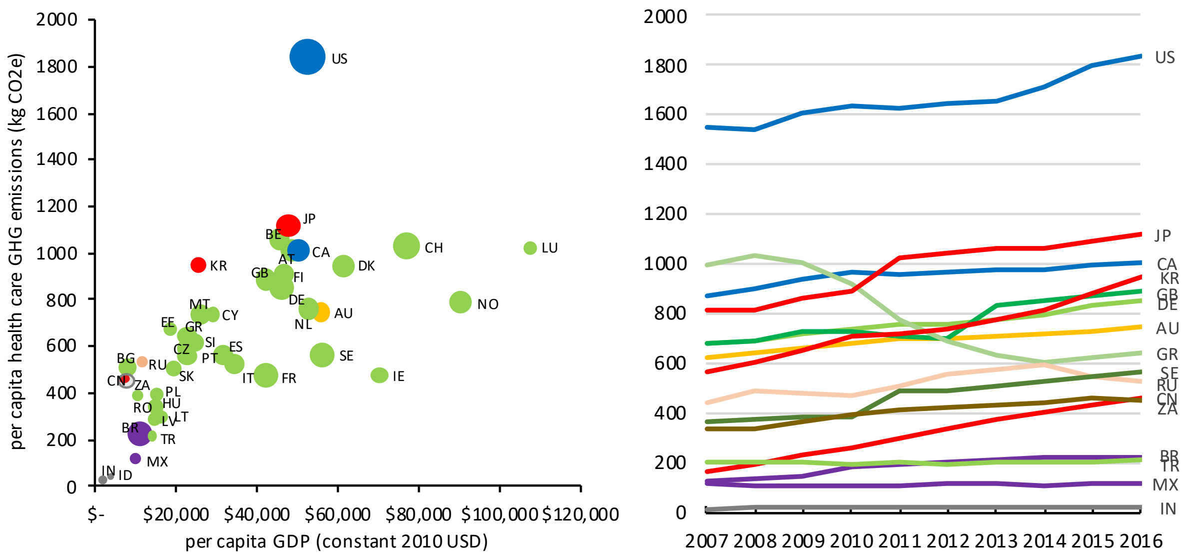


Figure 27: Per capita health care GHG emissions by country: (left) as a function of GDP per capita, bubble widths indicate proportion of national spending on health care; (right) over time 2007-2016. Colour key: green=Europe, light brown=Africa; grey=South/South/South East Asia, pink=North/Central Asia, red=East Asia, yellow=Oceania, blue=North America; purple=Latin America. Abbreviations follow ISO two-letter country codes.

Health systems are increasingly responding to the dual challenges of the health impacts of climate change and the contribution of the healthcare sector to GHG 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 a regular survey done as part of the Health Care Climate Challenge.

The survey includes questions around climate change risk assessments, health adaptation plans, fossil fuel and renewable energy project investments and working with government agencies to support GHG emissions reductions and healthcare sector adaptation.

Over 2017-2018, there were 155 survey respondents, 4 of which represented health systems and 151 of which represented hospitals. Three out of the four health systems and 51% of hospitals reported they had analysed local disaster risks due to climate change and their role in addressing these risks, with 50% of health systems and 41% of hospitals reporting having developed a plan to address healthcare service delivery needs resulting from climate change.

The data does not yet have sufficient global coverage and annual reproducibility, and majority of participants come from high-income countries. Additionally, participants in this survey represent the health systems most engaged in responding to climate change, thus creating a responder bias.

The largest example of a health system taking steps to reduce GHG emissions and other environmental impacts comes in the form of the UK National Health Service (NHS). From 2007 to 2017, a national-level analysis not included above, demonstrates that the NHS reduced its GHG emissions by 18.5%, while clinical activity increased by 27.5% over the same time period.[1] Efforts are also being made to reduce water use, plastic waste and air pollution from the NHS.

Panel 3: Healthcare sector response to climate change

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 the rate of electric vehicle sales. However, the carbon intensity of the energy system remains unchanged, with coal supply increasing, reversing the recent trend, and significant effort is required to decarbonise the agricultural and healthcare sectors. 2020 is important for two reasons – it is the year the implementation period of the Paris Agreement begins, and the year most studies suggest global emissions must peak then in order to remain on a 1.5°C pathway. To meet both commitments, a substantially stronger global response is required urgently, to reduce GHG emissions and minimise the future health risks of climate change.

Section 4: Finance & Economics

Section 4 examines the financial and economic dimensions of the impacts of climate change, and of mitigation efforts required to respond. Although many indicators in this section may appear to be distant from human health, they are key to tracking the health of 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, if the world were to experience warming of 5°C above pre-industrial levels by 2100, the Economist Intelligence Unit projects that around $18.4 trillion of the world's current stock of manageable assets would be at risk. At 6°C of warming, this rises to $43 trillion – equivalent to over half the current value of all the world's stock markets.[128]

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 GDPin 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.[129] 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 (Indicator 4.2);
- Investing in a low-carbon economy (Indicators 4.3.1, 4.3.2, 4.3.3, and 4.3.4);
- Pricing GHG 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 due to air pollution (Indicator 4.2).

Indicator 4.1: Economic losses due to climate-related extreme events

Headline Finding: *In 2018, climate-related extreme events resulted in $166 billion in overall economic losses. No events in low-income countries were covered by insurance.*

The indicators in section 1 presented changes in exposures and resulting health impacts of climate-related extreme events (Indicators 1.2.1, 1.2.2 and 1.2.3). The economic costs of extreme climate-related events may also exacerbate the direct health and wellbeing impacts they produce. This indicator tracks the present-day total annual economic losses (insured and uninsured) across country income groups relative to GDP, resulting from climate-related extreme events.

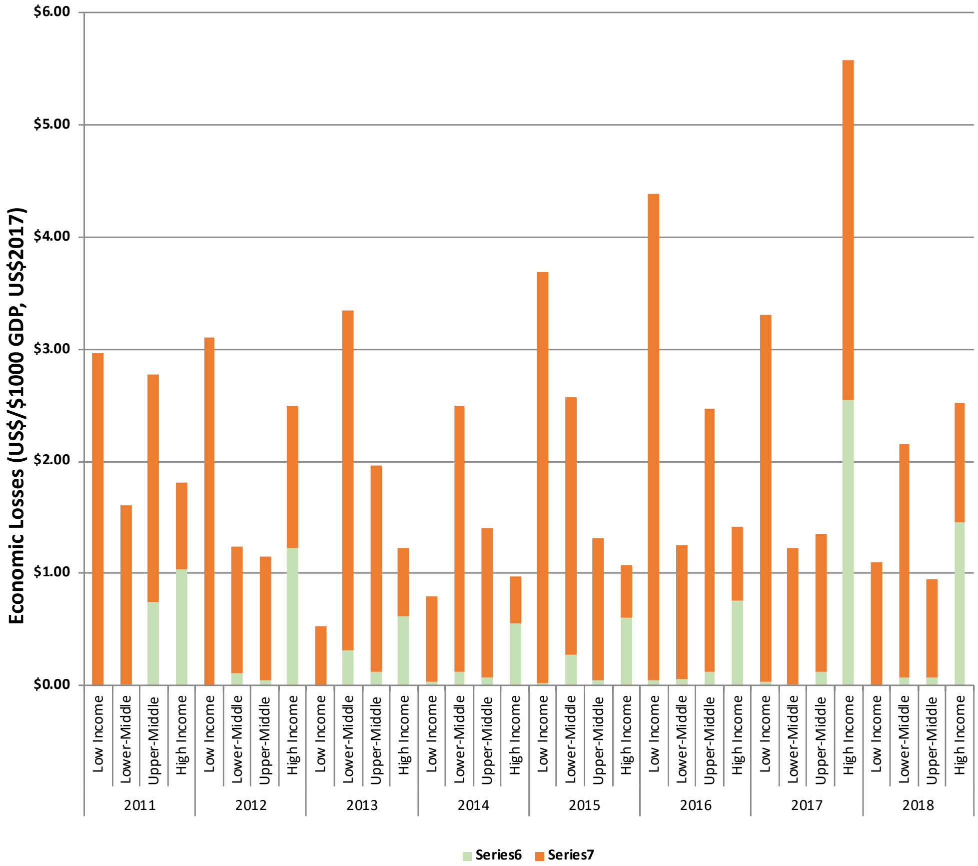


Figure 28: Economic Losses from Climate-Related Events Relative to GDP

DATA IN CHART FOR 2018 IS TENTATIVE USING 2017 GDP VALUES)

The data for this indicator is sourced from Munich Re's NatCatSERVICE,[131] 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.[132] The methodology remains the same as was used in the 2018 Report of the Lancet Countdown,[10] and full methodology, along with data for 1990-2018 can be found in the appendix.

Global economic losses due to extreme climate-related events in 2018 were $166 billion, around half the value experienced in 2017, but still higher than any other year since 2005 (Figure 31). As in previous years, the vast majority of economic losses are in high-income countries, where losses relative to GDP were $x.xx/$1000 GDP. Economic losses in low-income countries again reduced between 2017 and 2018, both in absolute terms and per unit GDP (falling from $x.xx/$1000 GDP to $x.xx/$1000 GDP). As in previous years, well over half of the losses in high-income countries were insured. Although in previous years less than 1% of losses in low-income countries were insured, in 2018 not a single event recorded presents losses covered by insurance.

Indicator 4.2: Economic value of change in mortality due to air pollution

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 experienced since 2011.*

Whilst Indicator 3.1.2 tracks progress on coal phase-out through the total primary energy supply of coal, this indicator looks to the future of coal-fired power generation through tracking investments in coal-fired capacity.

The data source for this indicator (IEA) remain the same as in the 2017 Lancet Countdown report,[13] however the methodology has altered, and been retrospectively applied to recalculate 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 were presented as 'overnight' investment, in which all capital spending on a new plant is assigned to the year in which the plant became operational. Further details are found in the appendix. Data for 2006-2017 using the old methodology are also presented in Figure 29 for comparison.

Whilst TPES for coal increased in 2018 (Indicator 3.1.2), investment in new coal-fired electricity generating capacity continues the downward trend experienced since 2011. Interestingly, this decline was in large part 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 (i.e. the decision to begin construction) declined 30% in 2018, with costs and construction times for new plants generally increasing due to larger, more efficient and complex designs, and the use of advanced pollution control systems, in response to concerns over air quality.[133]

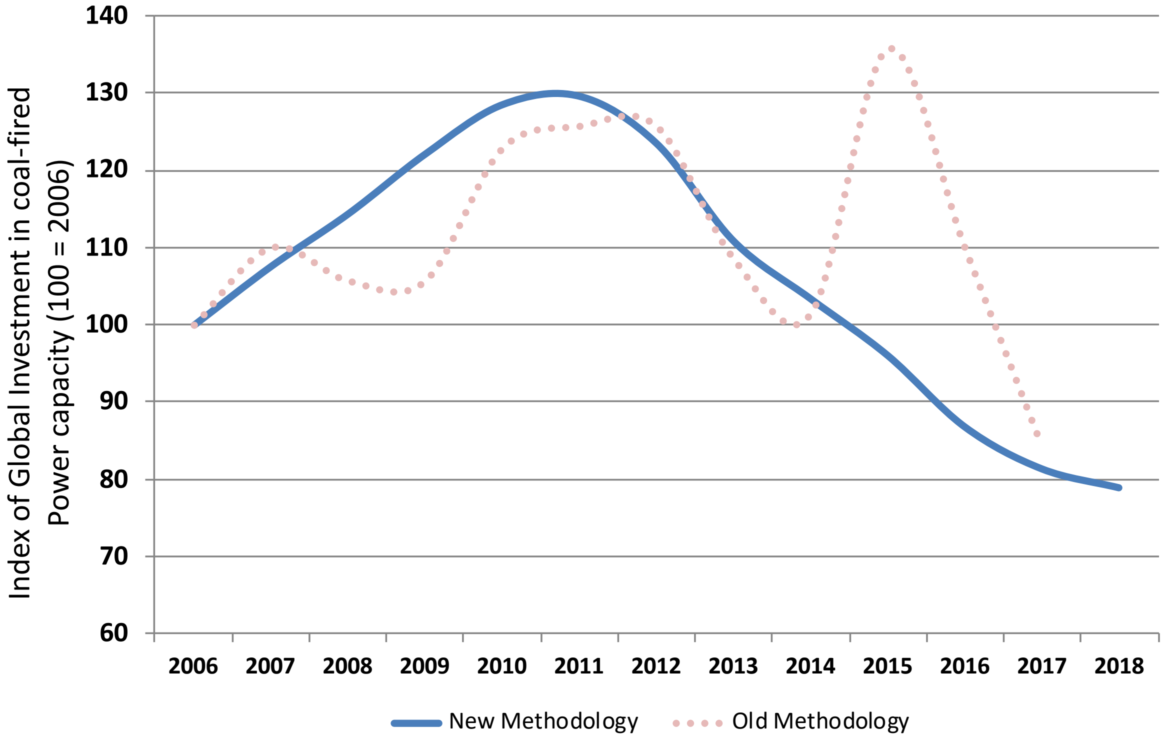


Figure 29: Annual investment in coal-fired capacity from 2006 to 2018 (an index score 100 corresponds to 2006 levels) (Source: IEA, 2019)[133]

Indicator 4.3.2: Investments in zero-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, whilst investments in zero-carbon energy decreased.*

Indicator 4.3 monitors global investment in zero-carbon energy, energy efficiency, fossil fuels, and electricity networks (both as a proportion of the total energy system, and in absolute terms). It complements the tracking of zero carbon electricity generation (Indicator 3.1.3) in section 3 and potentially predicts future trends in this indicator. All values reported are in US$2018, with data sourced from the IEA.[133] The data sources for this indicator remain the same as described in the 2017 Lancet Countdown report[13], however the methodology has been updated somewhat (see appendix).

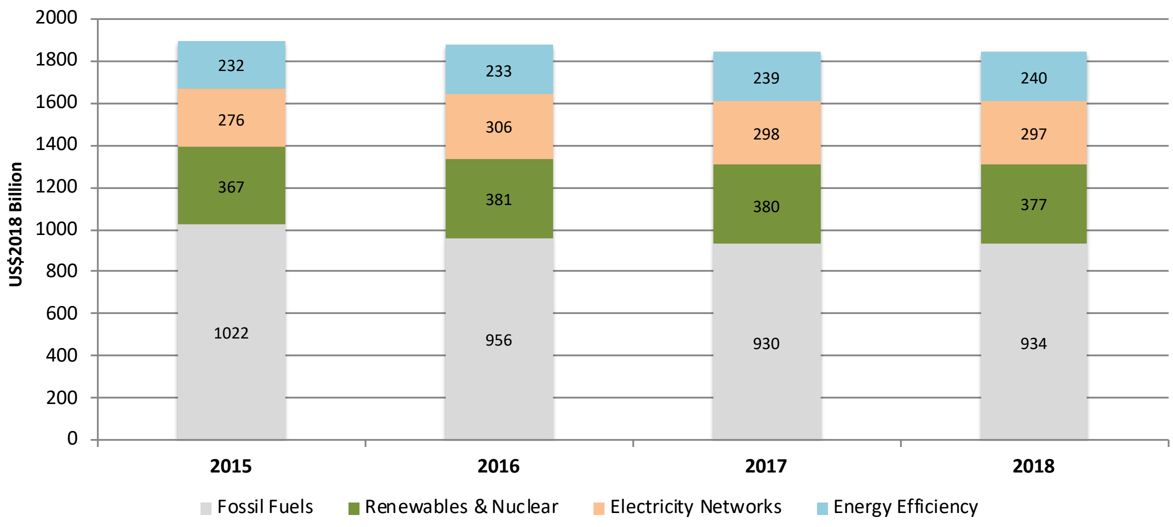


Figure 30: Annual Investment in the Global Energy System.

Total investment in the global energy system remained stable at around $1.85 trillion in 2018, following a steady decline between 2015 and 2017. Investment in fossil fuels increased slightly, driven by an increasing oil price, whilst investment in zero-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 with growth in zero carbon electricity generation (Indicator 3.1.3), these investment trends are currently 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 zero-carbon energy, electricity networks that enable it, and energy efficiency, must collectively grow by two-and-a-half times 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.[128]

Indicator 4.3.3: Employment in renewable and fossil fuel energy industries

Headline Finding: *In 2017, renewable energy provided 10.3 million jobs – an increase of 5.7% from 2016. Employment in fossil fuel extraction industries also increased to 12.9 million – a 2% increase from 2017.*

As the low-carbon transition gathers pace, fossil fuel energy industries and associated jobs will decline. Employment in some key fossil fuel industries, such as coal mining, have well documented impacts on human health, including risk of injury as well as risks to the respiratory system, skin and hearing.[13] However, in their place new low-carbon industries and employment opportunities, such as in the renewable energy sector, will be stimulated. With appropriate planning and enabling policy, the transition of employment opportunities between high and low-carbon industries may yield positive consequences for both the economy and human health. These can come in the form of improved air quality due to a shift from fossil fuel energy industries as well as improved employment, work conditions, socio-economic status and access to healthcare and education, key social determinants of health.[134]

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, presented in (Figure 34). The data for this indicator are sourced from the International Renewable Energy Agency (IRENA) (renewables) and IBIS World (fossil fuel extraction).[135-137] The data for fossil fuel extraction employment for 2012-2017 differs significantly from that presented in the 2018 Countdown report, due an improved methodology in the data collection and estimation methodology for global coal mining employment by IBISWorld. Further detail is found in the appendix.

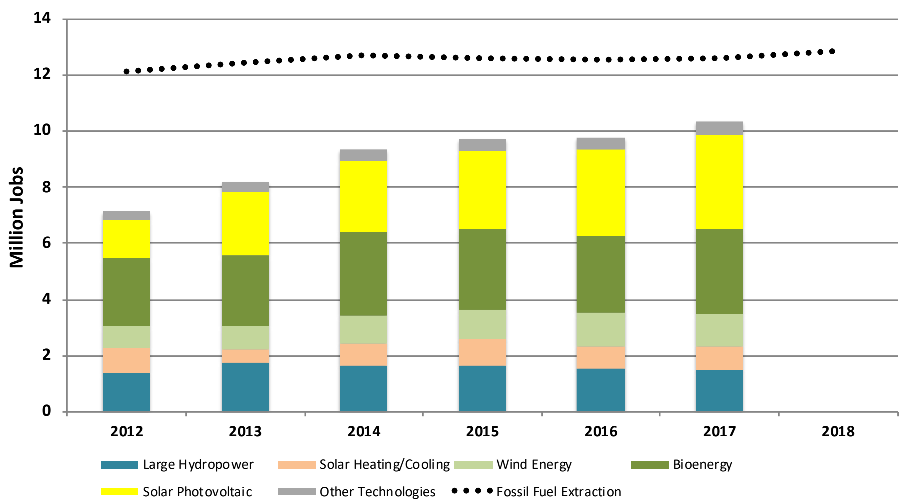


Figure 31: Employment in Renewable Energy and Fossil Fuel Extraction Sectors.

The number of direct and indirect jobs in the global renewable energy industry continues to increase, reaching 10.3 million in 2017 (a 5.7% increase from 2016). Solar photovoltaic (PV) overtook bioenergy to become the largest employer in 2016 and saw a further 9% growth in 2017 (driven by China and India). Employment in biofuels increased for the first time since 2014 (a 12% increase in 2017 from 2016 levels), due to increased production of ethanol and biodiesel (particularly in Brazil and the USA).[137]

Growth in employment in the fossil fuel extractive industries has been driven both the growth of coal mining in China and other emerging markets (particularly India), despite a decline in many higher-income countries, and the upstream oil and gas industries, following rising prices in 2018. However, it is expected that employment in both industries will decrease in the coming years due to 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, and a potential decline in oil and gas prices coupled with increasing productivity.[138,139]

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 $2.134 trillion, of which health institutions accounted for around $18 million; this represents a cumulative sum of $7.94 trillion since 2008, with health institutions accounting for $33.6 billion.*

Originating in the late 2000s, the divestment movement seeks to both remove from the fossil fuel industry its 'social license to operate' and guard against the risk of losses due to '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 on their effects only just beginning to emerge.[138]

This indicator tracks the total global value of funds divested from fossil fuels, and the value of divested funds coming from health institutions, using data provided by 350.org,[139] with full methodology described in the appendix.

From 2008 to the end of 2018, 1,025 organisations with cumulative assets worth at least $7.94 trillion, including 23 health organisations with assets of around $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 $428 billion in 2017 to $2.135 trillion in 2018. However, health institutions have divested at a reduced rate, with just $866.5 million divested in 2018, compared to $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 $429 billion - over a third higher 2017 levels, and over 50% higher than 2016 levels*.

Negative externalities, including the varied direct and indirect consequences for human health, mean that the true cost of fossil fuels is far greater than their market price.[140] Fossil fuel subsidies (both for their consumption and their extraction) artificially lower prices even further, promoting overconsumption, further exacerbating both GHG emissions and air pollution.

This indicator tracks the value of fossil fuel consumption subsidies, in 42 (mostly non-OECD) countries. Although these countries account for a large proportion of such subsidies around the world, they are by no means comprehensive, meaning the values reported are conservative. The methodology and data source (IEA) for this indicator remains unchanged since the 2017 Lancet Countdown report,[10] and is described there and the appendix. Data for 2008 and 2017, which was previously not available, are now included.

Whilst fossil fuel subsidies declined between 2012 and 2016, Figure 32 this trend was reversed in both 2017 and 2018,reaching $319 billion and $429 billion, respectively(Figure 35). The values presented above do not include the economic value of the unpriced negative externalities. If these were to be included, the IMF estimated that in 2017 subsidies to fossil fuels, using this definition, increases to $5.2 trillion – equivalent to 6.3% of Gross World Product (GWP).[141]

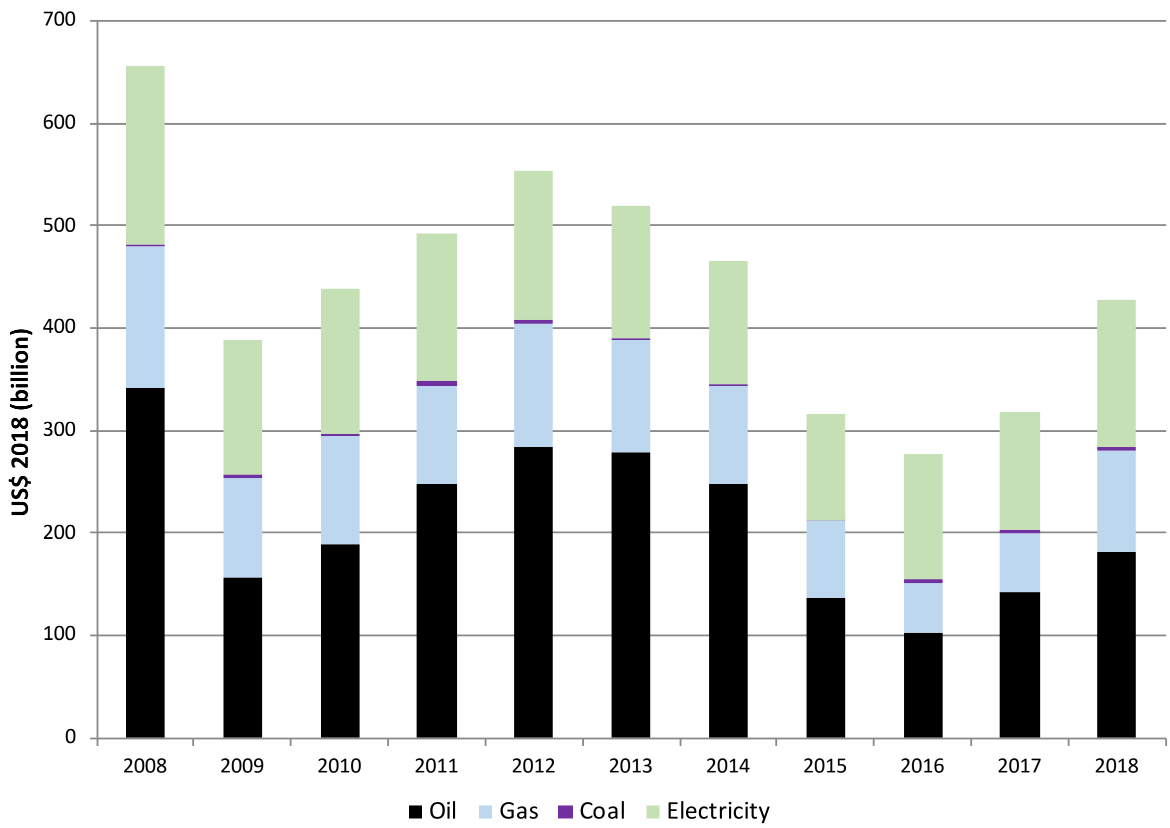


Figure 32: Global Fossil Fuel Consumption Subsidies – 2008-2018.

Indicator 4.4.2: Coverage and strength of carbon pricing

***Headline Finding:** Carbon pricing instruments in early 2018 continue to cover the 13.1% of global anthropogenic GHG emissions reached in 2017, but with average prices around 20% higher than experienced in 2017.*

Adequately pricing carbon (both in terms of strength, coverage, and integration of varying mechanisms) could potentially be the single-most important intervention in responding to climate change. This indicator tracks the extent to which carbon pricing instruments are applied around the world as a proportion of total GHG emissions, and the weighted average carbon price instruments provide (

Table 1: Carbon Pricing – Global Coverage and Weighted Average Prices per tCO2e. * Global emissions coverage is based on 2012 total anthropogenic GHG emissions.

	2016	**2017**	**2018**	**2019**
Global Emissions Coverage*	12.1%	13.1%	13.1%	TBC
Weighted Average Carbon Price of Instruments (*current prices, US$*)	$7.79	$9.28	$11.58	TBC
Global Weighted Average Carbon Price (*current prices, US$*)	$0.94	$1.22	$1.51	TBC

Figure 36: Carbon pricing instruments implemented, scheduled for implementation, and under consideration. Adapted from World Bank (2018)

The range of carbon prices across instruments remains vast (from <$1 /t$CO_2$e in Poland and Ukraine, to $139 /t$CO_2$e in Sweden), although weighted-average prices in early 2018 were

20% above 2017 levels (both across instruments, and total global anthropogenic GHG emissions). For example, the price under the EU Emissions Trading Scheme (ETS) (the largest carbon pricing instrument in the world) rose by $10 /t$CO_2$e between 1st December 2017 and 1st April 2018.

With the addition of instruments currently scheduled for implementation, including the Chinese national ETS (replacing the existing sub-national 'pilots'), around 20% of global anthropogenic GHG emissions will be subject to a carbon price.[142] As illustrated by **Error! Reference source not found.**, further carbon pricing instruments are under consideration in several other national and sub-national jurisdictions.

Indicator 4.4.3: Use of carbon pricing revenues

Headline Finding: *Revenues from carbon pricing instruments increased 50% between 2016 and 2017, reaching $33 billion, with $14.5 billion allocated to further climate change mitigation activities.*

Indicator 4.9 tracks the total government revenue from carbon pricing instruments and how such income is subsequently allocated (Table 2). Government revenue from carbon pricing instruments may be put to a range of uses. Revenue may be invested in climate change mitigation or adaptation activities, be explicitly recycled for other purposes (such as enabling the reduction of other taxes or levies), or simply contribute towards general government funds.

Table 2: Carbon pricing revenues and allocation in 2017.

	Mitigation	Adaptation	Revenue Recycling	General Funds	Total Revenue (US$)
Proportion of total funds (%)	44.3%	4.7%	15.7%	35.3%	
Value (US$)	$14.54 billion	$1.56 billion	$5.15 billion	$11.57 billion	$32.81 billion

Government revenue generated from carbon pricing instruments in 2017 totalled nearly $33 billion; a 50% increase from the $22 billion generated in 2016. This is driven by a combination of increasing carbon pricing coverage in 2017 (with the introduction of the Ontario ETS and carbon taxes in Alberta, Chile and Colombia), an increase in average prices, and an increasing share of ETS permits bought at auction (rather than distributed for free).[142]

The absolute value of allocated funds has increased in all four categories, with the proportional share remaining largely stable between 2016 and 2017. The most marked change is a shift of approximately 4% of total revenue from 'revenue recycling' to 'mitigation' (see Appendix 5 for a description of the four categories). This is in part driven by Colombia and particularly Ontario, committing to allocate all revenues from their newly-introduced instruments to further mitigation action.

Data on revenue generated are provided on the World Bank's Carbon Pricing Dashboard,[143] 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. The methodology and principle data source (World Bank) for this indicator has not changed since the 2017 Report of the Lancet Countdown report, and is described in the appendix, along with further detail on the various sources used to obtain this global picture of carbon pricing revenues, and data for individual instruments.

Conclusion

Section 4 has presented indicators on the economic impacts of climate change, the finance and economic underpinnings of climate change mitigation, and the economic value of the health-related benefits it brings. The results of these indicators suggest that the shift to a low carbon global economy is in some respects slowing, and in yet other cases, previously promising trends highlighted in the 2018 report are falling into reverse gear. Given the need to transition the global economy to net-zero GHG emissions by 2050 in order to limit warming to well below 2°C, governments at all levels, in collaboration with the private sector and the population at large, must take immediate steps towards implementing strong, ambitious policy and related action to steer and rapidly accelerate their economies towards a low-carbon state, conducive to human health and wellbeing.

) This indicator uses data from the World Bank Carbon Pricing Dashboard and the Emissions Database for Global Atmospheric Research to track carbon pricing mechanisms and their coverage of global GHG emissions .[118] Full methodology is presented in the appendix and remains unchanged from the 2017 Report of the Lancet Countdown.

The coverage of carbon pricing instruments remained at 13.1% of global anthropogenic GHG emissions between 2017 and 2018, implemented through 42 national and 25 sub-national instruments.

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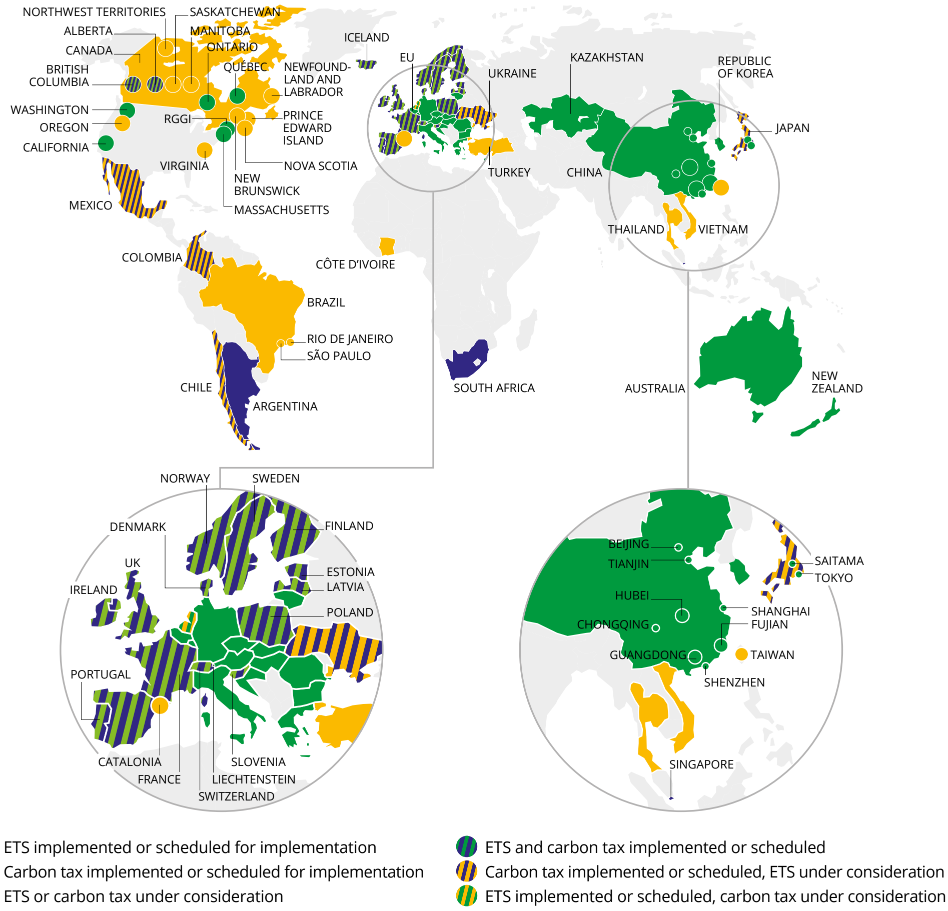

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The absolute value of allocated funds has increased in all four categories, with the proportional share remaining largely stable between 2016 and 2017. The most marked change is a shift of approximately 4% of total revenue from 'revenue recycling' to 'mitigation' (see Appendix 5 for a description of the four categories). This is in part driven by Colombia and particularly Ontario, committing to allocate all revenues from their newly-introduced instruments to further mitigation action.

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Section 4 has presented indicators on the economic impacts of climate change, the finance and economic underpinnings of climate change mitigation, and the economic value of the health-related benefits it brings. The results of these indicators suggest that the shift to a low carbon global economy is in some respects slowing, and in yet other cases, previously promising trends highlighted in the 2018 report are falling into reverse gear. Given the need to transition the global economy to net-zero GHG emissions by 2050 in order to limit warming to well below 2°C, governments at all levels, in collaboration with the private sector and the population at large, must take immediate steps towards implementing strong, ambitious policy and related action to steer and rapidly accelerate their economies towards a low-carbon state, conducive to human health and wellbeing.

Section 5: Public and political engagement

As earlier sections have made clear, climate change is human in both its origins and its impacts. Its origins lie in the burning of fossil fuels, particularly by early-industrialising and richer societies, and its impacts include an increasing toll on human health. Reductions in global GHG emissions at the speed required by the Paris Agreement depend upon engagement by all sectors of society.

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 section builds on methods used in earlier 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.[144-147] 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 Countdown report, we have additionally included 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.[148] The indicator has been further enhanced by a content analysis of the elite press in two contrasting societies, India and the U.S.A. Elite newspapers both reflect and shape engagement in climate change by governments and elite groups.[149-153]

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.[154] Because of its accessibility, breadth and user trust, Wikipedia is one of the most widely-used online resources.[155-159]

The third indicator relates to government engagement in health and climate change. The global public recognise that climate change is harming people and support government action to limit GHG emissions. [160-162] The indicator focuses on high-level government engagement in health and climate change at the United Nations General Assembly. It tracks references at the UN General Debate, the major international forum where national leaders have the opportunity to address the global community on issues they consider important.[163,164]

The fourth indicator relates to the corporate sector, recognised to be central to achieving a rapid transition to a carbon-free economy, both through its business practices of and via its wider political and public influence.[165-167] 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.[168]

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 paying attention to 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 what aspects of the health-climate change nexus are receiving attention in the elite media in India and the U.S.A. For the 2019 Report of the Lancet Countdown, methods to track newspaper coverage have been improved; greater attention is also given to the content of coverage.

Global media coverage of health and climate change has increased since 2010. As with broader coverage of climate change, spikes in media engagement with health and climate change coincided with major events in climate governance.[169] These include the 2009 and 2015 UNFCCC COPs in Copenhagen and Paris and, in 2016, the Paris Agreement and the Sustainable Development Goals coming into force. Nonetheless, health continued to represent only a small proportion of wider coverage of climate change. Analysis details, together with data sources and methodological enhancements, are described in the appendix. The indicator is based on 62 newspapers (English, German, Portuguese, Spanish) selected to provide a global spread of higher-circulation papers.

Extending this analysis, Figure 33 tracks coverage of health and climate change in the *People's Daily*. While the Chinese media has changed and diversified in recent decades, the *People's Daily* retains its dominance.[148,170,171]Across the 2008-18 period, there was an average of 2519 articles per year relating to climate change. A small proportion of these related to human health, with a mean of 14 articles a year. Spikes in coverage are less closely tied to landmarks in global climate change governance (such as the signing of the Paris Agreement in 2015) than in the global media. The explanation may lie in the timing of *People's Daily* coverage of global events, including the COPs, which occurs after their conclusion; coverage of November/December COPs may therefore occur in the following calendar year.

This addition to Indicator 5.1 was based on the *People's Daily* online archive,[172] and combined electronic searching of the text corpus (key word searches and algorithm-based natural language processing) with manual screening of the filtered articles. Full details of methods are provided in the appendix.

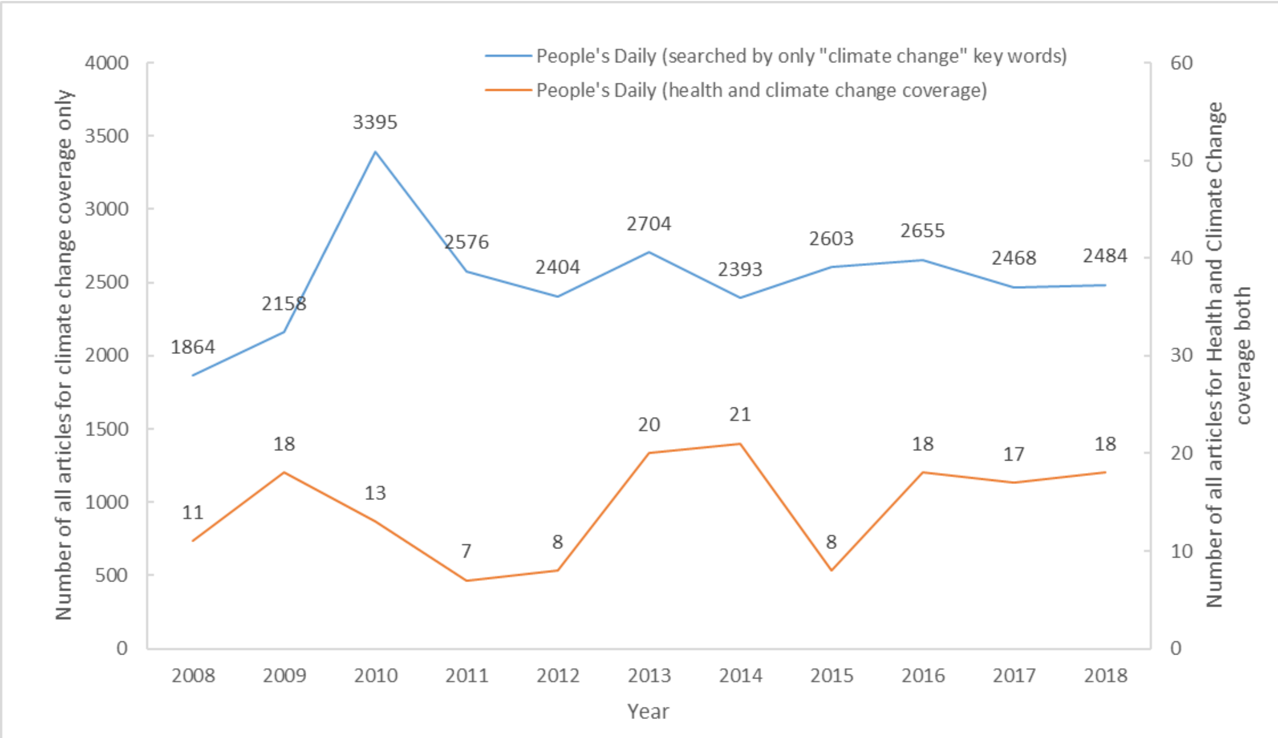

Figure 33: Number of articles reporting on climate change and on both health and climate change in the People's Daily 2008 to 2018.

The analysis of the content of coverage focused on the high-circulation elite press in India and the U.S.A: Times of India (TOI), Hindustan Times (HT), New York Times (NYT) and Washington Post (WP). Two time-periods were selected to cover months (July-September) where both countries experienced extreme weather events (monsoon flooding and wildfires respectively) together with months (November-December) covering the 2018 COP in Katowice. Articles in Nexis and Factiva were keyword searched and manually screened for inclusion. Template analysis was used to identify themes; *a priori* coding (Lancet Countdown indicator-derived) and inductive coding (from recurrent topics in the data) were employed. [173] Full details of methods are provided in the appendix, together with additional analyses.

Coverage of health and climate change clustered around three broad connections between health and climate change (Panel 4). The first theme related to the health impacts of climate change. Discussed in 62% of the articles, these impacts related to climate change-related stressors (e.g. increased temperatures, wildfires, precipitation extremes, food security, population displacement) and health sequelae (e.g. vector-borne disease, heat stress, mental ill-health). Heat-related health impacts were the most commonly-mentioned impact. A second theme (44% of articles) 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 (e.g. investment in clean energy, active travel and plant-based diets). The third theme 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 *HT, NYT* and *WP* while *ToI* gave greater emphasis to common causes and co-benefits (see appendix for further details).

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' (ToI, 9 August).

'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.' (NYT, 17 November)

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.' (HT, 5 December)

'For a short time on Thursday night, a small but fiercely determined group of marchers took over a busy D.C. 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."' (WP, 16 November)

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.' (ToI, 29 November)

'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.' (NYT, 13 December)

Panel 4: Dominant themes in elite newspaper coverage of health and climate change in India and the U.S.A.

Indicator 5.2 Individual engagement in health and climate change

***Headline finding:** Individuals typically seek information about either health or climate change; where 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.[174] This new indicator tracks individual-level engagement in health and climate change in 2018 through an analysis of usage of Wikipedia, the world's largest encyclopaedia. With reviews noting its accuracy,[155,175] Wikipedia is one of most-visited websites worldwide,[156] with a high correlation between user visits to Wikipedia and search activity on Google.[176] The analysis is based the English Wikipedia, which represents around 50% of global traffic to all Wikipedia language editions.

This is a new indicator for the 2019 Report of the Lancet Countdown and its analysis uses the online footprint of Wikipedia users to map the dynamics of public information-seeking in health and climate change.[154,177] 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.[178]

Articles were identified via key words and relevant hyperlinks within articles, refined using Wikipedia categories and then filtered by the initial key words. Data and methods are described in the appendix, together with further analysis.

Figure 34 indicates that articles on health and on climate change are internally networked, with extensive co-visiting within these clusters. However, it points to 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. In addition, the majority (79%) of co-visits originated from a health-related page, with only a minority driven by an initial interest in a climate-related topic (Figure 35).

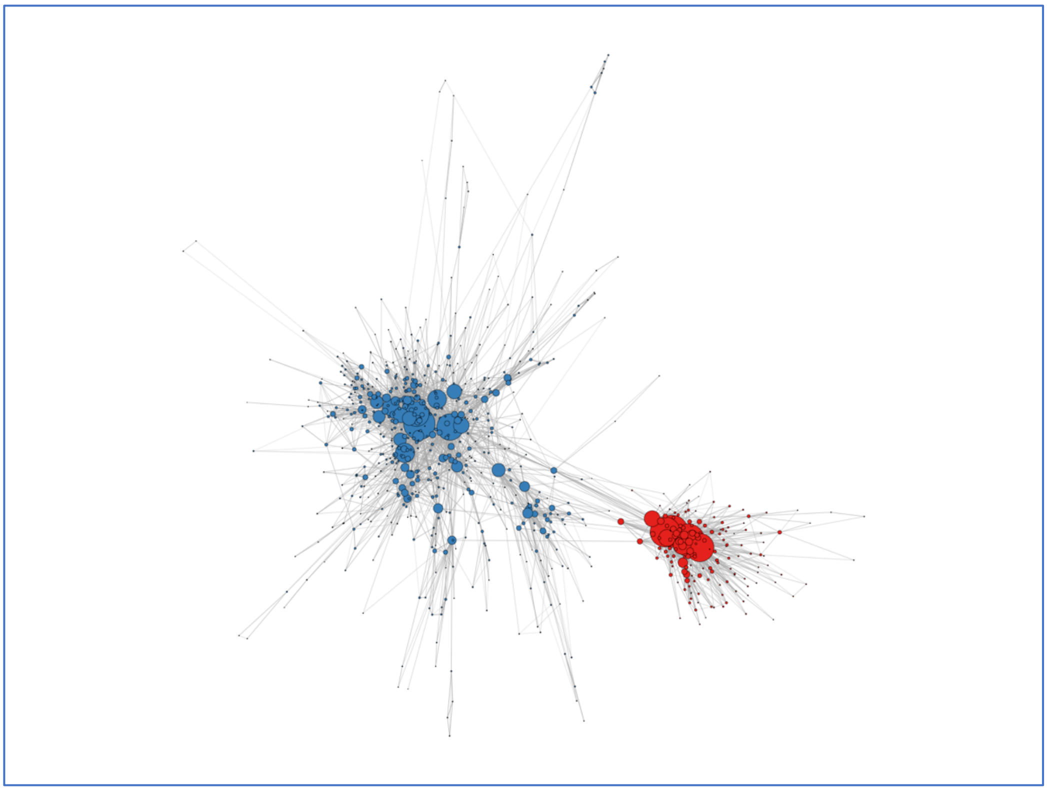

Figure 34: Connectivity graph of Wikipedia articles on climate change (red) and health (blue) visited in 2018. Popularity of articles is indicated by node size; lines represent co-visits in clickstream data

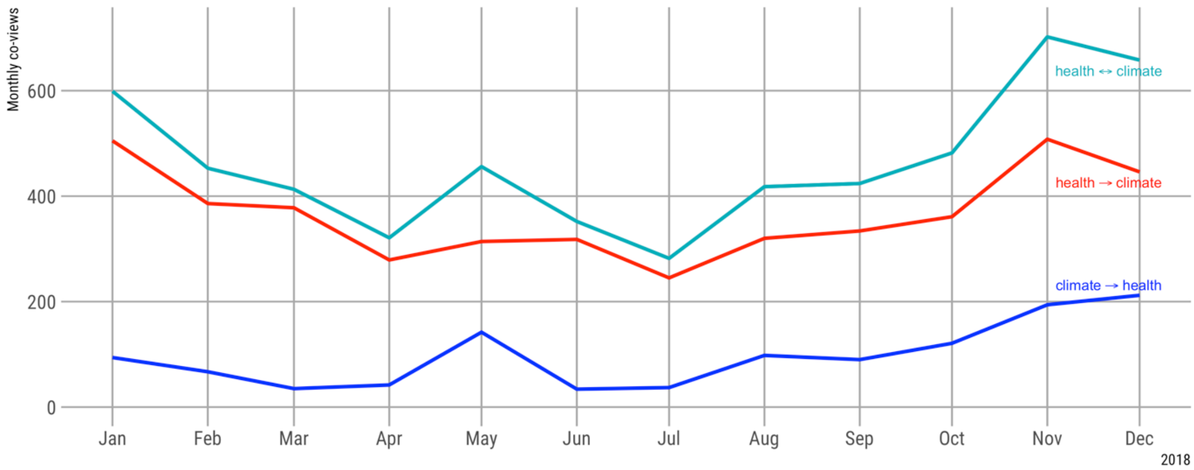

Figure 35: Aggregate monthly co-clicks on articles in Wikipedia related to human health and climate change in 2018

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 (UNGD) in a trend led by small island developing states (SIDS), with SIDS making up 10 out of 28 countries referencing the climate change-health link at the UNGD 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 UNGD. The UNGD takes place at the start of the annual UN General Assembly (UNGA) and provides a global platform for all UN member states to speak about their priorities and concerns.

An updated dataset, *the United Nations General Debate corpus*, was used for the analysis, based on 8,093 statements (1970-2018).[179,180] Key word searches used sets of health-related and of climate change-related terms; engagement in the health-climate change nexus was determined by the proximity of relevant key words within the statement. Methods and data, as well as further analyses are presented in full in the appendix.

Figure 36 shows the proportion of countries that make reference to the links between health and climate change in their UNGD statements, together with the proportion referring separately to climate change and/or to health. In 2018, 28 countries in total referenced the climate change-health link at the UNGD.

It points to an upward trend in government engagement in health and climate change since 1970, and one in-line with broader trends for 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 (MDGs) to the Sustainable Development Goals (SDGs) and 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, Figure 36 points to much higher levels of engagement in health and climate change as separate issues. 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 SIDS, for example, Fiji, Palau, Samoa, Dominica, and St Kitts and Nevis, with 10 SIDS making reference to the climate change-health link. 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 and climate change are two sides of the same coin” while 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.”

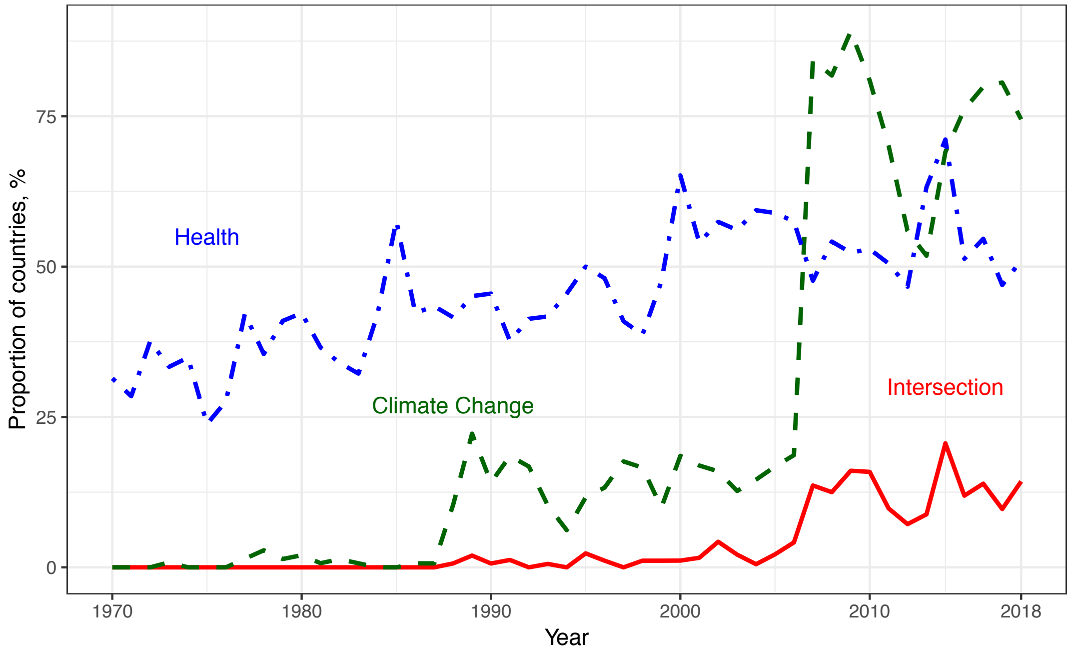

Figure 36: Proportion of countries referring to climate change, health, and the intersection between the two in their UNGD statements, 1970-2018

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 (UNGC), including companies in the healthcare sector.*

This indicator tracks corporate sector engagement through references to health and climate change in companies that are part of the UNGC, an 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. [181] While the UNGC has been the subject of critique, it remains the world’s largest corporate citizenship initiative. [182-184]

Companies submit annual Communication of Progress (CPs) 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. [168]

Analysis was based on key word searches of sets of health-related and of climate change-related terms in CP reports in the UNGC database;[168] conjoint engagement in health and climate change was identified by the proximity of relevant key words within the CP report. Methods, data and additional analyses are presented in full in the appendix. With very few reports available prior to 2011, the analysis focuses on the period from 2011 to 2018.

Up to 2017, a small proportion of companies made reference to the links between health and climate change. [10] The pattern continues in the 2018 CP reports. While around 45% and 60% of the 2018 reports refer to climate change and to health respectively, only 15% refer them together (see appendix). This pattern was even more pronounced in the corporate healthcare sector, which might be expected to be the global leader in addressing links between health and climate change (Figure 37). In 2018, while the majority of health sector companies referred to health (72%) and an increasing minority to climate change (47%), only 12% made conjoint reference to both.

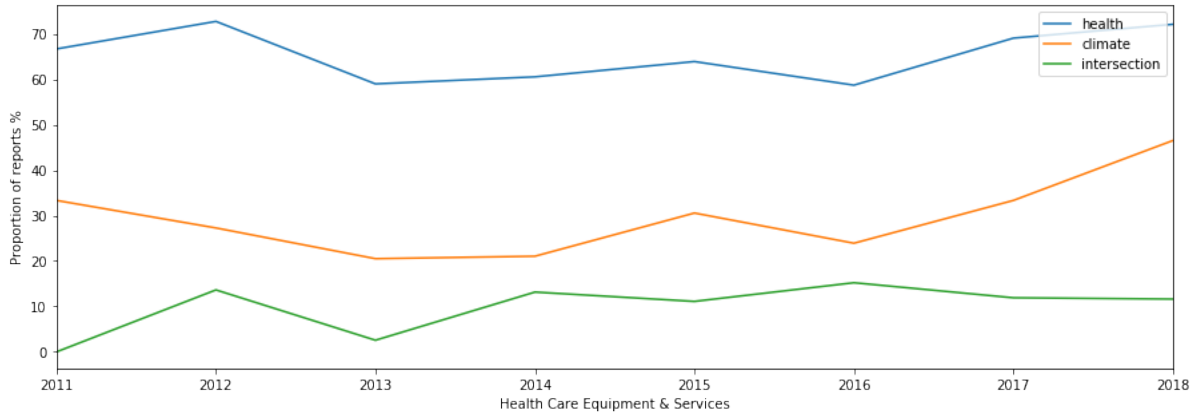

Figure 37: Proportion of healthcare sector companies referring to climate change, health, and the intersection of health and climate change in CP reports, 2011-2018

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 is recognised to be central to moving global emissions onto a pathway that holds global temperature increases to below 1.5°C. [185]

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 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

SIDS, these countries are highlighting 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 ‘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 elsewhere, 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. [169,186] The pattern for the corporate sector, including the healthcare sector, is different; it does not display spikes in engagement linked to the global governance of the planet.

Second, while engagement has increased over the last decade, our 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. The analysis of individual engagement illustrates this pattern. The online footprint of Wikipedia users confirms that, while health is a major area of individual interest, it is rarely connected with climate change. In the public’s mind, it appears that ‘health’ and ‘climate change’ represent different and separate realms of knowledge and concern and, where connections are made, this is driven by an interest in health rather than 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 2019 Report of the Lancet Countdown

The Lancet Countdown: Tracking Progress on Health and Climate Change was formed four years ago, building on the work of the 2015 Lancet Commission. Since then, the collaboration has grown from a small initiative based at University College London, in to a global, independent research collaboration, bringing together 28 of the world's leading academic institutions and UN agencies.

It remains committed to an open and iterative process, always looking to strengthen its methods, source new and novel forms of data, and partner with global leaders in public health and in climate change. The 42 indicators presented in the 2019 report represent the consensus and work of the last 12 months, and are grouped in to five categories: climate change impacts, exposures, and vulnerabilities; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; finance and economics; and public and political engagement.

The data published here elucidate ongoing trends of a warming world threatening human wellbeing. As the fourth hottest year on observed, 2018 saw a record-breaking 220 million additional exposures to extremes of heat, coupled with corresponding rising vulnerability across every continent. As a result of this and broader climatic changes, vectorial capacity for the transmission of dengue fever was the second highest ever seen, with 9 out of the last 10 most suitable years occurring since 2000.

Progress in mitigation and adaptation remains insufficient, with the carbon intensity of the energy system remaining flat; 3.1 million ambient air pollution deaths; and a reversal of the previous downward trend of coal use.

And yet, as the material effects of climate change reveal themselves, so too does the world's response. Just under 50% of countries tracked have developed national health adaptation plans, 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 global adaptation spend. Finally, public and political engagement continues to grow, with flash-points around the school climate strikes, the UNFCCC's annual meetings, and divestment announcements from medical and health associations.

Many of the indicators above describe a concerning narrative about an increasingly dangerous world. However, there are many reasons for optimism, and much data to support this position. With the full force of the Paris Agreement being implemented in 2020, the focus for the coming decade is no longer the direction of travel – that is now set – it is the pace of change.

In 2015, the Lancet Commission made ten policy recommendations. Of these ten recommendations, the 2019 Lancet Countdown report tracks progress on the following:

Recommendation 2: scale up financing for climate-resilient health systems
Spending on health adaptation as a proportion of total adaptation spending increased from 4.8% in 2017 to 5.0% (£13 billion) in 2018 (Indicator 2.7). In 2018, health-related adaptation spending (which includes disaster response and food and agriculture) was estimated to be 13.5% (£35 billion) of total adaptation spending.

Recommendation 3: phase out coal-fired power
Reversing the trend reported in 2018, coal as a proportion of total primary energy supply has increased by 1.7% from 2016 to 2018 (Indicator 3.1.2). However, investment in new coal capacity has been declining since 2011 (Indicator 4.3.1). Both of these trends have been driven largely by India and China.

Recommendation 4: encourage city-level low-carbon transition to reduce urban pollution
Whilst from 2015 to 2016 per capita fossil fuel use for road transport increased by 0.5%, the growth in biofuels and electricity for road transport was substantially greater at 3.3% and 206% respectively. Electricity as a proportion of total transportation fuels use is highest in China at 1.5%.

Recommendation 5: establish the framework for a strong and predictable carbon pricing mechanism

Recommendation 6: rapidly expand access to renewable energy, unlocking the substantial economic gains available from this transition
Solar generation continues to grow at an unprecedented rate of around 30% per annum (Indicator 3.1.3). From 2010 to 2016, access to electricity has risen from 83% to 87% and the global proportion of clean energy use in the residential sector rose from 17% to 24%, however approximately 1 billion people remain without access to electricity (Indicator 3.2).

Recommendation 7: support accurate quantification of the avoided burden of disease, reduced health-care costs, and enhanced economic productivity associated with climate change mitigation
Coal combustion across sectors is estimated to cause almost half a million $PM_{2.5}$ attributable premature deaths per year (Indicator 3.3.2). This loss of life is estimated to cost **X** in Europe alone (Indicator 4.2).

Recommendation 9: agree and implement an international treaty that facilitates the transition to a low-carbon economy
With the exception of one or two lone wolves who have announced their intention to withdraw, there continues to be strong support of the Paris Agreement, which shall enter implementation in 2020.

Recommendation 10: develop a new, independent collaboration to provide expertise in implementing policies that mitigate climate change and promote public health, and monitor progress over the next 15 years
The Lancet Countdown is a collaboration of 27 partners, committed to an iterative and open process of tracking the links between public health and climate change. For the second consecutive year, significant improvements have been made to a majority of indicators. The ability of the Lancet Countdown to monitor progress will continue to develop at an accelerated pace as additional funding and capacity from the Wellcome Trust and the Lancet Countdown's partners grows.

Panel 4: Progress towards the recommendations of the 2015 *Lancet* Commission on health and climate change

References

1. NHS England, Public Health England. Reducing the use of natural resources in health and social care. London: NHS England, 2018.
2. Anderson K, Bows A. Beyond 'dangerous' climate change: emission scenarios for a new world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 2011; **369**(1934): 20-44.
3. Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *Lancet* 2009; **373**(9676): 1693-733.
4. Haustein K, Allen M, Forster P, et al. A real-time global warming index. *Scientific reports* 2017; **7**(1): 15417.
5. IPCC. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change.: Intergovernmental Panel on Climate Change, 2018.
6. Legendre M, Bartoli J, Shmakova L, et al. Thirty-thousand-year-old distant relative of giant icosahedral DNA viruses with a pandoravirus morphology. *Proceedings of the National Academy of Sciences* 2014; **111**(11): 4274-9.
7. Revich BA, Podolnaya MA. Thawing of permafrost may disturb historic cattle burial grounds in East Siberia. *Global health action* 2011; **4**(1): 8482.
8. Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. *Lancet* 2015; **386**(10006): 1861-914.
9. United Nations. Transforming our World: The 2030 Agenda for Sustainable Development. New York: United Nations, 2015.
10. Watts N, Amann M, Arnell N, et al. The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. *The Lancet* 2018; **392**(10163): 2479-514.
11. Markandya A, Sampedro J, Smith SJ, et al. Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. *The Lancet Planetary Health* 2018; **2**(3): e126-e33.
12. New Climate Economy. Unlocking the Inclusive Growth Story of the 21st Century: Accelerating Climate Action in Urgent Times. Washington, 2018.
13. Watts N, et al. The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *The Lancet* 2017; **391**(10120): 581-630.
14. UNFCCC. Paris Agreement. 2015.
15. Szekely M, Carletto L, Garami A. The pathophysiology of heat exposure. *Temperature (Austin, Tex)* 2015; **2**(4): 452.
16. Sanz-Barbero B, Linares C, Vives-Cases C, Gonzalez JL, Lopez-Ossorio JJ, Diaz J. Heat wave and the risk of intimate partner violence. *The Science of the total environment* 2018; **644**: 413-9.
17. Levy BS, Sidel VW, Patz JA. Climate Change and Collective Violence. *Annual review of public health* 2017; **38**: 241-57.
18. Arbuthnott KG, Hajat S. The health effects of hotter summers and heat waves in the population of the United Kingdom: a review of the evidence. *Environ Health* 2017; **16**(Suppl 1): 119.
19. European Centre for Medium-Ranged Forecasts. Climate reanalysis. 2018.
20. NASA. Gridded Population of the World. 4 ed; 2019.
21. WBG. Population ages 65 and above, total. 2017.
22. Kjellstrom T, Freyberg C, Lemke B, Otto M, Briggs D. Estimating population heat exposure and impacts on working people in conjunction with climate change. *International journal of biometeorology* 2018; **62**(3): 291-306.

23. Flouris AD, Dinas PC, Ioannou LG, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. *The Lancet Planetary Health* 2018; **2**(12): e521-e31.
24. ECMWF. ERA Interim, Daily. 2019.
25. ILO. ILOSTAT. 2019.
26. Black C, Tesfaigzi Y, Bassein JA, Miller LA. Wildfire smoke exposure and human health: Significant gaps in research for a growing public health issue. *Environ Toxicol Pharmacol* 2017; **55**: 186-95.
27. Doerr SH, Santin C. Global trends in wildfire and its impacts: perceptions versus realities in a changing world. *Philos Trans R Soc Lond B Biol Sci* 2016; **371**(1696).
28. EarthData. Active Fire Data. 2019. https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data (accessed 4 February 2019).
29. Smith KR, Woodward A, Campbell-Lendrum D, et al. Human health: impacts, adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, et al., eds. Climate Change 2014: Impacts, Adaptation, and Vulnerability Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014: 709−54.
30. Centre for Research on the Epidemiology of Disasters. EM-DAT The International Disaster Database. 2019.
31. Miranda JJ, Castro-Ávila AC, Salicrup LA. Advancing health through research partnerships in Latin America. *bmj* 2018; **362**: k2690.
32. Novillo-Ortiz D, Dumit EM, D'Agostino M, et al. Digital health in the Americas: advances and challenges in connected health. *BMJ innovations* 2018; **4**(3): 123-7.
33. Vogenberg FR, Santilli J. Healthcare trends for 2018. *American health & drug benefits* 2018; **11**(1): 48.
34. IHME. Global Burden of Disease Study (2017) Data Resources. 2019.
35. Rocklöv J, Tozan Y. Climate change and the rising infectiousness of dengue. *Emerging Topics in Life Sciences* 2019; **3**(2): 133-42.
36. Martinez-Urtaza J, Trinanes J, Abanto M, et al. Epidemic Dynamics of Vibrio parahaemolyticus Illness in a Hotspot of Disease Emergence, Galicia, Spain. *Emerg Infect Dis* 2018; **24**(5): 852-9.
37. Martinez-Urtaza J, van Aerle R, Abanto M, et al. Genomic Variation and Evolution of Vibrio parahaemolyticus ST36 over the Course of a Transcontinental Epidemic Expansion. *MBio* 2017; **14**(8).
38. Wang H, Tang X, Su Y, Chen J, Yan J. Characterization of clinical Vibrio parahaemolyticus strains in Zhoushan, China, from 2013 to 2014. *PLoS One* 2017; **12**(7).
39. Hales S, Kovats S, Lloyd L, Campbell-Lendrum D. Quantitative risk assessment of the effects of climate change on selected causes of death , 2030s and 2050s: World Health Organization, 2014.
40. Hasegawa T, Slade R. Impacts of 1.5°C of Global Warming on Natural and Human Systems. In: Masson-Delmotte V, Zhai P, Pörtner H-O, et al., eds. Global warming of 15°C An IPCC Special Report: Intergovernmental Panel on Climate Change; 2018.
41. Adger WN, Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K.; Pulhin, J., Pulwarty, R., Smit, B., Takahashi, K.,. Assessment of Adaptation Practices, Options, Constraints and Capacity. Cambridge, UK,: Cambridge University Press; 2007.
42. WHO. International Health Regulations (IHR) monitoring framework: implementation status of IHR core capacities, 2010-2017. 2018.
43. Deutsch CA, Tewksbury JJ, Tigchelaar M, et al. Increase in crop losses to insect pests in a warming climate. *Science* 2018; **361**(6405): 916-9.
44. Meng Q, Chen X, Lobell DB, et al. Growing sensitivity of maize to water scarcity under climate change. *Scientific reports* 2016; **6**: 19605.

45. Mueller ND, Gerber JS, Johnston M, Ray DK, Ramankutty N, Foley JA. Closing yield gaps through nutrient and water management. *Nature* 2012; **490**(7419): 254.
46. Alexander P, Rounsevell MD, Dislich C, Dodson JR, Engström K, Moran D. Drivers for global agricultural land use change: The nexus of diet, population, yield and bioenergy. *Global Environmental Change* 2015; **35**: 138-47.
47. FAO I, UNICEF, WFP and WHO. The State of Food Security and Nutrition in the World. Building Climate Resilience for Food Security and Nutrition. Rome: FAO, 2018.
48. UNDP. SDG 2: Zero Hunger. 2019. https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-2-zero-hunger.html#targets (accessed 08/05 2019).
49. Challinor AJ, Koehler A-K, Ramirez-Villegas J, Whitfield S, Das B. Current warming will reduce yields unless maize breeding and seed systems adapt immediately. *Nature Climate Change* 2016; **6**(10): 954.
50. Zhao C, Liu B, Piao S, et al. Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences* 2017; **114**(35): 9326-31.
51. FAO. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome: Food and Agriculture Organization of the United Nations, 2018.
52. Porter J, Xie A, Challinor A, et al. Food Security and Food Production Systems. In: Field C, Barros V, Dokken D, et al., eds. Climate Change 2014: Impacts, Adaptation, and Vulnerability

Part A: Global and Sectoral Aspects Contribution of Working Group II to the Fifth Assessment Report of the

Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press; 2014.
53. Ortiz J-C, Wolff NH, Anthony KR, Devlin M, Lewis S, Mumby PJ. Impaired recovery of the Great Barrier Reef under cumulative stress. *Science advances* 2018; **4**(7): eaar6127.
54. Food and Agriculture Organization. Food balance sheets. 20172019).
55. NASA NEO NEO. Sea surface temperature (1 month – AQUA/MODIS). 2017.
56. NOAA. NOAA Coral Reef Watch Version 3.1 Daily Global 5-km Satellite Coral Bleaching Degree Heating Week Product. 2018.
57. Kelman I. Imaginary Numbers of Climate Change Migrants? *Social Sciences* 2019; **8**(5): 131.
58. Berry HL, Waite TD, Dear KBG, Capon AG, Murray V. The case for systems thinking about climate change and mental health. *Nature Climate Change* 2018; **8**(4): 282-90.
59. UNFCCC. Aggregate effect of the intended nationally determined contributions: an update, 2016.
60. Ford J, Berrang-Ford L, Lesnikowski A, Barrera M, Heymann S. How to track adaptation to climate change: a typology of approaches for national-level application. *Ecology and Society* 2013; **18**(3).
61. Ford JD, Berrang-Ford L. The 4Cs of adaptation tracking: consistency, comparability, comprehensiveness, coherency. *Mitig Adapt Strateg Glob Chang* 2016; **21**(6): 839-59.
62. Noble IR, Huq S, Anokhin YA, et al. Adaptation needs and options. In: Field CB, Barros VR, Dokken DJ, et al., eds. Climate Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014.
63. Watts N, Adger WN, Ayeb-Karlsson S, et al. The Lancet Countdown: tracking progress on health and climate change. *The Lancet* 2017; **389**(10074): 1151-64.
64. WHO. Operational framework for building climate resilient health systems. Geneva: World Health Organization, 2015.
65. World Health Organization. COP24 Special Report: Health and Climate Change. Geneva: Wolrd Health Organization, 2018.

66. World Health Organization. 2018 WHO health and climate change country survey. Geneva, 2019.
67. World Health Organization. Protecting health from climate change: vulnerability and adaptation assessment Geneva, 2013.
68. CDP. Data cities. 2019.
69. Bouchama A, Dehbi M, Mohamed G, Matthies F, Shoukri M, Menne B. Prognostic factors in heat wave related deaths: a meta-analysis. *Arch Intern Med* 2007; **167**(20): 2170-6.
70. Waite M, Cohen E, Torbey H, Piccirilli M, Tian Y, Modi V. Global trends in urban electricity demands for cooling and heating. *Energy* 2017; (127): 786-802.
71. Salamanca F, Georgescu M, Mahalov A, Moustaoui M, Wang M. Anthropogenic heating of the urban environment due to air conditioning. *Journal of Geophysical Research-Atmospheres* 2014; (119): 5949-65.
72. Purohit P, Hoglund-Isaksson L. Global emissions of fluorinated greenhouse gases 2005-2050 with abatement potentials and costs. *Atmospheric Chemistry and Physics* 2017; (17): 2795-816.
73. Velders G, Fahey D, Daniel J, Andersen S, McFarland M. Future atmospheric abundances and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions. *Atmospheric Environment* 2015; (123): 200-9.
74. Miettinen OS. Proportion of disease caused or prevented by a given exposure, trait or intervention. *Am J Epidemiol* 1974; **99**(5): 325-32.
75. IEA. The future of cooling: opportunities for energy-efficient air conditioning. 2018. https://webstore.iea.org/the-future-of-cooling (accessed April 11 2019.
76. OzonAction. The Kigali Amendment to the Montreal Protocol: HFC Phase-down. Paris: United Nations Environment Program, 2016.
77. kMatrix Ltd. Adaptation and Resilience to Climate Change dataset. 2019.
78. International Monetary Fund. World Economic Outlook, April 2019 Growth Slowdown, Precarious Recovery. Washington: International Monetary Fund, 2019.
79. UNEP. The Adaptation Gap Report 2018. Health Report. Nairobi: United Nations Environment Program, 2018.
80. UNEP. The Adaptation Gap Report 2017. Towards Global Assessment. Nairobi: United Nations Environment Program, 2017.
81. UNEP. The Emissions Gap Report 2018. Nairobi, 2018.
82. WHO. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. Geneva: World Health Organization, 2016.
83. Woodcock J, Edwards P, Tonne C, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *Lancet* 2009; **374**(9705): 1930-43.
84. Willett W, Rockstrom J, Loken B, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet* 2019; **393**(10170): 447-92.
85. IEA. Renewable Energy 2018: Market Analysis and Forecast from 2018 to 2023, 2018.
86. IEA. World Energy Outlook 2018. Paris, 2018.
87. IEA. World Extended Energy Balances. 2019.
88. Powering Past Coal Alliance. Powering Past Coal Alliance. 2019. https://poweringpastcoal.org/2019).
89. ILO. Solar PV. 2019. https://www.iea.org/tcep/power/renewables/solarpv/# (accessed 25 May 2019).
90. United Nations. Sustainable Development Goal 7. 2019. https://sustainabledevelopment.un.org/sdg7 (accessed 05/06 2019).
91. WHO. Energy access and resilience. 2019. https://www.who.int/sustainable-development/health-sector/health-risks/energy-access/en/ (accessed 05/06 2019).
92. IEA. World Energy Outlook 2018. Global Residential Sector Energy Consumption. Paris, 2018.

93. IEA. Methodology. Defining energy access. 2019. https://www.iea.org/energyaccess/methodology/ (accessed 06/05 2019).
94. IEA, IRENA, WMO, WBG, WHO. Tracking SDG7: The Energy Progress Report 2018: The World Bank, 2018.
95. WHO. Burden of disease from Household Air Pollution for 2012, 2012.
96. Bonjour S, Adair-Rohani H, Wolf J, et al. Solid fuel use for household cooking: country and regional estimates for 1980–2010. *Environmental health perspectives* 2013; **121**(7): 784-90.
97. Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The lancet* 2012; **380**(9859): 2224-60.
98. Egondi T, Muindi K, Kyobutungi C, Gatari M, Rocklöv J. Measuring exposure levels of inhalable airborne particles (PM2. 5) in two socially deprived areas of Nairobi, Kenya. *Environmental research* 2016; **148**: 500-6.
99. United States Department of Energy. EnergyPlus V8. 2013.
100. Muindi K, Kimani-Murage E, Egondi T, Rocklov J, Ng N. Household Air Pollution: Sources and Exposure Levels to Fine Particulate Matter in Nairobi Slums. *Toxics* 2016; **4**(3).
101. IIASA. Air Quality and Greenhouse Gases (AIR). 2018.
102. UN Habitat. Sustainable building design for tropical climates : principles and applications for eastern Africa. Nairobi, 2015.
103. Klimont Z, Kupiainen K, Heyes C, et al. Global anthropogenic emissions of particulate matter including black carbon. *Atmospheric Chemistry and Physics* 2017; **17**(14): 8681-723.
104. Burnett RT, Pope III CA, Ezzati M, et al. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environmental health perspectives* 2014; **122**(4): 397-403.
105. Burnett R, Chen H, Szyszkowicz M, et al. Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. *Proceedings of the National Academy of Sciences* 2018; **115**(38): 9592-7.
106. Gakidou E, Afshin A, Abajobir AA, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet* 2017; **390**(10100): 1345-422.
107. Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* 2015; **525**(7569): 367.
108. Amann M, Bertok I, Borken-Kleefeld J, et al. Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications. *Environmental Modelling & Software* 2011; **26**(12): 1489-501.
109. IEA. World Energy Outlook 2017. 2017.
110. United Nations DESA/Population Division. World Urbanization Prospects: 2018 Revision. 2018.
111. WHO. WHO Global Urban Ambient Air Pollution Database (Update 2018). Geneva: World Health Organization; 2018.
112. International Energy Agency. World Energy Investment 2016. Paris, 2016.
113. Chapman R, Keall M, Howden-Chapman P, et al. A Cost Benefit Analysis of an Active Travel Intervention with Health and Carbon Emission Reduction Benefits. *Int J Environ Res Public Health* 2018; **15**(5).
114. Maizlish N, Linesch NJ, Woodcock J. Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. *J Transp Health* 2017; **6**: 490-500.
115. Wolkinger B, Haas W, Bachner G, et al. Evaluating Health Co-Benefits of Climate Change Mitigation in Urban Mobility. *Int J Environ Res Public Health* 2018; **15**(5).

116. Buehler R, Dill J. Bikeway networks: A review of effects on cycling. *Transport Reviews* 2016; **36**(1): 9-27.
117. International Energy Agency. World Energy Investment 2017. Paris: International Energy Agency, 2017.
118. Watts N, Amann M, Ayeb-Karlsson S, et al. The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *Lancet (London, England)* 2018; **391**(10120): 581-630.
119. Allen J. Volkswagen will launch its last petrol and diesel-powered cars in 2026. The Sunday Times. 2018.
120. Barberan A, Monzon A. How did bicycle share increase in Vitoria-Gasteiz? *Transportation research procedia* 2016; **18**: 312-9.
121. Friel S, Dangour AD, Garnett T, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. *Lancet* 2009; **374**(9706): 2016-25.
122. Eckelman MJ, Sherman J. Environmental Impacts of the US Health Care System and Effects on Public Health. *PloS ONE* 2016; **11**(6): e0157014.
123. Eckelman MJ, Sherman JD, MacNeill AJ. Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis. *PLoS medicine* 2018; **15**(7): e1002623.
124. Malik A, Lenzen M, McAlister S, McGain F. The carbon footprint of Australian health care. *The Lancet Planetary Health* 2018; **2**(1): e27-e35.
125. Leontief W. Environmental repercussions and the economic structure: An inputoutput approach. *Review of Economics and Statistics* 1970; **52**(3): 262-71.
126. Hertwich EG, Peters GP. Carbon footprint of nations: A global, trade-linked analysis. *Environmental science & technology* 2009; **43**(16): 6414-20.
127. Pichler P-P, Jaccard I, Weisz U, Weisz H. International comparison of health care carbon footprints. *Environmental Research Letters* 2019.
128. EIU. The cost of inaction: Recognising the value at risk from climate change: The Economist Intelligence Unit, 2015.
129. CCC. Net Zero: The UK's contribution to stopping global warming. London: Committee on Climate Change, 2019.
130. IPCC. Climate Change 2014. Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York, 2014.
131. Munich Re. NatCatSERVICE. 2019.
132. WBG. World Development Indicators. In: Group WB, editor.; 2019.
133. IEA. World Energy Investment 2019. Paris: International Energy Agency, 2019.
134. WHO CoSDoH. Closing the gap in a generation. Health equity through action on the social determinants of health, 2008.
135. IBIS World. IBISWorld Industry Report: Global Oil & Gas Exploration & Production. Los Angeles, CA: IBISWorld, 2018.
136. IBIS World. IBISWorld Industry Report: Global Coal Mining. Los Angeles, CA: IBISWorld, 2017.
137. IRENA. Renewable Energy and Jobs: Annual Review 2018. Abu Dhabi, 2018.
138. Braungardt S, van den Bergh J, Dunlop T. Fossil fuel divestment and climate change: Reviewing contested arguments. *Energy Research & Social Science* 2019; **50**: 191-200.
139. 350.org. Divestment Commitments. 2019. https://gofossilfree.org/divestment/commitments/ (accessed 07/05 2019).
140. Machol B, Rizk S. Economic value of US fossil fuel electricity health impacts. *Environment international* 2013; **52**: 75-80.
141. Coady D, Parry I, Le N-P, Shang B. Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates: International Monetary Fund, 2019.

142. WBG, Ecofys. State and Trends of Carbon Pricing 2018. Washington DC, USA, 2018.
143. WBG. Carbon Pricing Dashboard. 2017. http://carbonpricingdashboard.worldbank.org (accessed 06.06.2017 2017).
144. Ryghaug M, Holtan Sørensen K, Næss R. Making sense of global warming: Norwegians appropriating knowledge of anthropogenic climate change. *Public Understanding of Science* 2011; **20**(6): 778-95.
145. Boykoff MT, Roberts JT. Media coverage of climate change: current trends, strengths, weaknesses. *Human development report* 2007; **2008**(3).
146. Happer C, Philo G. New approaches to understanding the role of the news media in the formation of public attitudes and behaviours on climate change. *European Journal of Communication* 2016; **31**(2): 136-51.
147. Nisbet MC. Communicating climate change: Why frames matter for public engagement. *Environment: Science and policy for sustainable development* 2009; **51**(2): 12-23.
148. Wang H, Sparks C, Huang Y. Measuring differences in the Chinese press: A study of People's Daily and Southern Metropolitan Daily. *Global Media and China* 2018; **3**(3): 125-40.
149. Chapman G, Fraser C, Gaber I, Kumar K. Environmentalism and the mass media: the North/South divide. 1st ed. New York: Routledge; 2003.
150. Nagarathinam S, Bhatta A. Coverage of climate change issues in Indian newspapers and policy implications. *Current Science* 2015; **108**(11): 1972-3.
151. Billett S. Dividing climate change: global warming in the Indian mass media. *Climatic change* 2010; **99**(1-2): 1-16.
152. Schäfer MS, Ivanova A, Schmidt A. What drives media attention for climate change? Explaining issue attention in Australian, German and Indian print media from 1996 to 2010. *International Communication Gazette* 2014; **76**(2): 152-76.
153. Shehata A, Hopmann DN. FRAMING CLIMATE CHANGE. *Journalism Studies* 2012; **13**(2): 175-92.
154. García-Gavilanes R, Tsvetkova M, Yasseri T. Dynamics and biases of online attention: the case of aircraft crashes. *Royal Society Open Science* 2016; **3**(10): 160460.
155. Giles J. Internet encyclopaedias go head to head. Nature Publishing Group; 2005.
156. Alexa. The top 500 sites on the Web. 2018. https://www.alexa.com/topsites.
157. Wikimedia Statistics. 2019.
158. Mesgari M, Okoli C, Mehdi M, Nielsen FÅ, Lanamäki A. "The sum of all human knowledge": A systematic review of scholarly research on the content of W ikipedia. *Journal of the Association for Information Science and Technology* 2015; **66**(2): 219-45.
159. Schroeder R, Taylor L. Big data and Wikipedia research: social science knowledge across disciplinary divides. *Information, Communication & Society* 2015; **18**(9): 1039-56.
160. WBG. Public attitudes toward climate change : findings from a multi-country poll. Background note to the world development report 2010. Washington, DC: World Bank Group, 2009.
161. Pew Research Center. Global concern about Climate Change. 2015.
162. Leiserowitz A, Maibech E, Rosenthal S, et al. Climate change in the American mind: December 2018. New Haven, CT: Yale University and George Mason University, 2018.
163. General Assembly of the United Nations. General Debate of the 73rd session: 25 September - 1st October 2018. 2018.
164. Smith CB. Politics and process at the United Nations: the global dance: Lynne Rienner Boulder, CO; 2006.
165. World Economic Forum. Two Degrees of Transformation. Businesses are coming together to lead on climate change. Will you join them?, 2019.
166. Wright C, Nyberg D. Climate change, capitalism, and corporations: Cambridge University Press; 2015.

167. Jeswani HK, Wehrmeyer W, Mulugetta Y. How warm is the corporate response to climate change? Evidence from Pakistan and the UK. *Business Strategy and the Environment* 2008; **17**(1): 46-60.
168. United Nations Global Compact. https://www.unglobalcompact.org/ (accessed 13.04.19.
169. Schmidt A, Ivanova A, Schäfer MS. Media attention for climate change around the world: A comparative analysis of newspaper coverage in 27 countries. *Global Environmental Change* 2013; **23**(5): 1233-48.
170. Zhengrong Hu. The Post-WTO Restructuring of the Chinese Media Industries and the Consequences of Capitalisation. *Javnost - The Public* 2003; **10**(4): 19-36.
171. Hassid J. Controlling the Chinese Media: An Uncertain Business. *Asian Survey* 2008; **48**(3): 414-30.
172. People's Daily (Renmin Ribao). http://data.people.com.cn/rmrb/20190116/1?code=2.
173. Brooks J, McCluskey S, Turley E, King N. The Utility of Template Analysis in Qualitative Psychology Research. *Qualitative Research in Psychology* 2015; **12**(2): 202-22.
174. Liaw S-S, Huang H-M. An investigation of user attitudes toward search engines as an information retrieval tool. *Computers in Human Behavior* 2003; **19**(6): 751-65.
175. Casebourne I, Davies C, Fernandes M, Norman N. Assessing the accuracy and quality of Wikipedia entries compared to popular online encyclopaedias: A comparative preliminary study across disciplines in English, Spanish and Arabic. Brighton, UK: Epic, 2012.
176. Yoshida M, Arase Y, Tsunoda T, Yamamoto M. Wikipedia page view reflects web search trend. Proceedings of the ACM Web Science Conference; 2015: ACM; 2015. p. 65.
177. Göbel S, Munzert S. Political Advertising on the Wikipedia Marketplace of Information. *Social Science Computer Review* 2017; **36**(2): 157-75.
178. Wikimedia. Research: Wikipedia clickstream. https://meta.wikimedia.org/wiki/Research:Wikipedia_clickstream.
179. Baturo A, Dasandi N, Mikhaylov SJ. Understanding state preferences with text as data: Introducing the UN General Debate corpus. *Research & Politics* 2017; **4**(2): 2053168017712821.
180. Jankin Mikhaylov S, Baturo A, Dasandi N. United Nations General Debate Corpus. In: Jankin Mikhaylov S, editor. V5 ed: Harvard Dataverse; 2017.
181. United Nations Global Compact. Corporate sustainability in the world economy. New York: UN Global Compact, 2008.
182. Nason RW. Structuring the Global Marketplace: The Impact of the United Nations Global Compact. *Journal of Macromarketing* 2008; **28**(4): 418-25.
183. Rasche A, Waddock S, McIntosh M. The United Nations Global Compact: Retrospect and Prospect. *Business & Society* 2012; **52**(1): 6-30.
184. Voegtlin C, Pless NM. Global Governance: CSR and the Role of the UN Global Compact. *Journal of Business Ethics* 2014; **122**(2): 179-91.
185. Akenji L, Lettenmeier M, Koide R, Toiviq V, Amellina A. 1.5-Degree Lifestyles: Targets and options for reducing lifestyle carbon footprints: Institute for Global Environmental Strategies, Aalto Univerisity, D-mat Ltd., 2019.
186. Newell P. Climate for change: Non-state actors and the global politics of the greenhouse: Cambridge University Press; 2006.