The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises

Article

Watts, N., Amann, M., Arnell, N. ORCID: https://orcid.org/0000-0003-2691-4436, Ayeb-Karlsson, S., Beagley, J., Belesova, K., Boykoff, M., Byass, P., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Coleman, S., Dalin, C., Daly, M., Dasandi, N., Dasgupta, S., Davies, M., Di Napoli, C., Dominguez-Salas, P., Drummond, P., Dubrow, R., Ebi, K. L., Eckelman, M., Ekins, P., Escobar, L. E., Georgeson, L., Golder, S., Grace, D., Graham, H., Haggar, P., Hamilton, I., Hartinger, S., Hess, J., Hsu, S.-C., Hughes, N., Jankin Mikhaylov, S., Jimenez, M. P., Kelman, I., Kennard, H., Kiesewetter, G., Kinney, P. L., Kjellstrom, T., Kniveton, D., Lampard, P., Lemke, B., Liu, Y., Liu, Z., Lott, M., Lowe, R., Martinez-Urtaza, J., Maslin, M., McAllister, L., McGushin, A., McMichael, C., Milner, J., Moradi-Lakeh, M., Morrissey, K., Munzert, S., Murray, K. A., Neville, T., Nilsson, M., Sewe, M. O., Oreszczyn, T., Otto, M., Owfi, F., Pearman, O., Pencheon, D., Quinn, R., Rabbaniha, M., Robinson, E. ORCID: https://orcid.org/0000-0002-4950-0183, Rocklöv, J., Romanello, M., Semenza, J. C., Sherman, J., Shi, L., Springmann, M., Tabatabaei, M., Taylor, J., Triñanes, J., Shumake-Guillemot, J., Vu, B., Wilkinson, P., Winning, M., Gong, P., Montgomery, H. and Costello, A. (2021) The 2020

The 2020 Report of The Lancet Countdown on Health and Climate Change

Nick Watts, Markus Amann, Nigel Arnell, Sonja Ayeb-Karlsson, Jessica Beagley, Kristine Belesova, Maxwell Boykoff, Peter Byass, Wenjia Cai, Diarmid Campbell-Lendrum, Stuart Capstick, Jonathan Chambers, Samantha Coleman, Carole Dalin, Meaghan Daly, Niheer Dasandi, Shouro Dasgupta, Michael Davies, Claudia Di Napoli, Paula Dominguez-Salas, Paul Drummond, Robert Dubrow, Kristie L. Ebi, Matthew Eckelman, Paul Ekins, Luis E. Escobar, Lucien Georgeson, Su Golder, Delia Grace, Hilary Graham, Paul Haggar, Ian Hamilton, Stella Hartinger, Jeremy Hess, Shih-Che Hsu, Nick Hughes, Slava Jankin Mikhaylov, Marcia P. Jimenez, Ilan Kelman, Harry Kennard, Gregor Kiesewetter, Patrick Kinney, Tord Kjellstrom, Dominic Kniveton, Pete Lampard, Bruno Lemke, Yang Liu, Zhao Liu, Melissa Lott, Rachel Lowe, Jaime Martinez-Urtaza, Mark Maslin, Lucy McAllister, Alice McGushin, Celia McMichael, James Milner, Maziar Moradi-Lakeh, Karyn Morrissey, Simon Munzert, Kris A. Murray, Tara Neville, Maria Nilsson, Maquins Odhiambo Sewe, Tadj Oreszczyn, Matthias Otto, Fereidoon Owfi, Olivia Pearman, David Pencheon, Ruth Quinn, Mahnaz Rabbaniha, Elizabeth Robinson, Joacim Rocklöv, Marina Romanello, Jan C. Semenza, Jodi Sherman, Liuhua Shi, Marco Springmann, Meisam Tabatabaei, Jonathon Taylor, Joaquin Trinanes, Joy Shumake-Guillemot, Bryan Vu, Paul Wilkinson, Matthew Winning, Peng Gong*, Hugh Montgomery*, Anthony Costello*

* Denotes Co-Chair

Word Count: 18,002

Table of Contents

113

114

List of Figures, Tables and Panels

List of Figures

159

List of Tables

164

List of Panels

List of Abbreviations

171   List of Abbreviations
172   A&RCC – Adaptation & Resilience to Climate Change
173   CDP – Carbon Disclosure Project
174   CFU – Climate Funds Update
175   CO_2 – Carbon Dioxide
176   CO_2e – Carbon Dioxide Equivalent
177   COP – Conference of the Parties
178   ECMWF – European Centre for Medium-Range Weather Forecasts
179   EE MRIO – Environmentally-Extended Multi-Region Input-Output
180   EJ – Exajoule
181   EM-DAT – Emergency Events Database
182   ERA – European Research Area
183   ETS – Emissions Trading System
184   EU – European Union
185   EU28 – 28 European Union Member States
186   FAO – Food and Agriculture Organization of the United Nations
187   GBD – Global Burden of Disease
188   GDP – Gross Domestic Product
189   GHG – Greenhouse Gas
190   GNI – Gross National Income
191    $GtCO_2$ – Gigatons of Carbon Dioxide
192   GW – Gigawatt
193   GWP – Gross World Product
194   HIC – High Income Countries
195   IEA – International Energy Agency
196   IHR – International Health Regulations
197   IPC – Infection Prevention and Control
198   IPCC - Intergovernmental Panel on Climate Change
199   IRENA - International Renewable Energy Agency
200   LMICs – Low- and Middle-Income Countries
201   LPG – Liquefied Petroleum Gas
202   Mt – Metric Megaton
203    $MtCO_2e$ – Metric Megatons of Carbon Dioxide Equivalent
204   MODIS – Moderate Resolution Imaging Spectroradiometer
205   MRIO – Multi-Region Input-Output
206   NAP – National Adaptation Plan
207   NASA – National Aeronautics and Space Administration
208   NDCs - Nationally Determined Contributions
209   NHS – National Health Service
210   NO_x – Nitrogen Oxide
211   NDVI – Normalised Difference Vegetation Index
212   OECD – Organization for Economic Cooperation and Development
213    $PM_{2.5}$ – Fine Particulate Matter
214   PV – Photovoltaic

215   SDG – Sustainable Development Goal
216   SIDS – Small Island Developing State
217   SDU – Sustainable Development Unit
218   SSS – Sea Surface Salinity
219   SST – Sea Surface Temperature
220   tCO_2 – Tons of Carbon Dioxide
221   tCO2/TJ – Total Carbon Dioxide per Terajoule
222   TJ – Terajoule
223   TPES – Total Primary Energy Supply
224   TWh – Terawatt Hours
225   UN – United Nations
226   UNFCCC – United Nations Framework Convention on Climate Change
227   UNGA – United Nations General Assembly
228   UNGD – United Nations General Debate
229   VC – Vectorial Capacity
230   WHO – World Health Organization
231   WMO – World Meteorological Organization

Executive Summary

The Lancet Countdown is an international collaboration, established to provide an independent, global monitoring system dedicated to tracking the emerging health profile of the changing climate.

The 2020 report presents 43 indicators across five sections: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement. This report represents the findings and consensus of the 35 leading academic institutions and UN agencies that make up the Lancet Countdown, and draws on the expertise of climate scientists, geographers, and engineers; of energy, food, and transport experts; and of economists, social and political scientists, data scientists, public health professionals, and doctors.

The Emerging Health Profile of the Changing Climate

Five years ago, countries committed to limit warming to "well below 2°C", as part of the landmark Paris Agreement. Five years on, global CO_2 emissions continue to rise steadily, with no convincing or sustained abatement, and a resultant 1.2°C of global average temperature rise. Indeed, the five hottest years on record have occurred since 2015.

The changing climate has already produced significant shifts in the underlying social and environmental determinants of health, at the global level. Indicators in all of the domains of *impacts, exposures and vulnerabilities* that the collaboration tracks are worsening. Here, concerning, and often accelerating trends are seen for each of the human symptoms of climate change monitored, with the 2020 indicators presenting the most worrying outlook reported since the Lancet Countdown was first established.

These effects are often unequal, disproportionately impacting populations who have contributed the least to the problem. This reveals a deeper question of justice, whereby climate change interacts with existing social and economic inequalities and exacerbates long-standing trends within and between countries. An examination of the causes of climate change reveals similar issues, and many carbon-intensive practices and policies lead to poor air quality, poor food quality, and poor housing quality, which disproportionately harms the health of disadvantaged populations.

Vulnerable populations experienced an additional 475 million heatwave exposure events globally, which is in turn reflected in excess morbidity and mortality, with a 53.7% increase in heat-related deaths over the last 20 years, up to a total of 296,000 deaths in 2018 (Indicators 1.1.2 and 1.1.3). The high cost in terms of human lives and suffering is associated

267 with impacts on economic output, with more than 80 billion hours of potential labour
268 capacity lost in 2019 (Indicators 1.1.3 and 1.1.4). China, India, and Indonesia are among the
269 worst affected countries, experiencing potential labour capacity losses equivalent to 4-6% of
270 their annual gross domestic product (Indicator 4.1.3). In Europe, the monetised cost of heat-
271 related mortality was equivalent to 1.2% of its gross national income, or the average income
272 of 11 million European citizens (Indicator 4.1.2).

273 Turning to extremes of weather, advancements in climate science increasingly allow for
274 greater accuracy and certainty in attribution, with studies from 2015 to present day
275 demonstrating the fingerprints of climate change in 76 floods, droughts, storms, and
276 temperature anomalies (Indicator 1.2.3). Further, 114 countries experienced an increased
277 number of days where people were exposed to very high or extremely high wildfire risk up
278 to present day (Indicators 1.2.1). Correspondingly, 67% of global cities surveyed expect
279 climate change to seriously compromise their public health assets and infrastructure
280 (Indicator 2.1.3).

281 The changing climate has down-stream effects, impacting broader environmental systems,
282 which in turn harms human health. Global food security is threatened by rising
283 temperatures and increases in the frequency of extreme events, with a 1.8-5.6% decline in
284 global yield potential for major crops observed from 1981 to present day (Indicator 1.4.1).
285 The climate suitability for infectious disease transmission has been growing rapidly since the
286 1950s, with a 15% increase for dengue from *Aedes albopictus* globally, and similar regional
287 increases for malaria and *Vibrio* (Indicator 1.3.1). Projecting forward based on current
288 populations, between 145 million and 565 million people face potential inundation from sea
289 level rise (Indicator 1.5).

290 Despite these clear and escalating signs, the global response to climate change has been
291 muted and national efforts continue to fall far short of the commitments made in the Paris
292 Agreement. The carbon intensity of the global energy system has remained almost flat for
293 30 years, with global coal use increasing by 74% over this time (Indicators 3.1.1 and 3.1.2).
294 The reduction in global coal use that had been observed since 2013 has now reversed for
295 the last two consecutive years as coal use rose by 1.7% from 2016 to 2018. The health
296 burden here is substantial – over one million deaths occur every year as a result of air
297 pollution from coal-fired power, and some 390,000 of these as a result of particulate
298 pollution in 2018 (Indicator 3.3). The response in the food and agricultural sector has been
299 similarly concerning. Emissions from livestock grew by 16% from 2000 to 2017, 82% of
300 which came from cattle (Indicator 3.5.1). This mirrors increasingly unhealthy diets seen
301 around the world, with excess red meat consumption contributing to some 990,000 deaths
302 in 2017 (Indicator 3.5.2). Five years on from when countries reached agreement in Paris, a
303 concerning number of indicators are showing an early, but sustained reversal of previously
304 positive trends identified in past reports (Indicators 1.3.2, 3.1.2 and 4.2.3).

305

307   Despite limited economy-wide improvement, relative gains have been made in a number of
308   key sectors, with a 21% annual increase in renewable energy capacity from 2010 to 2017,
309   and low-carbon electricity now responsible for 28% of capacity in China (Indicator 3.1.3).
310   However, the indicators presented in the 2020 report of the Lancet Countdown suggest that
311   some of the most significant progress can be seen in the growing momentum of the health
312   profession's engagement with climate change, globally. Doctors, nurses, and the broader
313   profession have a central role to play in health system adaptation and mitigation, in seeking
314   to understand and maximise the health benefits of any intervention, and in communicating
315   the need for an accelerated response.

316   In the case of national health system adaptation, this change is underway. Impressively,
317   health services in 86 countries are now connected with their equivalent meteorological
318   services to assist in health adaptation planning (Indicator 2.2). At least 51 countries have
319   developed national health adaptation plans, which is coupled with a sustained 5.3% rise in
320   health adaptation spending globally, reaching US$18.4 billion in 2019 (Indicators 2.1.1 and
321   2.4).

322   The healthcare sector – responsible for 4.6% of global greenhouse gas emissions – is taking
323   early but significant steps to reduce its own emissions (Indicator 3.6). In the United
324   Kingdom, the National Health Service has declared an ambition to deliver a 'net-zero health
325   service' as soon as possible, building on a decade of impressive progress that achieved a
326   57% reduction in 'delivery of care' emissions from 1990, and a 22% reduction when
327   considering its supply chain and broader responsibilities. Elsewhere, the Western Australian
328   Department of Health used its 2016 *Public Health Act* to conduct Australia's first Climate
329   and Health Inquiry, and the German Ministry of Health has restructured to include a new
330   department on Climate, Sustainability and Health Protection. This progress is becoming
331   more evenly distributed around the world, with 73% of countries making explicit reference
332   to health and wellbeing in their national commitments under the Paris Agreement, and
333   100% of countries in South East Asia and the East Mediterranean doing so (Indicator 5.4).
334   Similarly, Least Developed Countries and Small Island Developing States are providing
335   increasing global leadership within the UN General Debate on the connections between
336   health and climate change (Indicator 5.4).

337   Individual health professionals and their associations are responding as well, with health
338   institutions committing to divest over US$42 billion worth of assets from fossil fuels
339   (Indicator 4.2.4). In academia, there has been a nine-fold increase in publication of original
340   scientific articles on health and climate change from 2007 to 2019 (Indicator 5.3).

341   These shifts are being translated into the broader public discourse. From 2018 to 2019, the
342   coverage of health and climate change in the media has risen by 96% around the world,
343   outpacing the increased attention in climate change overall, and reaching the highest

344   observed point to-date (Indicator 5.1). Just as it did with advancements in sanitation and
345   hygiene and with tobacco control, growing and sustained engagement from the health
346   profession over the last five years is now beginning to fill a crucial gap in the global response
347   to climate change.

348
349   The Next Five Years: A Joint Response to Two Public Health Crises

350   December 12, 2020, marks the anniversary of the 2015 Paris Agreement, with countries set
351   to update their national commitments and review them every five years. These next five
352   years will be pivotal. In order to reach the 1.5°C target and maintain temperature rise "well
353   below 2°C", the 56 gigatons of CO_2e currently emitted annually will need to drop to 25 Gt
354   CO_2e within only 10 years (by 2030). In effect, this requires a 7.6% reduction every year,
355   representing a five-fold increase in current levels of national government ambition. Without
356   further intervention over the next five years, the reductions required increase to 15.4%
357   every year, moving the 1.5°C target out of reach.

358   The need for accelerated efforts to tackle climate change over the next five years will be
359   contextualised by the impacts of, and the global response to, COVID-19. With the loss of life
360   from the pandemic and from climate change measured in the hundreds of thousands, the
361   potential economic costs measured in the trillions, and the broader consequences expected
362   to continue for years to come, the measures taken to address both of these public health
363   crises must be carefully examined, and closely linked. In May 2020, over 40 million health
364   professionals wrote to global leaders, emphasising this point. These health professionals are
365   well placed to act as a bridge between the two issues, and considering the clinical approach
366   to managing a patient with COVID-19 may be useful in understanding the ways in which
367   these challenges should be jointly addressed.

368   In an acute setting, a high priority is placed on rapidly diagnosing and comprehensively
369   assessing the situation. Likewise, further work is required to understand the problem,
370   including: which populations are vulnerable to both the pandemic and to climate change;
371   how global and national economies have reacted and adapted, and the health and
372   environmental consequences of this; and which aspects of these shifts should be retained to
373   support longer term sustainable development. Secondly, appropriate resuscitation and
374   treatment options are reviewed and administered, with careful consideration of any
375   potential side-effects, the goals of care, and the life-long health of the patient. Economic
376   recovery packages that prioritise out-dated fossil fuel-intensive forms of energy and
377   transport will have unintended side-effects, unnecessarily adding to the seven million
378   people that die every year from air pollution. Instead, investments in health imperatives
379   such as renewable energy and clean air, active travel infrastructure and physical activity,
380   and resilient and climate-smart healthcare, will ultimately be more effective.

381 Thirdly, attention turns to secondary prevention and long-term recovery, seeking to
382 minimise the permanent effects of the disease and prevent its recurrence. Many of the
383 steps taken to prepare for unexpected shocks such as a pandemic are similar to those
384 required to adapt to the extremes of weather and new threats expected from climate
385 change. This includes the need to identify vulnerable populations, assess the capacity of
386 public health systems, develop and invest in preparedness measures, and emphasise
387 community resilience and equity. Indeed, without considering the current and future
388 impacts of climate change, efforts to prepare for future pandemics will likely be
389 undermined.

390 At every step and in both cases, acting with a level of urgency proportionate to the scale of
391 the threat, adhering to the best-available science, and practising clear and consistent
392 communications is paramount. The consequences of the pandemic will contextualise
393 governments' economic, social, and environmental policies over the next five years, a
394 period that is crucial in determining whether temperatures will remain "well below 2°C".
395 Unless the global response to COVID-19 is aligned with the response to climate change, the
396 world will fail to meet the target laid out in the Paris Agreement, damaging public health
397 both in the short-term and in the long-term.
398

Introduction

The world has already warmed by over 1.2°C compared to pre-industrial levels, resulting in profound, immediate, and rapidly worsening health impacts, and moving dangerously close to the agreed limit of maintaining temperatures "well below 2°C".[1-4] These are seen on every continent, with the ongoing spread of dengue fever across South America; the cardiovascular and respiratory effects of record heatwaves and wildfires in Australia, California, and Western Europe; and the undernutrition and mental health impacts of flood and drought in China, Bangladesh, Ethiopia, and South Africa.[5-8] In the long-term, climate change threatens the very foundations of human health and wellbeing, with the Global Risks Report registering it as one of the five most damaging or likely global risks, every year, for the last decade.[9]

It is clear that human and environmental systems are inextricably linked, and that any response to climate change must harness, rather than damage these connections.[10] Indeed, a response commensurate to the size of the challenge – which prioritises health system strengthening, invests in local communities, and ensures clean air, safe drinking water, and nourishing food – will provide the foundations for future generations to not only survive, but to thrive.[11] Recent evidence suggests that increasing ambition from current climate policies to those which would limit warming to 1.5°C by 2100 would generate a net global benefit of US$264 to $610 trillion.[12] The economic case is further strengthened when the benefits of a healthier workforce and of reduced healthcare costs are considered.[13-15]

The present-day impacts of climate change will continue to worsen without meaningful intervention. These tangible, if less-visible, public health impacts have so far resulted in a delayed and inadequate policy response. By contrast and on a significantly shorter time-scale, COVID-19, the disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has rapidly developed in to a global public health emergency. Since it was first detected in December 2019, the loss of life and livelihoods has occurred with staggering speed. However, as for climate change, much of the impact is expected to unfold over the coming months and years, and is likely to disproportionately affect vulnerable populations as both the direct impacts of the virus, and the indirect effects of the response to the virus are felt throughout the world. Panel 1 takes stock of this, and draws a number of lessons and parallels between climate change and COVID-19, focusing on the response to, and recovery from the two health crises.

The Lancet Countdown exists as an independent, multi-disciplinary collaboration dedicated to tracking the links between public health and climate change. It brings together 35 academic institutions and UN agencies from every continent, and structures its work across five key 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 2). The 43 indicators and conclusions presented in this report are the cumulative result of the last eight years of collaboration,

438 and represent the consensus of its 86 climate scientists; geographers; engineers; energy,
439 food, and transport experts; economists; social and political scientists; public health
440 professionals; and doctors.

441 Where the pandemic has direct implications for an indicator being reported (and where
442 accurate data exists to allow meaningful comment), these will be discussed in-text. Beyond
443 this, the 2020 report of the Lancet Countdown will maintain its focus on the connections
444 between public health and climate change, and the collaboration has worked hard to ensure
445 the continued high quality of its indicators, with only minor amendments and omissions
446 resulting from the ongoing disruptions.

447

448

449 ## Expanding and strengthening a global monitoring system for health and climate
450 change

451 The Lancet Countdown's work draws on decades of underlying scientific progress and data,
452 with the initial indicator set selected as part of an open, global consultation that sought to
453 identify which of the connections between health and climate change could be meaningfully
454 tracked.[16] Proposals for indicators were considered and adopted based on a number of
455 criteria, including: the existence of a credible underlying link between climate change and
456 health that was well described in the scientific literature; the availability of reliable and
457 regularly updated data across expanded geographical and temporal scales; the presence of
458 acceptable methods for monitoring; and the policy relevance and availability of actionable
459 interventions.

460 An iterative and adaptive approach has seen substantive improvements to the vast majority
461 of this initial set of indicators, as well as the development of a number of additional
462 indicators. Given this approach, and the rapidly evolving nature of the scientific and data
463 landscape, each annual update replaces the analysis from previous years. The Appendix
464 describes the methods, data sources, and improvements for each indicator in full, and is an
465 essential companion to the main report.

466 The 2020 report of the Lancet Countdown reflects an enormous amount of work refining
467 and improving these indicators, conducted over the last 12 months, including an annual
468 update of the data.

469 A number of key developments have occurred, including:
470 - The strengthening and standardisation of methods and datasets for indicators that
471   capture heat and heatwave; flood and drought; wildfires; the climate suitability of
472   infectious disease; food security and undernutrition; health adaptation spending;

473   food and agriculture; low-carbon healthcare; the economics of air pollution; and
474   engagement in health and climate change from the media, the scientific community,
475   and individuals.
476   - Improved or expanded geographical or temporal coverage of indicators that track:
477   heat and heatwave; labour capacity loss; flood and drought; the climate suitability of
478   infectious disease; climate change risk assessments in cities; use of healthy
479   household energy; and household air pollution.
480   - The development of new indicators, exploring: heat-related mortality; migration and
481   population displacement; access to urban green space; the health benefits of low-
482   carbon diets; the economics of extremes of heat and of labour capacity loss; net
483   carbon pricing; and the extent to which the UNFCCC's Nationally Determined
484   Contributions (NDCs) engage with public health.

485   This continued progress has been supported by the Lancet Countdown's Scientific Advisory
486   Group and the creation of a new, independent Quality Improvement Process, which
487   provides independent expert input on the indicators prior to the formal peer review
488   process, adding rigour and transparency to the collaboration's research. In every case, the
489   most up-to-date data available is presented, with the precise nature and timing of these
490   updates varying depending on the data source. This has occurred despite the impact of
491   COVID-19, which has only impacted on the production of a small sub-set of indicators for
492   this report.

493   The Lancet Countdown has also taken a number of steps to ensure that it has the expertise,
494   data, and representation required to build a global monitoring system. Partnering with
495   Tsinghua University and Universidad Peruana Cayetano Heredia, the collaboration launched
496   two new regional offices for South America (in Lima), and for Asia (in Beijing), as well as the
497   development of a new partnership to build capacity in West Africa. This expansion is
498   coupled with ongoing work to develop national and regional Lancet Countdown reports: in
499   Australia, in partnership with the Medical Journal of Australia; in the European Union, in
500   partnership with the European Environment Agency; in China; and in the United States. At
501   the same time, a new data visualisation platform has been launched, allowing health
502   professionals and policymakers to investigate the indicators in this report.
503   (lancetcountdown.org/data-platform).

504   Future work will be concentrated on supporting these regional and national efforts, on
505   building communications and engagement capacity, on developing new indicators (with a
506   particular interest in developing indicators related to mental health and to gender), and on
507   further improving existing indicators. To this end, the continued growth of the Lancet
508   Countdown depends on the dedication of each of its composite experts and partners,
509   continued support from the Wellcome Trust, and ongoing input and offers of support from
510   new academic institutions willing to build on the analysis published in this report.

Panel 1: Health, Climate Change, and COVID-19

As of the 31st of July 2020, the COVID-19 pandemic has spread to 188 countries, with over 17,320,000 cases confirmed, and over 673,800 deaths recorded.[17] The scale and extent of the suffering, and the social and economic toll will continue to evolve over the coming months, with its effects likely felt for years to come.[18] The relationship between the spread of existing and novel infectious diseases, and worsening environmental degradation, deforestation and land-use change, and animal ill-health have long been analysed and described. Equally, both climate change and COVID-19 act to exacerbate existing inequalities within and between countries.[19-21]

As a direct consequence of the pandemic, an 8% reduction in greenhouse gas (GHG) emissions is projected for 2020, which would be the most rapid one-year decline on record.[22] Crucially, these reductions do not represent the decarbonisation of the economy required to respond to climate change, but simply the freezing of economic activity. Equally, the 1.4% reduction which followed the 2008 global financial crisis was followed by a rebound, with emissions rising by 5.9% in 2010. Likewise, it is unlikely that the current fall in emissions will be sustained, with any reductions potentially outweighed by a shift away from otherwise ambitious climate change mitigation policies. However, this need not be the case.[22] Over the next five years, considerable financial, social, and political investment will be required to continue to protect populations and health systems from the worst effects of COVID-19, to safely restart and restructure national and local economies, and to rebuild in a way that prepares for future economic and public health shocks. Harnessing the health co-benefits of climate change mitigation and adaptation will ensure the economic, social, and environmental sustainability of these efforts, while providing a framework that encourages investment in local communities and health systems, as well as synergies with existing health challenges.[23]

Multiple, 'ready-to-go' examples of such alignment are available, such as commonalities seen in future pandemic preparedness and effective health adaptation climate-related impacts.[24] In the latter, decision-making under deep uncertainty necessitates the use of the principles of flexibility, robustness, economic low-regrets, and equity to guide decisions.[25,26] At the broader level, poverty reduction and health system strengthening will both stimulate and restructure economies, and are among the most effective measures to enhance community resilience to climate change.[27]

Turning to mitigation, at a time when more and more countries are closing down the last of their coal-fired power plants and oil prices are reaching record lows, the fossil fuel sector is expected to be worse affected than renewable energy.[22] If done with care and adequate protection for workers, government stimulus packages are well placed to prioritise investment in healthier, cleaner forms of energy. Finally, the response to COVID-19 has encouraged a re-thinking of the scale and pace of ambition. Health systems have restructured services practically overnight to conduct millions of general practitioner and specialist appointments online, and a sudden shift to online work and virtual conferencing has shifted investment towards communications infrastructure instead of aviation and road transport.[28,29] A number of these changes should be reviewed, improved on, and retained over the coming years.

It is clear that a growing body of literature and rhetoric will be inadequate, and this work must take advantage of the moment, to combine public health and climate change policies in a way that addresses inequality directly. The UNFCCC's COP26 – postponed to 2021, in Glasgow – presents an immediate opportunity for this, to ensure the long-term effectiveness of the response to COVID-19 by linking the recovery to countries' revised commitments (Nationally Determined Contributions) under the Paris Agreement. It is essential that the solution to one economic and public health crisis does not exacerbate another, and in the long-term, the response to COVID-19 and climate change will be most successful when they are closely aligned.

511

Working Group	Indicator	
Climate Change Impacts, Exposure, and Vulnerability	1.1: Health and Heat	1.1.1: Vulnerability to Extremes of Heat
		1.1.2: Exposure of Vulnerable Populations to Heatwaves
		1.1.3: Heat-Related Mortality
		1.1.4: Change in Labour Capacity
	1.2: Health and Extreme Weather Events	1.2.1: Wildfires
		1.2.2: Flood and Drought
		1.2.3: Lethality of Weather-Related Disasters
	1.3: Climate-Sensitive Infectious Diseases	1.3.1: Climate Suitability for Infectious Disease Transmission
		1.3.2: Vulnerability to Mosquito-Borne Diseases
	1.4: Food Security and Undernutrition	1.4.1: Terrestrial Food Security and Undernutrition
		1.4.2: Marine Food Security and Undernutrition
	1.5: Migration, Displacement and Sea-Level Rise	
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
		2.3.3: Urban Green Space
	2.4: Spending on Adaptation for Health and Health-Related Activities	
Mitigation Actions and Health Co-Benefits	3.1: Energy System and Health	3.1.1: Carbon Intensity of the Energy System
		3.1.2: Coal Phase-Out
		3.1.3: Zero-Carbon Emission Electricity
	3.2: Clean Household Energy	
	3.3: Premature Mortality from Ambient Air Pollution by Sector	
	3.4: Sustainable and Healthy Transport	
	3.5: Food, Agriculture, and Health	3.5.1: Emissions from Agricultural Production and Consumption
		3.5.2: Diet and Health Co-Benefits
	3.6: Mitigation in the Healthcare Sector	
Economics and Finance	4.1: The Health and Economic Costs of Climate Change and Benefits from Mitigation	4.1.1: Economic Losses due to Climate-Related Extreme Events
		4.1.2: Costs of Heat-Related Mortality
		4.1.3: Loss of Earnings from Heat-Related Labour Capacity Loss
		4.1.4: Costs of the Health Impacts of Air Pollution
	4.2: The Economics of the Transition to Zero-Carbon Economies	4.2.1: Investment in New Coal Capacity
		4.2.2: Investments in Zero-Carbon Energy and Energy Efficiency
		4.2.3: Employment in Low-Carbon and High-Carbon Industries
		4.2.4: Funds Divested from Fossil Fuels
		4.2.5: Net Value of Fossil Fuel Subsidies and Carbon Prices
Public and Political Engagement	5.1: Media Coverage of Health and Climate Change	
	5.2: Individual Engagement in Health and Climate Change	
	5.3: Coverage of Health and Climate Change in Scientific Journals	
	5.4: Government Engagement in Health and Climate Change	
	5.5: Corporate Sector Engagement in Health and Climate Change	

512   *Panel 2: The Indicators of the 2020 report of the Lancet Countdown*

Section 1: Climate Change Impacts, Exposures, and Vulnerability

A changing climate threatens to undermine the last 50 years of gains in public health, disrupting the wellbeing of communities, and the foundations on which health systems are built.[30] Its effects are pervasive, and impact the food, air, water, and shelter that society depends on, extending across every region of the world and every income group. These effects act to exacerbate existing inequities, with vulnerable populations within and between countries affected more frequently, and with more lasting impact.[3]

Section 1 of the 2020 report tracks the links between climate change and human health along several exposure pathways, from the climate signal through to the resulting health outcome. This section begins by examining a number of dimensions of the effects of heat and heatwave, ranging from exposure and vulnerability, through to the effects on labour capacity, and on mortality (Indicators 1.1.1-1.1.4). The indicator on heat mortality has been developed for 2020, and while ongoing work will strengthen these findings in subsequent years, it complements existing indicators on exposure and vulnerability, and represents an important step forward.

The second cluster of indicators navigate the effects of extreme weather events, tracking wildfire risk and exposure, flood and drought, and the lethality of extreme weather events (Indicators 1.2.1-1.2.3). The wildfire indicator now tracks wildfire risk as well as exposure, the classification of drought has been updated to better align with climate change trends, and an overview of the attribution of climate change to the health impacts of certain extreme weather events is presented for the first time presented. The climate suitability and associated population-vulnerability of several infectious diseases are monitored, and so too are the evolving impacts of climate change on terrestrial and marine food security (Indicators 1.3.1-1.4.2), with the consideration of regional variation providing more robust estimates of the effects of temperature rise on crop yield potential. Another new indicator closes this section, tracking population exposure to sea level rise in the context of migration and displacement, alongside the resulting health impacts and the policy responses (Indicator 1.5).

1.1 Health and Heat

Exposure to high temperature and heatwave results in in a range of negative health impacts, from morbidity and mortality due to heat stress and heat stroke, to exacerbations of cardiovascular and respiratory disease.[31,32] The worst affected are the elderly, those with disability or pre-existing medical conditions, those working outdoors or in non-cooled environments and those living in regions already at the limits for human habitation.[33] The

549 following indicators track the vulnerability, exposure, and impacts of heat and heatwave in
550 every region of the world.

551

552 ## Indicator 1.1.1: Vulnerability to Extremes of Heat

553 *Headline finding: Vulnerability to extremes of heat continue to rise in every region of the*
554 *world, led by populations in Europe, and with those in the Western Pacific, South East Asia*
555 *and Africa all seeing an increase of more than 10% since 1990.*

556 This indicator re-examines the index results presented in the 2019 report, and introduces a
557 more comprehensive index of heat vulnerability, which combines heatwave exposure data
558 with data on the population susceptibility and the health system's ability to cope.[30]

559 As a result of aging populations, high prevalence of chronic disease and rising levels of
560 urbanisation, since 1990, European and the Eastern Mediterranean populations have been
561 the most vulnerable to extremes of heat, with vulnerabilities of 40.6% and 38.7%
562 respectively in 2017. However, no region of the world is immune, with vulnerability
563 worsening everywhere, and has risen since 1990 in Africa (28.4% to 31.3%), South-East Asia
564 (28.3% to 31.3%) and the Western Pacific (33.2% to 36.6%). By taking into account health
565 system strengthening and heat wave exposure across these regions, this vulnerability
566 indicator can be more usefully built in to one which captures population risk. This has been
567 done for the 2020 report (see Appendix), demonstrating trends similar to those seen above,
568 with risk rising in every region. This index will be further developed over the course of 2020,
569 and presented in-full alongside a broader suite of risk indicators, in future reports.

570

571 ## Indicator 1.1.2: Exposure of Vulnerable Populations to Heatwaves

572 *Headline finding: A record 475 million additional heatwave exposures affecting vulnerable*
573 *populations were observed in 2019, representing some 2.9 billion additional days of*
574 *heatwave experienced.*

575 Figure 1 presents the change in days of heatwave exposure since 1980, relative to a historic
576 1986-2005 baseline. It highlights a dramatic rise since 2010, driven by the combination of
577 increasing heatwave occurrences and aging populations. In 2019 there were 475 million
578 additional exposure events. Expressed as the number of days a heatwave was experienced,
579 this breaks the previous 2016 record by an additional 160 million person-days.

580 Indicator 1.1.2 tracks heatwave exposure of vulnerable populations, now updated to make
581 use of the latest climate data and a hybrid population dataset.[34-36] This indicator has

582 undergone several additional improvements (detailed in full, in the Appendix) in order to
583 best capture heatwave exposure in every region of the world, including an improved
584 definition of heatwave; the quantification of exposure-days to capture changing frequency
585 and duration; and improved estimates of demographic breakdown.

586
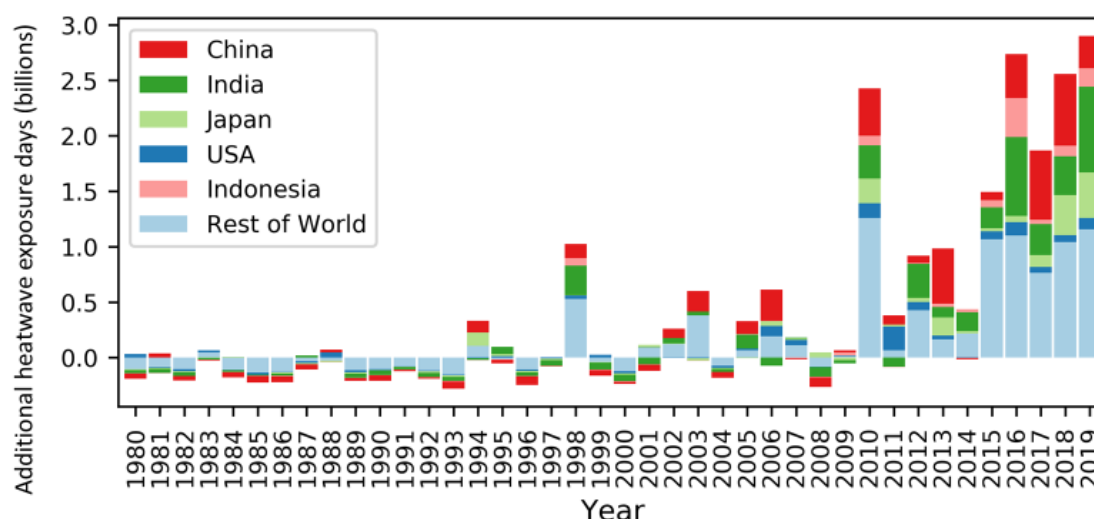
587
588 *Figure 1: Change in days of heatwave exposure relative to the 1986-2005 baseline in the over 65*
589 *population.*

590

591 Indicator 1.1.3: Heat-Related Mortality

592 *Headline finding: In the past two decades, heat-related mortality in the over-65 population*
593 *has increased by 53.7%, reaching 296,000 deaths in 2018, with the majority occurring in*
594 *Japan, eastern China, northern India, and central Europe.*

595 This metric, newly created for the 2020 report, tracks global heat-related mortality in
596 populations over 65. Using methods originally described by the World Health Organization
597 (WHO), it applies the exposure-response function and optimum temperature described by
598 Honda et al (2014) to the daily maximum temperature exposure of the over 65 population
599 to estimate the attributable fraction and thus the heat-related excess mortality.[37,38] Daily
600 maximum temperature data is taken from ERA5 and gridded population data was taken
601 from a hybrid of NASA GPWv4 and ISIMIP population data, with a full methodology
602 described in the Appendix. [34-36]

603 This indicator estimates that global average annual heat-related mortality in the over 65
604 population has increased by 53.7% from 2000-2004 to 2014-2018, with a total of 296,000
605 deaths in 2018 (Figure 2 and Figure 3). With the largest populations, China and India were
606 greatest affected, with over 62,000 and 31,000 heat-related deaths respectively, followed
607 by Germany (over 20,000), the USA (almost 19,000), Russia (18,600), and Japan (over
608 14,000). At over 104,000 deaths, Europe was the most affected of the WHO regions.
609 Importantly, the effects of temperature on mortality vary by region, and are modified by
610 local factors including population urban green space, and inequality both within and
611 between countries.[39,40] Work has begun to develop a future form of this indicator, which
612 builds in more localised exposure-response functions, as they become available.

613

614
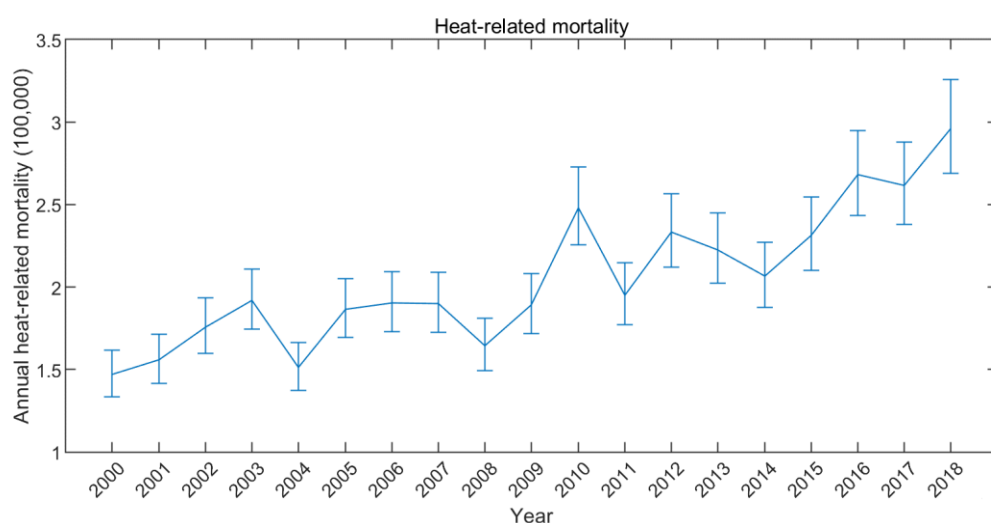
615 *Figure 2: Global heat-related mortality for populations over the age of 65, from 2000-2018.*
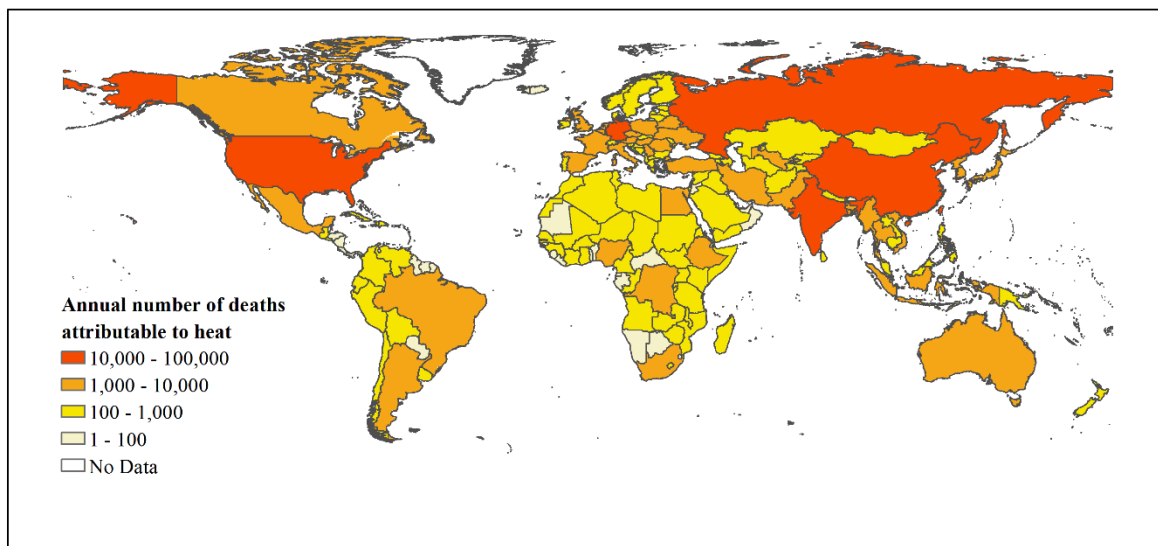
616
617 *Figure 3: Annual heat-related mortality in the over 65 population, averaged from 2014 to 2018.*

618

619 Indicator 1.1.4: Change in Labour Capacity

620 *Headline finding: Rising temperatures were responsible for an excess of 100 billion potential*
621 *work-hours hours lost globally in 2019 compared to 2000, with India's agricultural sector*
622 *among the worst affected.*

623 This indicator tracks the effects of heat exposure on working people, with impact expressed
624 as potential work hours lost.[41] It has been updated to capture construction, alongside
625 service, manufacturing, and agriculture sectors, drawing climate data from the ERA5
626 models, with methods and data described in full in the Appendix and previously.[35,42-45]

627 Across the globe a potential 302 billion work hours were lost in 2019 – 103 billion hours
628 greater than in 2000. Thirteen countries represent approximately 80% of the global hours
629 lost in 2019 (Table 1), with India experiencing by far the greatest loss (39% of total global
630 work hours lost in 2019) and Cambodia the highest impact per capita loss. Agricultural
631 workers experience the worst of these effects in many countries in the world, whereas the
632 burden is often on those in construction in high-income countries such as the USA.

21

633 *Table 1: Work hours lost (WHL) due to heat. These estimates are assuming all agricultural and*
634 *construction work was in the shade or indoors – the lower bounds of potential work hours lost. Work*
635 *hours lost per person are estimated for the population over 15.*

636

Country	WHL 2000 (billions)	WHL 2019 (billions)	% of Global WHL, 2019	WHL per person, 2019
Global	199.0	302.4	100%	52.7
India	75.0	118.3	39.1%	111.2
China	33.4	28.3	9.4%	24.5
Bangladesh	13.3	18.2	6.0%	148.0
Pakistan	9.5	17.0	5.6%	116.2
Indonesia	10.7	15.0	5.0%	71.8
Vietnam	7.7	12.5	4.1%	160.3
Thailand	6.3	9.7	3.2%	164.4
Nigeria	4.3	9.4	3.1%	66.7
Philippines	3.5	5.8	1.9%	71.4
Brazil	2.8	4.0	1.3%	23.3
Cambodia	1.7	2.2	0.7%	202.2
USA	1.2	2.0	0.7%	7.1
Mexico	0.9	1.7	0.6%	17.4
Rest of world	28.7	58.3	19.3%	27.5

637

1.2 Health and Extreme Weather Events

Extreme weather events, including wildfires, floods, storms, and droughts, affect human health in a variety of ways, with the frequency and intensity of such events shifting as a result of climate change. Death and injury as a direct result of an extreme event is often compounded by effects that are mediated through the environment – for example, the exacerbation of respiratory symptoms from wildfire smoke, or the spread of vector- and water-borne diseases following a flood or drought. Finally, impacts are mediated through social systems – for example, the disruption to health services, and the mental ill-health that can result from storms and fires.[3,46] The following indicators track population risk and exposure to wildfires, changes in meteorological flood and drought, and the lethality of extreme weather events.

Indicator 1.2.1: Wildfires

Headline finding: 114 countries experienced an increase in the number of days people were exposed to 'very high' or 'extremely high' fire danger risk for the four-year period ending 2019. At the same time, 128 countries experienced an increase in population exposure to wildfires.

For the 2020 report, analysis on the effects of wildfires has been developed to track the average number of days people are exposed to very high and extremely high wildfire risk annually, as well as the change in actual population wildfire exposure across the globe, using both model-based risk to wildfires and satellite-observed exposure. Climatological wildfire risk is estimated by combining fire danger indices (FDI ≥ 5) with climate and population data for every 0.25° x 0.25° grid cell.[34,47] For wildfire exposure, satellite-observed active fire spots were detected using the Moderate Resolution Imaging Spectroradiometer (MODIS), and then aggregated and spatially joined with gridded global population data on a global 10 km resolution grid, with urban areas excluded.[34,48] A full description of the methodology can be found in the Appendix.

Increased wildfire risk was observed in 114 out of 196 countries for the period 2016-2019 compared to 2001-2004, with the most prominent increases occurring in Lebanon, Kenya and South Africa (Figure 4). Considering area-weighted rather than population-weighted change, Australia, devastated by the 2019-2020 fire season, had one of the largest increases in wildfire risk. Over the same time period, this risk translated into an additional 194,000 daily exposures to wildfires happening annually, around the world, and 128 countries experiencing an increase in this metric. Driven by the record-breaking 2017 and 2018 fires,

672 the USA experienced one of the largest increases globally, with over 470,000 additional
673 annual daily exposures to wildfires occurring from 2001-2004 to 2016-2019.

674

Change in number of days of exposure
to high or very high wildfire risk
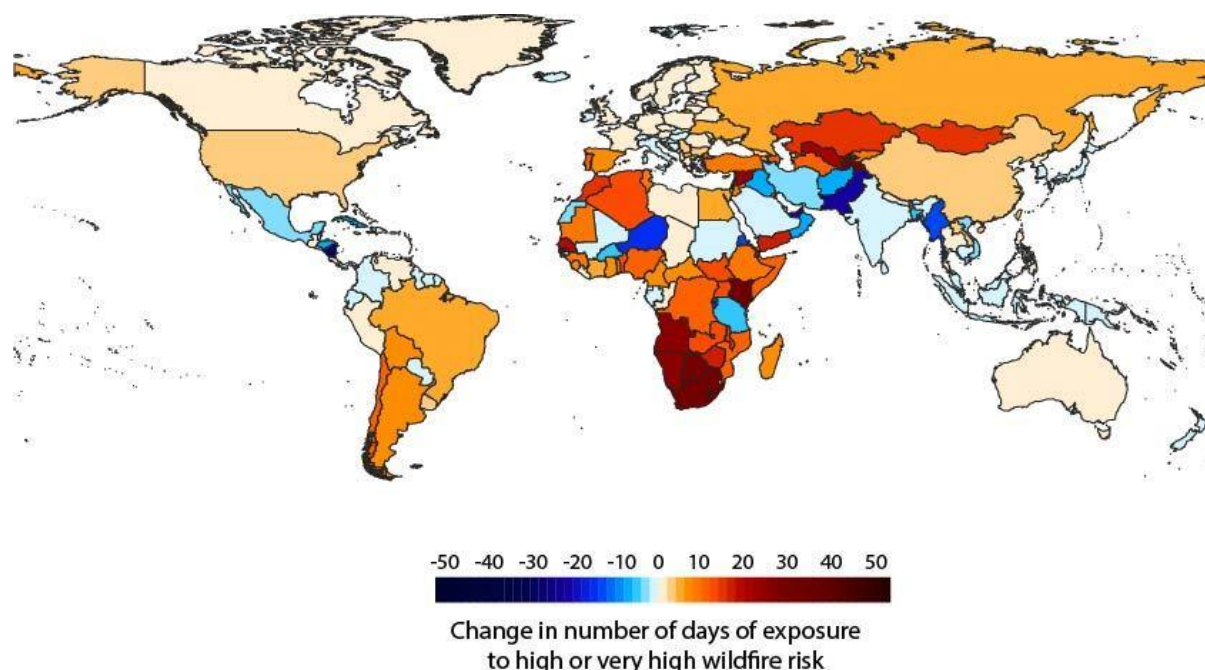
675
676 *Figure 4: Population-weighted mean changes in extremely high and very high fire danger days in*
677 *2016-2019 compared with 2001-2004. Large urban areas with population density ≥ 400 persons/km²*
678 *are excluded.*

679

680 Indicator 1.2.2: Flood and Drought

681 *Headline finding: 2019 saw over twice the global land surface area affected by excess*
682 *drought compared with the historical baseline.*

683 Climate change alters hydrological cycles, tending to make dry areas drier and wet areas
684 wetter.[27] By altering rainfall patterns and increasing temperatures, climate change affects
685 the intensity, duration and frequency of drought events.[3,49] Drought poses multiple risks for
686 health, threatening drinking water supplies and sanitation, crop and livestock productivity,
687 enhancing the risk of wildfires and potentially leading to forced migration.[50] At the same
688 time, altered precipitation patterns increase the risk of localised flood events, resulting in
689 direct injury, the spread of infectious diseases and impacts on mental health.[51]

690 In the 2020 report, meteorological drought is tracked through using the Standardised
691 Precipitation-Evapotranspiration Index (SPEI), which takes into account both precipitation

692 and temperature, as well as its impact on the loss of soil moisture. This measures significant
693 increases in the number of months of drought compared with an extended historical
694 baseline, from 1950-2005, in order to account for periodic variations such as those
695 generated by the El Niño Southern Oscillation.[52] A full explanation of the methodology and
696 additional analysis are in the Appendix.

697 Since the turn of the century, the area affected by excess number of months in drought has
698 increased globally, with more exceptional drought events affecting all populated continents
699 in 2018. Areas that experienced unusually high number of months under excess drought in
700 2018 include Europe, the Eastern Mediterranean region, and specifically, Mongolia.

701

Indicator 1.2.3: Lethality of Extreme Weather Events

703 *Headline finding: Long term increasing trends in the number of weather-related disasters*
704 *from 1990 to 2019 were accompanied by increasing trends in the number of people affected*
705 *by these disasters, in the countries where health expenditure has reduced or minimally*
706 *increased over the last two decades.*

707 The links between climate change and the health impacts of extreme weather events are
708 presented in two ways for this indicator. The first studies long-term trends in the occurrence
709 of such events along with the change in the number of people affected, and the resultant
710 mortality. The methods and data for this are similar to that used in previous reports, and
711 described in full in the Appendix.[53,54] Recognising that an increase in the variability and
712 intensity of these events is also expected, the second part considers the attribution of
713 climate change to individual extreme events in recent years, and the effects that a selection
714 of events have had on the health of populations (Table 2 and Panel 3).

715 There are clear, statistically significant trends in the number of occurrences of weather-
716 related disasters, however insufficient evidence in either direction with respect to the
717 number of deaths or number of people affected per event. Within the sub-set of countries
718 demonstrating a reduction, or minimal increase in healthcare expenditure from 2000-2017,
719 a significant increase in the number of people affected is identified. By contrast, in countries
720 with the greatest increase in healthcare expenditure, the number of people affected by
721 extreme weather events has declined despite an increasing frequency of events. One
722 possible explanation for this could be the adaptive effects of health system strengthening.
723 This relationship will be further explored, considering variables such as expenditure for
724 specific healthcare functions and excess deaths in addition to the immediate event-related
725 deaths.

726 *Table 2: Detection and attribution studies linking recent extreme weather events to climate change*
727 *from 2015 to 2020.*

Event type	Anthropogenic influence increased event likelihood or strength	Anthropogenic influence decreased event likelihood or strength	Anthropogenic influence not identified or uncertain, or had varied effects (*)
Heat *36 studies* *32 events*	**2015:** India; Pakistan; China; Indonesia; Europe;[8,55] Egypt; Japan; Southern India and Sri Lanka; Australia; Global.[8,56] **2016:** Southern Africa; Thailand; Asia; Global. **2017:** Australia;[57] USA; South Korea; Western Europe;[58] China; Euro-Mediterranean. **2018:** Northeast Asia; Iberia; Europe. **2019:** France;[59] Western Europe.[60] **2020:** Australia.[61]		**2015-2016:** India.[62]
Cold and frost *9 studies* *8 events*	**2016:** Australia.	**2015:** USA. **2016:** China**.** **2018:** North America;[63] UK.	
Drought and reduced precipitation *26 studies* *24 events*	**2015:** USA; Canada; Ethiopia; Indonesia; Australia. **2016:** Southern Africa; Thailand. **2017:** East Africa; USA; China**.** **2018:** South Africa;[64] China; USA		**2015:** Brazil;[65] Nigeria; Ethiopia.[66] **2016:** Brazil; USA; Somalia;[67] Western Europe. **2017:** Kenya.[68] USA. **2019:** Australia.[61]
Wildfire *5 studies* *6 events*	**2015:** USA. **2016:** Australia; Western North America. **2018:** Australia. **2020:** Australia.[61]		**2017:** Australia.
Heavy precipitation and flood *23 studies* *19 events*	**2015:** China; USA. **2016:** France;[69] China; Louisiana, USA.[70] **2017:** Bangladesh; Peru; Uruguay; China. **2018:** USA; Japan.[6,71]	**2018:** China.	**2015:** India. **2016:** Germany;[69] Australia; **2017:** Bangladesh.[72] **2018:** Mozambique, Zimbabwe and Zambia; Australia; India;[73] China.*
Storms *8 events* *8 studies*	**2015:** UK;[74] Western North Pacific[75] **2017:** USA.[76] **2018:** USA.[77] **2019:** USA.[78]		**2016:** USA. **2018:** Western Europe.[79]
Marine heat and melting sea ice *10 events* *13 studies*	**2015:** Northern Hemisphere. **2016:** USA; Australia; Coral Sea;[7,80] North Pole;[7,81] Gulf of Alaska and Bering Sea; Central Equatorial Pacific. **2018:** Tasman Sea; Bering Sea.		**2015:** Central Equatorial Pacific. **2016:** Eastern Equatorial Pacific.
Total events and studies	**76 events, 81 studies**	**5 events, 6 studies**	**28 events, 27 studies**

728
729 Events have been listed according to the year in which they ended. In some countries and regions multiple events in the same year were
730 studied. References are in Herring et al, 2016,[8] Herring et al, 2018,[7] Herring et al, 2019,[5] Herring et al 2020,[6] or listed separately. Adapted
731 from the Bulletin of the American Meteorological Society.
732

<div style="border: 1px solid black; padding: 10px;">

Panel 3: Quantifying the Links between Climate Change, Human Health, and Extreme Events

Formal statistical methods, grouped as detection and attribution studies (D&A) are already used widely in other sectors, and are increasingly deployed to quantify the extent to which climate change has had observed impacts on population health and health systems.[82-84] However, recent D&A studies focusing on the changing likelihood and intensity of extreme events are generally limited to meteorological events in high- and upper-middle income countries. Further development of this body of literature offers an essential and unique way of improving understanding of current impacts and future risks of climate change on lives and livelihoods, guiding evidence-based management and adaptation.

The following three case studies illustrate the linkage of D&A studies of meteorological events to the resulting health impacts.

1. Reduced sea ice in the Arctic Region

The Arctic Region is warming two to three times faster than the global annual average, with observable impacts for Arctic communities, but limited data on the health consequences.[85] Extreme weather events, shifting migration patterns, and warmer and shorter winters now threaten food security and vital infrastructure.

The winter of 2017-18 heralded warm temperatures and an extreme 'low ice year' in the Bering Sea.[86] Sea ice extent was the lowest in recorded and reconstructed history: an estimated two in 1800-year event compared with pre-industrial levels. One study suggested that climate change was responsible for 90% of the attributable risk , and that this level may become the mean within 20 years.[87]

This had multiple detrimental effects on communities in Western Alaska, although the health impacts have rarely been measured. These communities generally depend on sea ice for transportation, hunting and fishing, coastal buffering from storms, and a host of other ecosystem services. During this period of record-low sea ice, a range of events occurred, from the loss of power, and damage to the water treatment plant in Little Diomede to a fatal accident that resulted from open water-holes along a previously frozen travel corridor on the Kuskokwim River.[88-90]

2. Northern European Heatwaves in 2018 and 2019

During the summer of 2018, parts of northern Scandinavia experienced record-breaking daily temperatures more than 5°C warmer than in 1981-2010, an occurrence that evidence suggests was made five times more likely as a result of climate change.[91] In Sweden, the Public Health Agency estimated an excess mortality of 750 deaths between July and August, with more than 600 of these attributed to higher temperatures when compared with the same weeks in 2017.[92]

Countries across Western Europe and Scandinavia again experienced record-breaking temperatures in 2019, with several countries exceeding 40°C for 3-4 days during June and July. Attribution studies suggest climate change was responsible for a 10-fold increase in the likelihood of the event occurring, and a 1.2-3°C increase in temperature of these events, with almost 1,500 deaths in France and 400 deaths in the Netherlands.[60,93,94]

3. Japan Heatwave 2018

The summer of 2018 in Japan saw a combination of a national emergency resulting from extreme precipitation, followed closely by record-breaking temperatures. The event had roughly a 20% probability of occurring in today's world compared with a zero probability in a world without climate change.[95,96] Another attribution study compared modest and extreme heatwave days with a 1941-79 baseline, concluding that the probability of the defined heatwave event was 1.5 times higher for 1980-2018 and 7-8 times higher for 2019-2050. This hot summer had large health implications. In 2018, there were an estimated 14,200 heat-related deaths in Japan's over 65 population – over 3,000 more deaths than the previous record set in 2010, and 8,100 greater than the 2000-2004 average (Indicator 1.1.3).

</div>

733

1.3 Climate-Sensitive Infectious Diseases

735 Indicator 1.3.1: Climate Suitability for Infectious Disease Transmission

736 *Headline finding: Changing climatic conditions are increasingly suitable for the transmission*
737 *of numerous infectious diseases. From 1950 to 2018, the global climate suitability for the*
738 *transmission of dengue fever increased by 8.9% for A. aegypti, and 15.0% for A. albopictus. In*
739 *the last 5 years, suitability for malaria transmission in highland areas was 38.7% higher in the*
740 *WHO African region and 149.7% higher in the WHO Western Pacific Region compared to a*
741 *1950s baseline.*

742 Climate change is affecting the distribution and risk of many infectious diseases to humans,
743 including vector-, food- and water-borne diseases.[3] Using three different models, this
744 indicator tracks the change in climate suitability for the transmission of infectious diseases
745 of particular global significance: dengue; malaria; and pathogenic *Vibrio* bacteria (*V.*
746 *parahaemolyticus*, *V. vulnificus*, and non-toxigenic *V. cholerae*). In the case of *Aedes aegypti*
747 and *A. albopictus,* temperature-driven process-based mathematical models were used to
748 capture the vectorial capacity (VC) for the transmission of dengue.[97] Change in the climate
749 suitability for *Plasmodium falciparum* malaria is modelled based on empirically derived
750 thresholds of precipitation, temperature and relative humidity.[97,98] Highland areas (≥1500m
751 above sea-level) are highlighted in the model, as increasing temperatures are eroding the
752 effect altitude once had as a barrier to malaria transmission, resulting in more favourable
753 conditions in densely populated highland areas, as seen in Ethiopia.[99] In the case of
754 pathogenic *Vibrio* species, which cause a range of human infections including
755 gastroenteritis, wound infections, septicaemia, and cholera, recent changes in climate
756 suitability were compared with a 1980s baseline globally, as well as for one region each in
757 Europe (Baltic), the Northeast Atlantic coast of the USA and the Pacific North West coast of
758 North America.[100-102] Full descriptions of the context of these diseases, the methodology of
759 the models, and additional analysis can be found in the Appendix.

760 Climate suitability for disease transmission is rising globally, for all diseases being tracked.
761 2018 was particularly favourable for the transmission of dengue, with a global rise of 8.7%
762 and 14.5% above the 1950s baseline for *A. aegypti* and *A. albopictus*, respectively (Figure 5).
763 Although average suitability for dengue remains low in Europe, 2018 was the most suitable
764 year yet recorded for both vector species in this region (25.8% and 40.7% for *A. aegypti* and
765 *A. albopictus*, respectively). There have been significant increases in the environmental
766 suitability for the transmission of falciparum malaria in highland areas of four of the five
767 malaria-endemic regions, with an increase of 38.7% in the African Region and 149.7% in the
768 Western Pacific Region in 2015-2019 compared to a 1950s baseline (**Error! Reference**
769 **source not found.**). The coastal area suitable for *Vibrio* infections in the past five years has
770 increased at northern latitudes (40-70° N) by 50.6% compared to a 1980s baseline.
771 Regionally, the area of coastline suitable for *Vibrio* has increased by 61.2% and 98.9% for the

772 Baltic and USA Northeast respectively. In 2019, for the second consecutive year, the entirety
773 of the Baltic coastline was suitable for disease transmission.

774
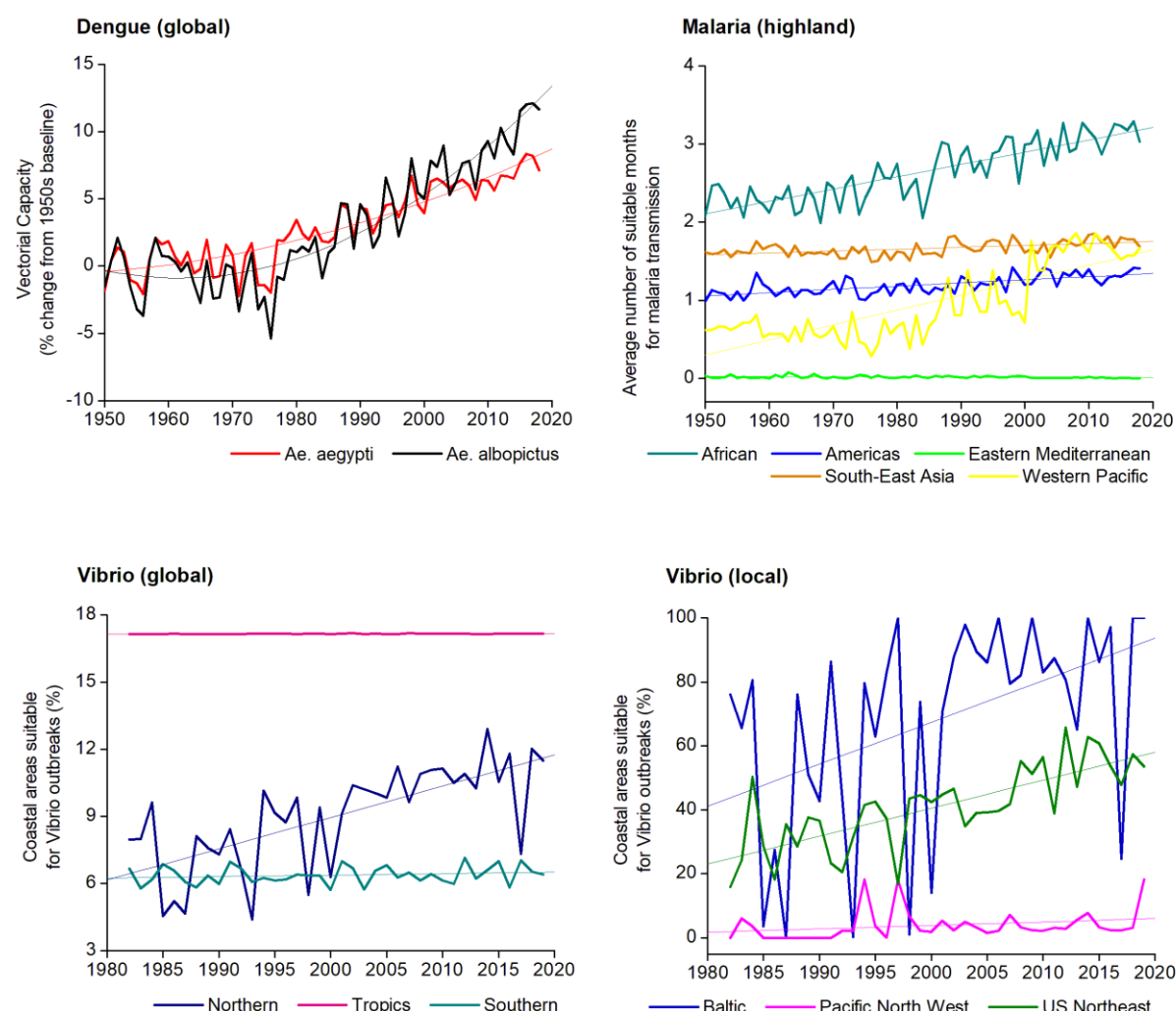
775
776 *Figure 5: Change in climate suitability for infectious diseases: dengue (*A. aegypti*); malaria (highland*
777 *regions ≥1500m); and* Vibrio *species.*

778

Indicator 1.3.2: Vulnerability to Mosquito-Borne Diseases

780 *Headline finding: Following a sharp decline over the last decade, 2016 to 2018 saw small up-*
781 *ticks in national vulnerability to dengue outbreaks in four out of six WHO regions, with*
782 *further data required to establish a trend.*

783 As discussed above, climate change is expected to facilitate the expansion of *Aedes*
784 mosquito vectors that transmit dengue. Improvements in public health services may
785 counteract these threats in the short- to medium-term, however climate change will
786 continue to make such efforts increasingly difficult and costly.[103] This indicator tracks
787 vulnerability to mosquito-borne disease by combining the above indicator on climate
788 suitability for the transmission of dengue, with countries' health system core capacities as
789 outlined by the International Health Regulations (IHR), which have been shown to be an
790 effective predictor of protection against disease outbreak.[104] The methods used here remain
791 unchanged from previous reports, and are described in the Appendix in full.[97,105]

792 From 2010, a substantial decline in vulnerability for the four most vulnerable WHO regions,
793 is seen around the world, reflecting significant improvements in their core health capacities.
794 However, from 2016 to 2018, this trend begins to halt, and then reverse, with further data
795 required to confirm any long-term shift.

796

797 ## 1.4 Food Security and Undernutrition

798 Whilst the global food system still produces enough to feed a growing world population,
799 poor management and distribution has resulted in a lack of progress on the second
800 Sustainable Development Goal (SDG) on hunger, as the global number of under-nourished
801 people projected to rise to over 840 million in 2030.[106]

802 Climate change threatens to exacerbate this further, with increasing temperatures, climatic
803 shocks and ground-level ozone impacting crop yields, and with sea surface temperature
804 (SST) and coral bleaching impacting marine food security.[107] These effects will be
805 experienced unequally, disproportionately affecting countries and populations already
806 facing poverty and malnutrition, and exacerbating existing inequalities. The following two
807 indicators monitor these changes, tracking the change in crop yield potential and SST.

808

809 ### Indicator 1.4.1: Terrestrial Food Security and Undernutrition

810 *Headline finding: Crop yield potential for maize, winter wheat, soybean, and rice has*
811 *followed a consistently downward trend from 1980 to 2019, with reductions of 5.6%, 2.1%,*
812 *4.8% and 1.8% seen respectively.*

813 Here, crop yield potential is characterised by "crop growth duration" (the time taken to
814 reach a target sum of accumulated temperatures), over its growing season. If this sum is
815 reached early then the crop matures too quickly and yields are lower than average, with a
816 reduction in crop growth duration therefore representing a reduction in yield potential.[108]

817   This indicator tracks the change in the crop growth duration for four key staple crops:
818   maize, wheat, soybean, and rice at the individual country level and globally, using a similar
819   approach to previous reports, which has been improved to provide more accurate local
820   estimates, and now uses ERA5 data.[36]

821   The yield potential of maize, winter wheat, soybean, and rice continue to decline globally
822   and for most individual countries, with this indicator demonstrating that it is increasingly
823   difficult to continue to increase or even maintain global production due to the changing
824   climate. In 2019, the reduction in crop growth duration relative to baseline, was 7.9 days
825   (5.6%), 4.9 days (2.1%), 6.1 days (4.8%), and 2 days (1.8%) for maize, winter wheat, soybean,
826   and rice respectively (Figure 6). For maize, most countries in the world experienced a
827   decline, with large areas of South Africa, the USA, and Europe experiencing reductions in
828   their crop growing seasons of over 20 days – a reduction of over 14% of the global average
829   crop duration. This compounds the current negative impacts of weather and climate shocks,
830   made more frequent and more extreme by climate change, that are hampering localised
831   efforts to reduce undernutrition.

832
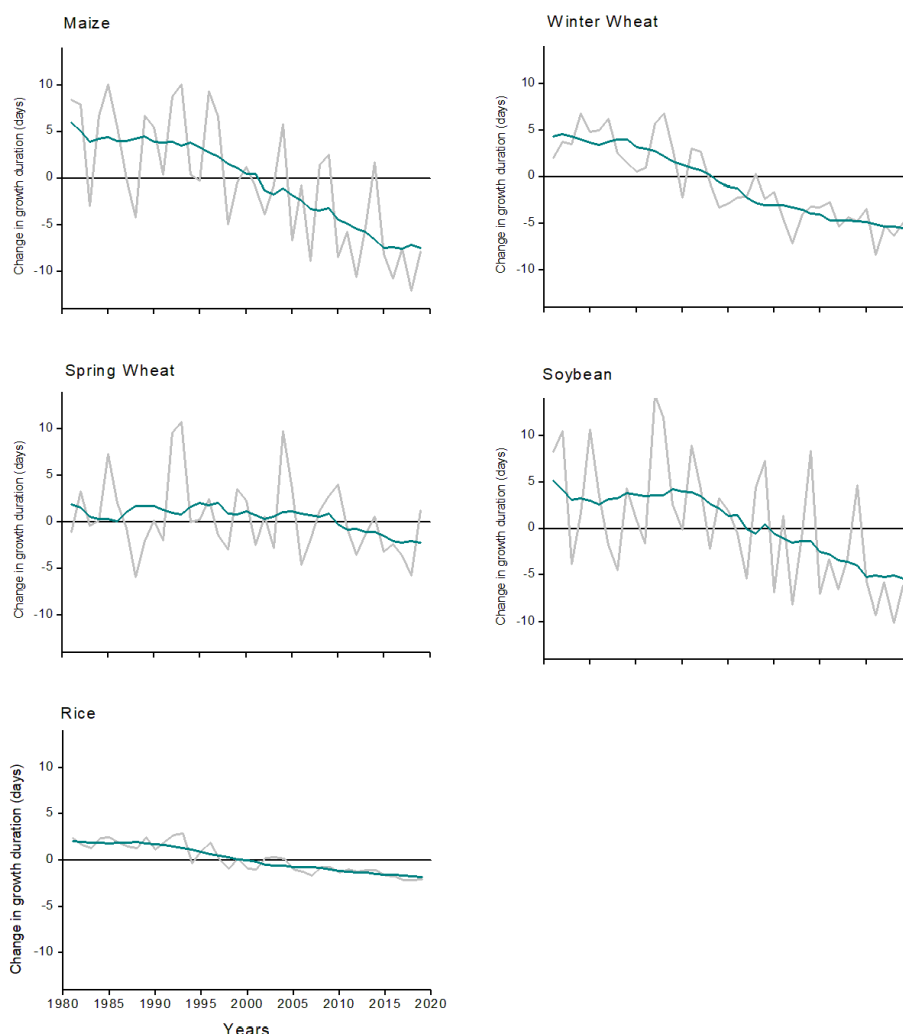
Figure 6: Change in crop growth duration for maize, soybean, spring wheat, winter wheat, and rice, relative to the 1981-2010 global average.

Indicator 1.4.2: Marine Food Security and Undernutrition

Headline finding: Average sea surface temperature rose in 46 of 64 investigated territorial waters between 2003-2007 and 2015-2019, presenting a risk to marine food security.

A large proportion of the global population, especially in low- and middle-income countries is highly dependent on fish sources of protein.[109] Additionally, omega-3 is important in the prevention of ischaemic heart disease and diets low in seafood omega-3 fatty acids, a risk factor to which over 1.4 million deaths globally were attributed in 2017.[110] Sea surface temperatures, rising as a consequence of climate change, impair marine fish capacity and capture through a number of mechanisms, including the bleaching of coral reefs and

846 reduced oxygen content, putting populations at risk.[111] This indicator tracks SST in territorial
847 waters of 64 countries located in 16 Food and Agriculture Organization (FAO) fishing
848 areas.[112-114]

849 Comparing 2003-07 and 2015-19 time periods, average SST rose in 46 of the 64 investigated
850 areas, with a maximum increase of 0.87°C observed in the territorial waters of Ecuador.
851 Farm-based fish consumption has increased consistently over the last four decades, with a
852 corresponding decline in capture-based fish consumption, exacerbated in part by these
853 evolving temperature trends.[111] Between 1990 and 2017, diets low in seafood ω3 increased
854 by 4.7% at global level with more than 70% of the countries experiencing an increase in
855 exposure to this risk factor, increasing the mortality risk from ischemic heart disease.

856

857

858 Indicator 1.5: Migration, Displacement and Sea Level Rise
859
860 *Headline finding: Without intervention, between 145 million and 565 million people living in*
861 *coastal areas today will be exposed to and affected by future sea level rise.*
862
863 Through its impacts on extreme weather events, land degradation, food and water security,
864 and sea level rise (SLR), climate change is influencing human migration, displacement, and
865 relocation with human health consequences.[115,116] Left unabated, average estimates for
866 global mean sea level rise (GMSLR) range from 1-2.5 metres (m) by the end of the century,
867 with projections rising as high as 5m when taking into account regional and local coastal
868 variation.[117,118] This indicator, newly introduced for the 2020 report, tracks current
869 population exposure to future SLR and provides a measure of the extent to which health or
870 well-being are considered in national policies which connect climate change and human
871 mobility.
872
873 Population exposure to GMSLR of 1m and 5m was determined using a Coastal Digital
874 Elevation Model (CoastalDEM) and current population distribution data, with a full
875 description of this new indicator outlined in the Appendix.[119,120] Based on today's
876 population distributions, 1m of GMSLR could expose 145.5 million of the world's current
877 population to potential inundation, rising to 565 million people with 5m of SLR (Figure 7). A
878 range of SLR-related health impacts are likely to be experienced, with changes in water and
879 soil quality and supply, livelihood security, disease vector ecology, flooding, and saltwater
880 intrusion.[121,122] The health consequences of these effects will depend on a variety of factors,
881 including both *in situ* and migration adaptation options.[123-125] These effects could be
882 moderated if countries begin to prepare. A review in 2019 identified 43 national policies,
883 across 37 countries, connecting climate change and migration, and 40 of these policies
884 across 35 countries explicitly referencing health or wellbeing. The policies commonly accept

885   that mobility could be domestic and international, although mention of immobility was
886   lacking.

887

Exposure to 1m Global Mean Sea Level Rise
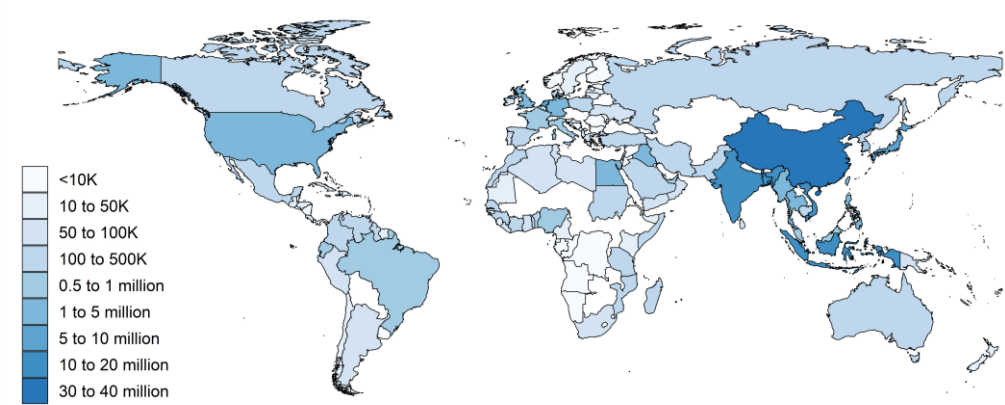
Exposure to 5m Global Mean Sea Level Rise

---
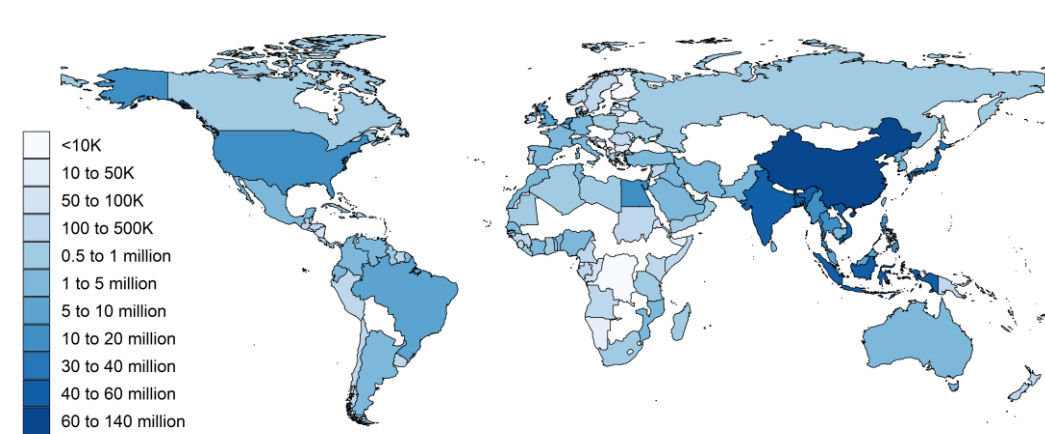
888   *Figure 7: Number of people exposed to 1m and 5m of global mean sea level rise by country.*

Conclusion

890 The indicators that comprise Section 1 of the 2020 report describe a warming world that is
891 affecting human health both directly and indirectly, and putting already vulnerable
892 populations at higher risk. Metrics of exposure and vulnerability to extreme weather are
893 complemented by trends of worsening global yield potential and climatic suitability for the
894 transmission of infectious disease. Subsequent reports will continue to develop the
895 methods and data underlying these indicators, with a particular focus on the creation of a
896 new indicator on mental health, and the exploration of the gender dimensions of existing
897 indicators.

898 Correlating climate change and mental health is challenging for a number of reasons,
899 including local and global stigma and underreporting, differences in health systems, and
900 variation in cultural understandings of wellbeing. In part because of this, the literature has
901 focused on extremes of heat, with investigations reporting correlations between higher
902 temperatures and heatwaves, and the risk of violence or suicide. Proposed reasons for this
903 association vary from the effects of disrupted sleep through to short-term agitation.[126,127]
904 Stronger evidence exists outlining the links between extreme weather events and mental ill-
905 health, with emerging research describing the impact of a loss of access to the environment
906 and ecosystem services.[128]

907 Taken as a whole, the data described in Section 1 provides a compelling justification for an
908 accelerated response. There are clear limits to adaptation, necessitating increasingly urgent
909 interventions to reduce GHG emissions. How communities, governments, and health
910 systems will be able to moderate the impacts of a changing climate is discussed in Section 2
911 and Section 3.
912

913

Section 2: Adaptation, Planning, and Resilience for Health

With a growing understanding of the human costs of a warming climate, the need for adaptation measures to protect health is now more important than ever. The current COVID-19 pandemic makes clear the challenges experienced by health systems around the world, when faced with large unexpected shifts in demand, without sufficient adaptation or integration of health services across other sectors.[129] As this public health crisis continues, and is compounded by climate-attributable risks, rapid and proactive interventions are crucial in order to prepare for and build resilience to both the health threats of climate change and of pandemics.[130]

Heavily determined by regional hazards and underlying population health needs, the implementation of adaptation and resiliency measures require localised planning and intervention. National adaptation priorities must take into account subnational capacities, as well as the distribution of vulnerable populations and inequality, locally. As health adaptation interventions are being increasingly introduced, evidence of their success often remains mixed.[131] Measuring the impact of these long-term interventions at the global scale presents particular challenges, and the indicators in this section aim to monitor adaptation progress through the lens of the WHO Operational Framework for Building Climate Resilient Health Systems.[24] The adaptation indicators expand beyond the health system to focus on the following domains: planning and assessment (Indicators 2.1.1-2.1.3), information systems (Indicator 2.2), delivery and implementation (Indicators 2.3.1-2.3.3), and spend (Indicator 2.4). As is often the case in adaptation, several of these indicators rely on self-reported data on adaptation plans, assessments, and services, which also presents challenges. Where possible, efforts have been made to validate this data.

Numerous indicators in this section have been further developed for the 2020 report and one new indicator is presented. The data on national health adaptation planning and assessments (Indicators 2.1.1 and 2.1.2) has been presented in greater detail, whilst calculations of the effectiveness of air conditioning as an intervention (Indicator 2.3.2) have been improved using more recent evidence. The definition of health-related adaptation spending (Indicator 2.4) has been expanded to capture activities that are closely health-related, in a variety of non-health sectors. Importantly, a new indicator, focusing on the use of urban green spaces as an adaptive measure with numerous health benefits, has been introduced in this year's report (Indicator 2.3.3).

2.1 Adaptation Planning and Assessment

Adaptation planning and risk management is essential across all levels of government, with national strategy and coordination linked to sub-national and local implementation and delivery.[132] In every case, risk assessments are an important first step of this process.

The following three indicators track national- and city-level adaptation plans and assessments, using data from the WHO Health and Climate Change Survey and the CDP Annual Cities Survey.[133,134] Information on the data and methods for each are presented in the Appendix. Data from the WHO survey has not been updated for this year, and hence further qualitative analysis has been conducted to investigate the barriers to adaptation.

Indicator 2.1.1: National Adaptation Plans for Health

Headline finding: 51 out of 101 of countries surveyed have developed national health and climate change strategies or plans. However, funding remains a key barrier to implementation, with less than 10% of countries reporting to have the funds to fully implement their plans.

National governments identified financing as one of the main barriers to the implementation of national health and climate change plans.[30,134] Of the countries with these plans, only four report having adequate national funding available to fully implement them. This highlights the importance of access to international climate finance for governments from low-resource settings. Despite this, less than half of national health authorities from low and lower-middle income countries (17 out of 35 LLMICs) report having current access to climate funds from mechanisms such as the Global Environment Facility, the Adaptation Fund, the Green Climate Fund (GCF) or other donors. The GCF, which so far has not funded a single health sector project for the 10th year running, is now looking to align its programming to incorporate health and wellbeing co-benefits in light of, and in response to COVID-19. While not yet accredited to submit and implement projects, WHO became a GCF Readiness Partner in 2020, giving WHO the ability to support countries in their efforts to develop health components of National Adaptation Plans and to strengthen health considerations related to climate change.

A second key barrier to the implementation of national health and climate strategies is a lack of multisectoral collaboration within government. Progress on cooperation across sectors remains uneven, with 45 out of 101 countries reporting the existence of a memorandum of understanding between the health sector and the water and sanitation sector, on climate change policy. However, less than a third of countries have a similar agreement with the agricultural, or social service sectors. Furthermore, only about a quarter of countries reported agreements in places between health and the transport, household

984 energy or electricity generation sectors. This represents a significant missed opportunity to
985 recognise the health implications of national climate policies and to promote activities that
986 maximise health benefits, avoid negative health effects and evaluate the associated health
987 savings that may result.

988

989 Indicator 2.1.2: National Assessments of Climate Change Impacts, Vulnerabilities, and
990 Adaptation for Health

991 *Headline finding: Just under half of 101 countries surveyed have conducted a national*
992 *vulnerability and adaptation assessment for health, with further investment required to*
993 *adequately fund these vital components of health system resilience.*

994 Strengthening all aspects of a health system allows it to protect and promote the health of a
995 population in the face of known and unexpected stressors and pressures. In the case of
996 climate change, this requires a comprehensive assessment of current and projected risks,
997 and population vulnerability. This indicator focuses on national-level vulnerability
998 assessments and the barriers faced by national health systems.[134]

999 Similar to the lack of funding highlighted above, it is clear that vulnerability assessments for
1000 health are also under-resourced. Indeed, conducting vulnerability assessments were among
1001 the top three adaptation priorities identified as being underfunded by national health
1002 authorities, alongside the strengthening of surveillance and early warning systems, and
1003 broader research on health and climate change. This was thought to be particularly true for
1004 sub-national assessments and for those designed to be particularly sensitive to the needs of
1005 vulnerable population groups.

1006

1007 Indicator 2.1.3: City Level Climate Change Risk Assessments

1008 *Headline finding: Of the 789 global cities surveyed, 76% have either already completed or*
1009 *are currently undertaking climate-change risk assessments, with 67% expecting climate*
1010 *change to seriously compromise their public health assets and services, a substantial*
1011 *increase from 2018.*

1012 Cities are home to more than half of the world's population, produce 80% of global gross
1013 domestic product (GDP), consume two thirds of the world's energy, and represent a crucial
1014 component of the local adaptation response to climate change.[135] As such, this indicator
1015 captures cities that have undertaken a climate change risk or vulnerability assessment, as
1016 well as their expectations on the vulnerability of their public health assets. First presented in

1017 the 2017 report of the Lancet Countdown and since improved to include further public
1018 health-specific questions, data for this indicator is sourced from the CDP's 2019 survey of
1019 789 global cities: a 33% increase in survey respondents from 2018.[133,136]

1020 In 2019, 62% of cities had completed a climate-change risk or vulnerability assessment, and
1021 a further 28% of city assessments were either in the process of doing so, or will have
1022 completed one within the next two years. While some selection bias likely exists, it is
1023 important to note that a growing number of risk assessments are being completed by cities
1024 in low-income countries (63% of cities in LICs in 2019), highlighting the beginning of
1025 adaptation where it is arguably most needed. The survey also reveals a core driving factor in
1026 these assessments - some 67% of cities report that their vital public health infrastructure
1027 would be seriously compromised by climate change.

1028

1029 ## Indicator 2.2: Climate Information Services for Health

1030 *Headline finding: The number of countries with meteorological services providing climate*
1031 *information to the health sector has continued to grow, increasing from 70 to 86 counties*
1032 *over the past 12 months.*

1033 The use of meteorological services in the health sector is an essential component of
1034 adaptation. This indicator tracks the collaboration between these two parts of government,
1035 using data reported by national meteorological and hydrological services to the World
1036 Meteorological Organization (WMO).[137] Further detail is provided in the Appendix.

1037 A total of 86 national meteorological and hydrological services of WMO member states
1038 reported providing climate services to the health sector, an increase of 16 from the 2019
1039 report of the Lancet Countdown.[30] By WHO region, 19 of the countries reporting were from
1040 Africa, 16 from the Americas, seven from the Eastern Mediterranean Region, 23 from
1041 Europe, eight from South East Asia, and 13 from the Western Pacific Region. Of the 86
1042 positive respondents, 66 reported being 'highly engaged' with their corresponding health
1043 service, alongside other sectors such as agriculture, water, and electricity generation. As
1044 detailed in Indicator 2.1.1, multi-sector collaborations present governments with the
1045 opportunity to support a fully integrated adaptation approach to the risks of climate
1046 change.

1047

1048

2.3 Adaptation Delivery and Implementation

Indicator 2.3.1: Detection, Preparedness and Response to Health Emergencies

Headline finding: In preparation for a multi-hazard public health emergency, 109 countries have reported medium to high implementation of a national health emergency framework.

The International Health Regulations (IHR) are an instrument of international law designed to aid the global community in preventing and responding to potential public health emergencies.[105] This indicator focuses on core capacity eight (C8), which evaluates the degree to which countries have implemented a national health emergency framework by assessing levels of planning, management and resource allocation.[105] The national health emergency framework applies to all public health events and emergencies, air pollution, extreme temperatures, droughts, floods, and storms. The IHR core capacities are also important components of the response to infectious disease threats, with similar capacities and functions considered when assessing preparedness to a pandemic such as COVID-19.[138] The results of this survey are provided in full, in the Appendix.

In 2019, 166 out of 194 WHO member states completed the assessment portion related to C8, 16 fewer than in 2018. Of these, 109 countries have reported having medium to high degrees of implementation of multi-hazard preparedness and capacity, a 10% increase compared to 2018 data. The level of implementation varies by region, with medium-to-high levels reported in over 85% of countries in the Americas, Western Pacific, and Europe, 60% of Eastern Mediterranean and South East Asian countries, but only 26% of African countries. Despite disparities here, capacities have increased across all regions, and the global average increased from 59% in 2018 to 62% in 2019.

Indicator 2.3.2: Air Conditioning Benefits and Harms

Headline finding: Between 2016 and 2018, the world's air conditioning stock continued to rise, further contributing to climate change, air pollution, peak electricity demand and urban heat islands, whilst also conferring protection against heat-related illness.

Air conditioning represents one of a number of effective indoor cooling mechanisms for preventing heat-related illness and mortality.[139] However, in 2018, air conditioning accounted for an enormous 8.5% of total global electricity consumption, contributing to, if sourced from fossil fuels, CO_2 emissions, fine particulate matter ($PM_{2.5}$) emissions, and ground-level ozone formation, with the potential to leak hydrofluorocarbons which act as powerful GHGs. On hot days, air conditioning can be responsible for more than half of peak electricity demand locally, and emits waste heat that contributes to the urban heat island

1083 effect.[140,141] Further research is needed to determine if the overall harms of air conditioning
1084 outweigh its benefits. However, increased air conditioning use in response to the warming
1085 climate could result in around 1,000 additional air-pollution-related deaths every summer in
1086 the eastern USA by 2050.[142]

1087 International programs and organisations, including Sustainable Energy for All, the Kigali
1088 Cooling Efficiency Program, and the International Energy Agency (IEA), are working to
1089 develop solutions to provide efficient indoor cooling that protects vulnerable populations
1090 against heat-related illness whilst minimising the health-associated harms. Such measures
1091 include building designs with improved insulation, energy efficiency measures, and
1092 improved ventilation, as well as increasing urban green space, detailed in Indicator 2.3.3.
1093 Recent evidence suggests that simple electric fans could also be an effective stay-at-home
1094 measure against most heatwaves during the COVID-19 pandemic.[143]

1095 This indicator draws on data provided by the IEA, and includes an improved calculation of
1096 the prevented fraction of deaths from air conditioning, making use of an updated meta-
1097 analysis which builds on the previously available 2007 assessment, with full detail described
1098 in the Appendix.[139,144]

1099 Between 2016 and 2018, the world's air conditioning stock (residential and commercial)
1100 increased from 1.74 to 1.90 billion units and the proportion of households with air
1101 conditioning increased from 31.1% to 33.0%: a 56.7% rise since 2000 (Figure 8).
1102 Correspondingly, the global prevented fraction of heatwave related mortality increased
1103 from 23.6% in 2016 to 25.0% in 2018, but global emissions from air conditioning electricity
1104 consumption increased from 1.04 to 1.07 $GtCO_2$ (2% of total global emissions), highlighting
1105 the need for sustainable cooling methods in the face of a warming climate.
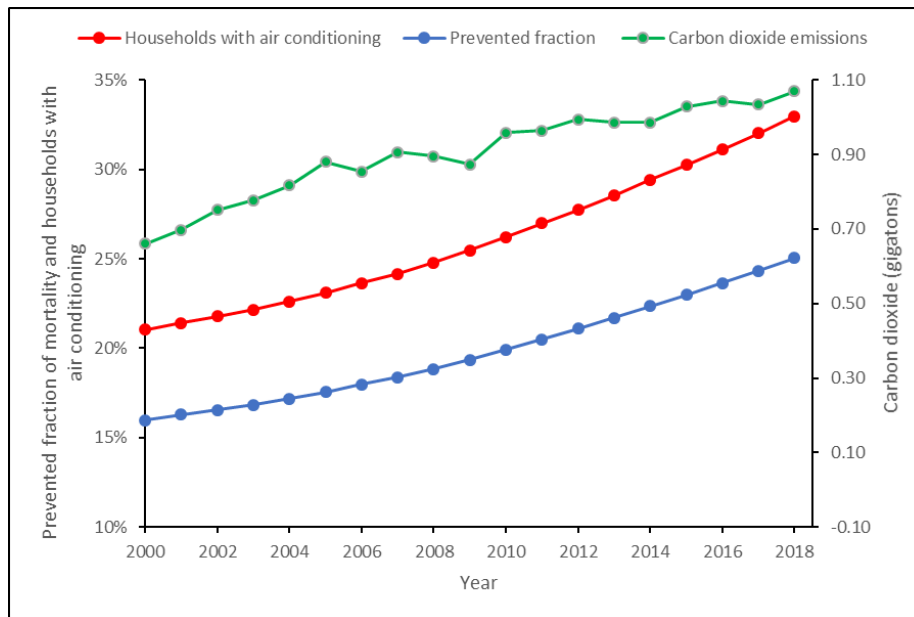
Figure 8: Global proportion of households with air conditioning (red line), prevented fraction of heatwave-related mortality due to air conditioning (blue line), and carbon dioxide emissions from air conditioning (green line), 2000-2018.

Indicator 2.3.3: Urban Green Space

Headline finding: Urban green space is an important measure to reduce population heat exposure, with 8.5% of global urban centres having a very high or exceptionally high degree of greenness in 2019, and over 156 million people living in urban centres with concerningly low levels.

Access to urban green space provides benefits to human health by reducing exposure to air and noise pollution, relieving stress, providing a setting for social interaction and physical activity, and reducing all-cause mortality.[145,146] In addition, green space sequesters carbon and provides local cooling benefits which disrupt urban heat islands, providing both climate change mitigation and heat adaptation benefits. As access can often disproportionately benefit the most privileged in society, it is important that careful consideration is given to how green spaces are designed and distributed, ensuring safety and equitable access.[147,148]

This indicator, new in the 2020 report, quantifies urban green space exposure for 2019 in the 467 urban centres of over one million inhabitants, as defined by the Global Human Settlement (GHS).[149,150] It is based on remote sensing of green vegetation through the satellite-based normalised difference vegetation index (NDVI), which measures the reflectance signature of visible red and near-infrared parts of spectrum of green plants, providing an indication of the level of green coverage of the earth surface. The maximum

1129 NDVI for all seasons was used to define the average level of greenness of each urban area. A
1130 full description of the methodology can be found in the Appendix.

1131 In 2019, only 8.5 % of global urban centres had very high to exceptionally high levels of
1132 greenness, with five capital cities – Colombo, Washington DC, Dhaka, San Salvador, and
1133 Havana – highlighted (Figure 9). Concerningly, 9.9% of urban centers, home to over 156
1134 million people and including 21 capital cities, lie at the opposite end of the spectrum, with
1135 very low levels of urban green space.[40]
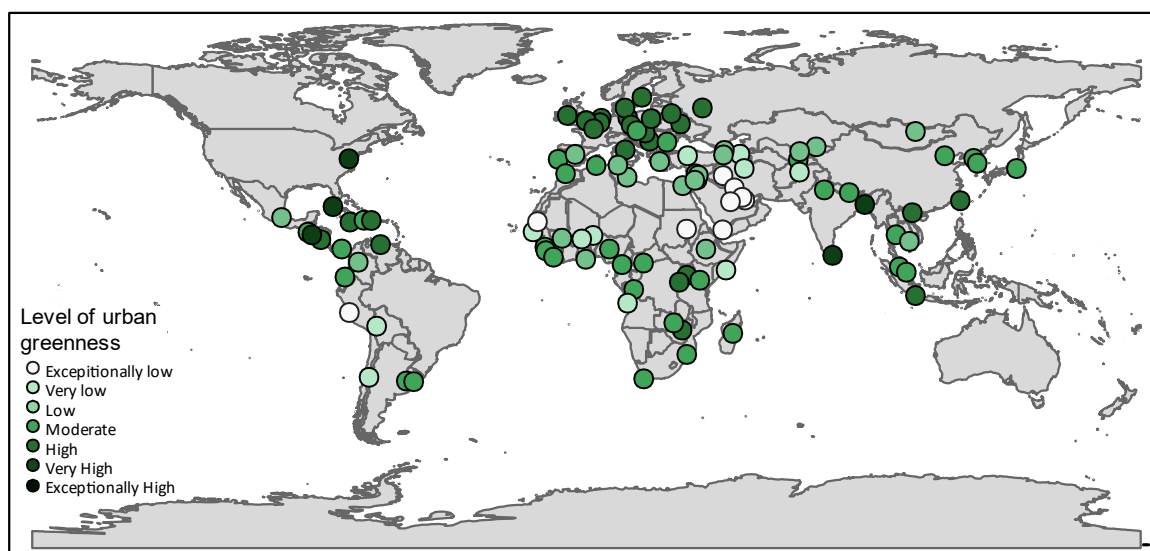
1136
1137 *Figure 9: Urban greenness in capital cities >1 million inhabitants in 2019.*

1138

1139 Indicator 2.4: Spending on Adaptation for Health and Health-Related Activities

1140 *Headline finding: At US$18.43 billion in 2019, global spending on health adaptation rose to*
1141 *5.3% of total adaptation spending, while health-related spending remained flat at*
1142 *approximately 28.4% from 2015 to 2019.*

1143 As noted in the evaluation of national adaptation plans (Indicator 2.1.1), inadequate
1144 financial resource poses the largest barrier to the implementation of adaptation measures.
1145 This indicator tracks health and health-related adaptation spending within the Adaptation
1146 and Resilience to Climate Change dataset from the data research firm, kMatrix, which
1147 includes spend data from 191 countries.[151] Health-specific spend is that which occurs within
1148 the formal healthcare sector. For the 2020 report, an enhanced definition of health-related
1149 spending was developed through an expert review workshop to more accurately categorise
1150 spend. It captures adaptation spending within other sectors (agriculture & forestry, the built
1151 environment, disaster preparedness, energy, transportation, waste, or water) that have a
1152 direct impact on one or more of the basic determinants of health (food, water, air, or

1153   shelter), with a demonstrated link to health outcomes in the literature. A full description of
1154   the methodology can be found in the Appendix.

1155   Climate change adaptation spending within the healthcare sector increased by 12.7% to
1156   US$18.43 billion in 2018/19, compared to 2017/18 data (Figure 10). As a share of all
1157   adaptation spending globally, health adaptation spending is now at 5.3% in 2018/19, above
1158   5% for the first time. The wider measure of health-related adaptation spending increased by
1159   7.2% to US$99.9 billion in 2018/19, although as a share of global adaptation spending, it has
1160   remained more or less constant: 28.4% in 2015/16 and 28.5% in 2018/19.

1161   Grouped by WHO region, spending for health adaptation varies from US$0.48 per capita in
1162   Africa to US$5.92 in the Americas, remaining below US$1 per capita in South East Asia.
1163   Again, taking the broader health-related adaptation spend, a wider variation, ranging from
1164   US$2.63 (Africa) to US$30.82 (Americas), is evident.

1165
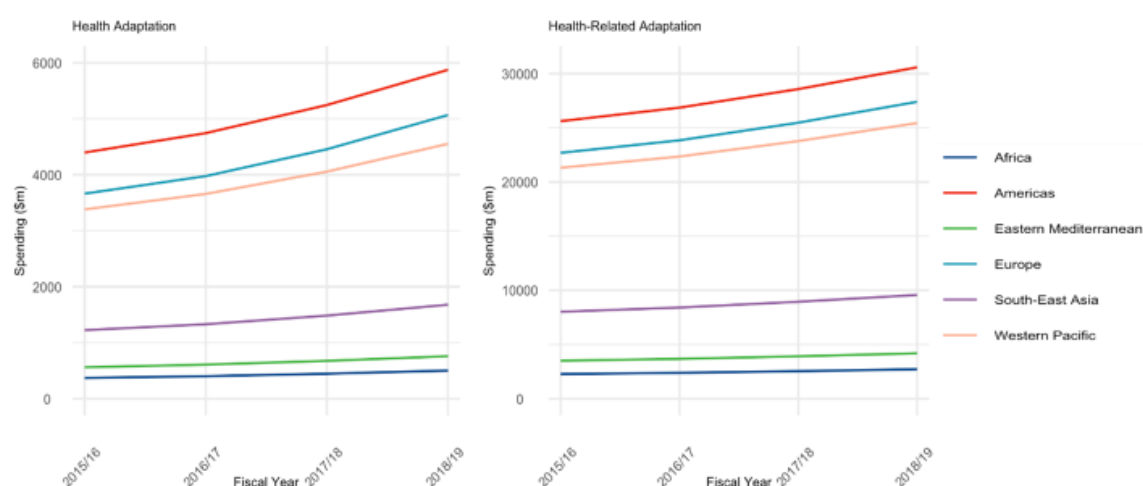
1166
1167   *Figure 10: Adaptation and Resilience to Climate Change (A&RCC) spending for financial years*
1168   *2015/16 to 2018/19 by WHO Region. A) Health A&RCC spending ($m), B) Health-related A&RCC*
1169   *adaptation spending ($m).*

1170

1171

Conclusion

1172

1173   The indicators presented in this section continue to move in a positive direction, with
1174   growing recognition of the impacts of climate change within the health community.
1175   However, there is much more work to do, with a need to move from planning to
1176   implementation, and to better engage with other sectors of society in adaptation
1177   interventions (Indicators 2.1.2, 2.1.2, and 2.2). The IHR core capacity scores show a need for
1178   support across many African and Eastern Mediterranean countries (Indicator 2.3.1),
1179   requiring additional engagement and resource.

1180   Global spending trends have shown promise over recent years for health and health-related
1181   adaptation (Indicator 2.4), however governments remain unable to fully implement their
1182   national health adaptation plans (Indicator 2.1.1). The findings here reiterate the need to
1183   strengthen underlying health systems and create multi-sectoral alignment to protect human
1184   health, particularly for the most vulnerable populations. COVID-19 has dramatically altered
1185   the pattern of healthcare demand, with health systems restructuring services overnight.[152]
1186   While the full impact of these changes are unclear, the rapid introduction of new online and
1187   telemedicine services brings many synergies with efforts to reduce the emissions of the
1188   healthcare sector, and with those to increase service delivery resilience. As governments
1189   continue to respond to the public health and economic effects of COVID-19, it will be
1190   important to align these priorities and ensure that enhanced preparedness for future
1191   pandemics also confers increased capacity to respond to climate change.

1192

Section 3: Mitigation Actions and Health Co-Benefits

In 2018, GHG emissions rose to an unprecedented 51.8 GtCO$_2$e (55.3 GtCO$_2$e including land use change), with fossil fuel emissions from transport, power generation, and industry accounting for 72%.[153] The vast majority of the growth in emissions, the economy, and the demand for energy occurred in low- and middle-income countries, despite global economic headwinds.[154]

COVID-19 has had a profound effect on the global economy and on emissions. Ongoing volatility makes the projections of any long-term effects challenging, although daily CO$_2$ emissions were 17% lower in April 2020 compared with April 2019, with some countries experiencing emissions reductions of up to 26%.[155] Current estimates suggest that global emissions will fall by 8% in 2020 as a result of both the economic downturn, and restrictions to local and international travel.[22,155] As efforts to revitalise the economy take effect, aligning such interventions with those necessary to mitigate climate change will allow governments to generate a synergistic response, improving public health in the short-term and in the long-term.

If carefully planned and implemented, these interventions will yield major health benefits, underlining the importance of a "health in all policies" approach.[156,157] Highlighting this practice, the following section tracks climate change mitigation efforts in the sectors most relevant to public health: power generation and air pollution (Indicators 3.1.1-3.1.3 and 3.3); household energy and buildings (Indicator 3.2); transport (Indicator 3.4); diets and agriculture (Indicators 3.5.1 and 3.5.2); as well as mitigation within the healthcare sector (Indicator 3.6). New in the 2020 report are indicators of the national emissions from agricultural consumption (Indicator 3.5.1) as well as the associated premature mortality from unhealthy and emissions-intensive diets (Indicator 3.5.2). The methodologies of each of the existing indicators have also improved, particularly Indicator 3.6, which, based on feedback, has been revised to better estimate emissions from the healthcare sector.

Importantly, this section must be interpreted with the understanding that enhanced ambition is urgently required, and that countries will need to increase the strength of their mitigation commitments within the Paris Agreement's NDCs by a factor of three to achieve a 2°C target, and by a factor of five for 1.5°C.[153]

3.1 Energy System and Health

Indicator 3.1.1: Carbon Intensity of the Energy System

1226 *Headline finding: The carbon intensity of the global primary energy supply has remained flat*
1227 *for the last three decades. Whilst in 2017 it was at its lowest since 2006, it still remained*
1228 *0.4% higher than 1990 levels.*

1229 As fossil fuel combustion in the energy system continues to be the biggest source of GHG
1230 emissions, mitigation in this area is key to meeting the commitments of the Paris
1231 Agreement. This indicator tracks the carbon intensity of the global energy system, expressed
1232 as the CO_2 emitted per terajoule of total primary energy supply (TPES), with methods and
1233 data described in the Appendix.[158,159]

1234 The carbon intensity of the global energy system has barely altered in almost 30 years: in
1235 2017 it was 0.4% higher than in 1990 (Figure 11). Regional values have changed
1236 substantially, however, with reductions in the carbon intensity of the USA and north and
1237 western Europe now 12% and 20% lower than 1990 levels. China's carbon intensity of TPES
1238 remains high at 72 tCO_2/TJ, however it is decreasing, and in 2017 was 4% lower than its
1239 peak in 2013. Early statistics for 2020 suggest that global demand for all fossil fuels has
1240 reduced in the first quarter due to COVID-19, and will continue to decline across the year,
1241 with resulting reductions in emissions.[22] However, without targeted intervention, emissions
1242 could rebound, as they did following the 2008-2009 global financial crisis, where a 1.4%
1243 decrease in CO_2 emissions in 2009 was offset by a 5.9% rise in 2010.[160]

1244

1245
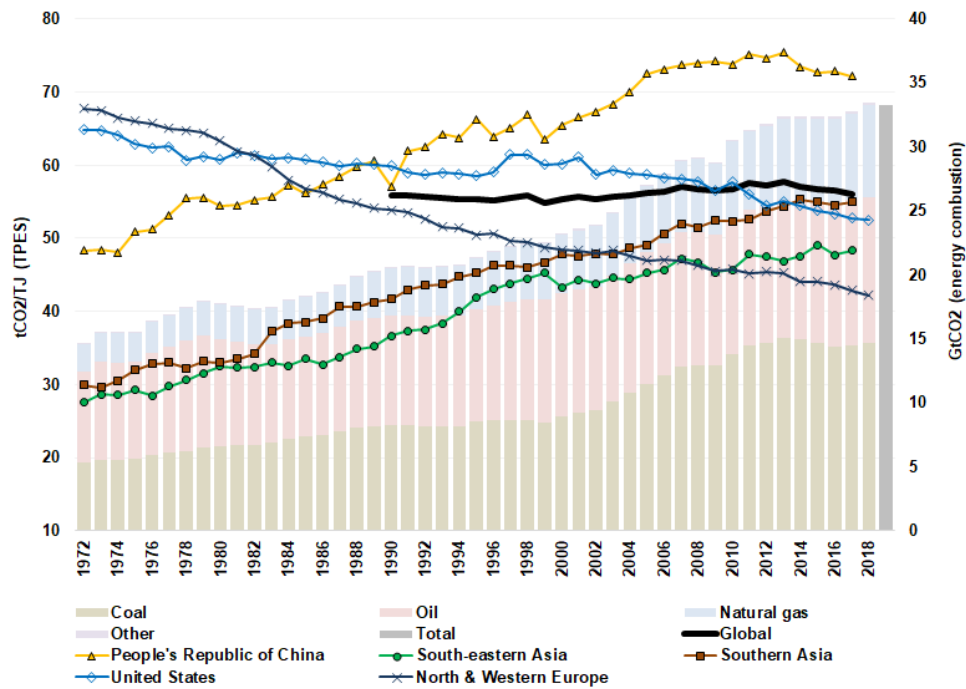
1246
1247 *Figure 11: Carbon intensity of Total Primary Energy Supply (TPES) for selected regions and countries,*
1248 *and global CO₂ emissions by fuel type, 1971-2019. Carbon intensity trends are shown by trend line*
1249 *(primary axis) and global emissions by stacked bars (secondary axis). This carbon intensity metric*
1250 *estimates the tonnes of CO₂ for each unit of total primary energy supplied (tCO₂/TJ). For reference,*
1251 *carbon intensity of fuels (tCO₂/TJ) are as follows: coal 95-100, oil 70-75, and natural gas 56.*

1252

1253 Indicator 3.1.2: Coal Phase-Out

1254 *Headline finding: Global energy supply from coal in 2018 increased by 1.2% from 2017 and*
1255 *was 74% higher than in 1990.*

1256 Coal combustion continues to be the largest contributor to emissions from the energy
1257 sector, and is a major contributor to premature mortality due to air pollution (Indicator 3.3).
1258 The phase-out of coal-fired power is therefore an important first step in the mitigation of
1259 climate change. This indicator reports on progress towards a global phase-out, tracking the
1260 TPES from coal, as well as coal's share of total electricity generation, with methods provided
1261 in full in the Appendix.[161]

1262 Global coal use for energy increased by 1.2% from 2017 to 2018, and while it remains below
1263 its 2014 peak, it has increased by 74% overall since 1990. China, responsible for 52% of
1264 global coal consumption, has driven the rise in recent years, counteracting a 2017-2018

1265 reduction in coal use from other major economies such as Germany (-6%), the USA (-4.2%),
1266 Australia (-3.3%), and Japan (-1.2%). Importantly, Figure 12 makes clear that this is not the
1267 full picture: China's share of coal in its power generation is falling rapidly, from 80% in 2007,
1268 to 66% in 2018, as it moves to other sources to meet rising demand for electricity. Likewise,
1269 northern and western Europe have seen falls in their share of coal power, from 21% in 2013
1270 to 13% in 2018.

1271 As a result of the COVID-19 pandemic, as well as cheap oil and continued growth in
1272 renewables, global demand for coal fell by almost 8% in the first quarter of 2020, where it is
1273 expected to remain throughout the year.[22] Additionally, Austria and Sweden closed their
1274 last coal-fired power plants in April 2020, with other countries soon to follow.[162]

1275

1276
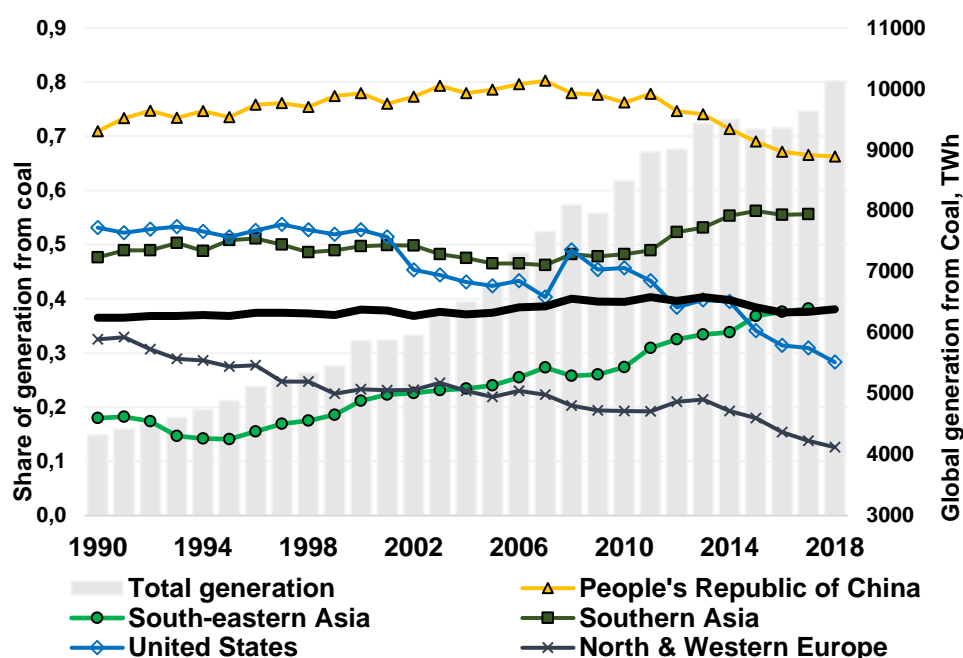1277 *Figure 12: Share of electricity generation coal in selected countries and regions, and global coal*
1278 *generation. Regional shares of coal generation are shown by the trend lines (primary axis) and total*
1279 *coal generation by the bars (secondary axis). Global share of generation from coal is shown with the*
1280 *thick black line. Data series are shown to at least 2017 and extended to 2018 where data allows.*

1281

1282

Indicator 3.1.3: Zero-Carbon Emission Electricity

1284 *Headline finding: The average annual growth rate in power generation from wind and solar*
1285 *was 21% globally and 38% in China, from 2010 to 2017, with all forms of low-carbon energy*
1286 *responsible for 33% of total generation, globally.*

1287 Continued growth in renewable energy, particularly wind and solar, is key to displacing fossil
1288 fuels. This indicator tracks electricity generation (in TWh) and the share of total electricity
1289 generation from all low-carbon sources (nuclear and all renewables, including hydro) as well
1290 as renewables (wind and solar, excluding hydro and biomass). A full description of the
1291 methods and data can be found in the Appendix.[161]

1292 Low-carbon electricity generation continues to rise, growing by 10% from 2015 to 2017, to
1293 then account for 33% of total generation. China experienced a 21% increase over the same
1294 period, reaching 1800 TWh and 28% of all electricity produced.

1295 Focussing on wind and solar energy reveals a similar picture, with a global annual rate of
1296 21% between 2010 and 2017. China saw an even higher growth rate of approximately 38%
1297 per year, due to a rapid increase in solar, reaching 425 TWh in 2017. Despite this, its share
1298 of renewable energy generation remains relatively small at 6.5%; comparable to India's at
1299 5%. Contrary to the decline in demand for fossil fuels, the IEA expect renewable energy
1300 demand to increase in 2020, due to low operational costs compared to fossil fuel sources,
1301 but further policy support is necessary in order to continue this growth.[22,163]

1302
1303 Indicator 3.2: Clean Household Energy

1304 *Headline finding: Primary reliance on healthy fuels and technology for household cooking*
1305 *continued to rise, reaching 63% in 2018. However total consumption of zero emission energy*
1306 *for all household needs remains low, at 26%.*

1307 The use of unhealthy and unsustainable fuels and technologies for cooking, heating and
1308 lighting in the home contributes both to GHG emissions and to dangerous concentrations of
1309 household air pollution.[164] Primary reliance on such fuels and technologies for cooking is
1310 particularly problematic, resulting in recurrent direct exposure to high concentrations of
1311 poor quality air, causing over 3.8 million premature deaths every year.[165] This
1312 disproportionately affects women and children, who in many cultural contexts spend more
1313 time in the home, may be in charge of food preparation, and face threats to their safety
1314 associated with the gathering of cooking fuels.[164]

1315 This indicator draws on national surveys collected by the WHO across 194 countries, to track
1316 the proportion of the population using clean fuels and technologies for cooking, defined

1317 those whose emission rate targets meeting WHO air quality guidelines. It also tracks zero-
1318 emission energy usage in the residential sector, measured as fuels with both zero GHG and
1319 zero particulate emissions at the point of use (mainly electricity and renewable heating)
1320 using data from the IEA.[161]

1321 In 2018, 63% of the global population relied primarily on clean fuels and technologies for
1322 cooking, an increase of 26% since 2000. In China, this proportion increased from 43% in
1323 2000 to 64% in 2018, while in Viet Nam it increased from 13% to 64% over the same period
1324 (Figure 19). However, little progress has been made in Sub-Saharan Africa, where only 15%
1325 of households rely on clean fuels and technology for cooking. Importantly, overall use of
1326 zero emission energy in the home (for all sources, including heating and lighting) remains
1327 low, at 26% globally, increasing by only 2% per year since 2010 (Figure 13).

1328 This section of the report is continuously evolving to understand the health co-benefits of
1329 mitigation efforts, and is now able to present findings from a new indicator under
1330 development, that tracks mortality from household air pollution. Taking data on fuel and
1331 stove types used for cooking as well as typical housing ventilation characteristics, this
1332 indicator calculates household fine particulate matter ($PM_{2.5}$) exposure, both from cooking
1333 and from air pollution infiltrating from outside. A full explanation of the methods is
1334 described in the Appendix. Here, the estimated effect of household factors on deaths
1335 attributable to $PM_{2.5}$ pollution in 2018 are presented for selected countries (Figure 14). In
1336 the middle-income countries assessed, the use of solid fuels for cooking is combined with
1337 poor housing ventilation to increase mortality from $PM_{2.5}$ exposure. For other mostly high-
1338 income countries, housing design and extract ventilation are preventing ambient air
1339 pollution from entering the home. Combined with the use healthy cooking fuels, this results
1340 in a net negative effect on total (both household and ambient) $PM_{2.5}$ attributable mortality,
1341 demonstrating a clear co-benefit of mitigation.

1342

1343

1344
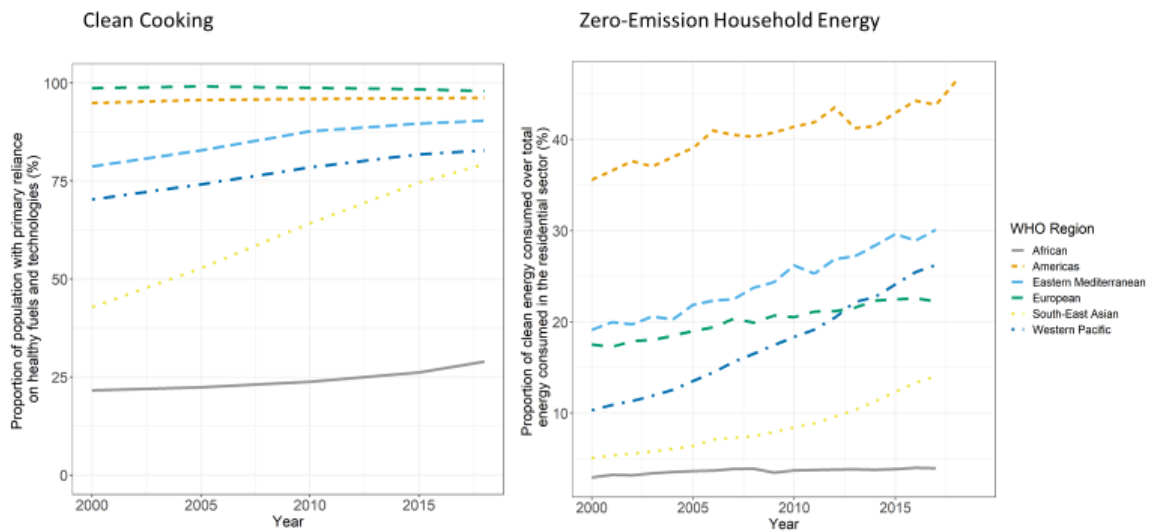
Figure 13: Household energy usage: proportion of population with primary reliance on healthy fuels
and technology for cooking by WHO region 2000-2018 (left); and proportion of clean energy
consumption in the global residential sector, 2000-2016 (right). Proportion is measured as fuels with
no emissions at point of use (not generation) over total residential sector consumption. Electricity
comprises 75% of total clean energy use in 2016.

1350
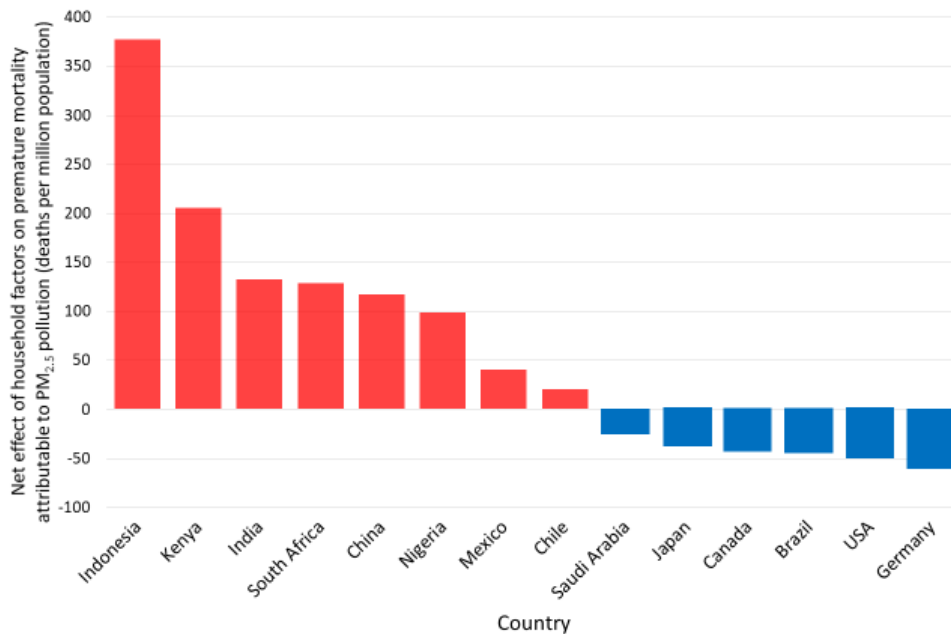
1351
1352 *Figure 14: Estimated net effect of housing design and indoor fuel burning on premature mortality due*
1353 *to air pollution in 2018.*

Indicator 3.3: Premature mortality from ambient air pollution by sector

Headline finding: Premature deaths from ambient particulate pollution attributed to coal use are rapidly declining, from 440,000 in 2015 to 390,000 in 2018. However, total deaths from ambient particulate pollution have increased slightly over this time period, from 2.95 million to 3.01 million, highlighting the need for accelerated intervention.

Many of the leading contributors to global GHG emissions also contribute to ambient air pollution, disproportionately impacting on the health of low-socioeconomic communities.[166] Indeed, some 91% of deaths from ambient air pollution come from LMICs.[167] This indicator tracks the source-attributable premature mortality from outdoor ambient air pollution. The methods remain unchanged and are described in the Appendix.[168,169]

Trends in air pollution mortality vary by world region, with decreases in Europe and China as a result of the implementation of emission control technologies and reductions in the use of raw coal in the power and residential sectors.[170] The overall number of deaths attributable to ambient $PM_{2.5}$ in 2018 is estimated at 3.01 million, a slight increase from 2.95 million deaths in 2015. Nonetheless, the total and per-capita deaths attributable to coal combustion have decreased from roughly 440,000 in 2015 to fewer than 390,000 in 2018 (Figure 15). Decreases are also seen in the contribution from biomass burning to ambient $PM_{2.5}$ deaths (about 410,000 deaths in 2015 decreasing to 360,000 in 2018), mostly due to increasing access to cleaner household fuels, although 2.6 billion people still rely on fuelwood combustion in the home.[171]

If measures to respond to the economic fall-out from COVID-19 are aligned with the priorities of the Paris Agreement, transient reductions in air pollution following the sudden halt in economic activities and road transport, could become more permanent, resulting in further improvements in health and air quality in 2020 and into the future.
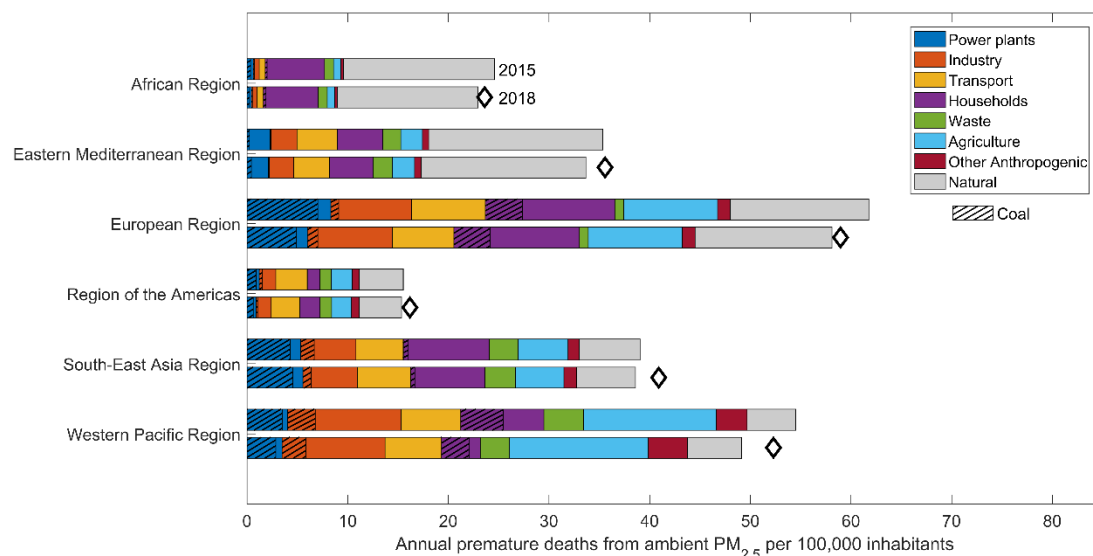
1380 *Figure 15: Premature deaths attributable to exposure to ambient fine particulate matter (PM₂.₅) in*
1381 *2015 and 2018, by key sources of pollution in WHO-specified regions. Coloured bars: attributable*
1382 *deaths with constant 2015 population structure, diamonds: totals for 2018 when considering*
1383 *demographic changes.*

1384

1385 Indicator 3.4: Sustainable and Healthy Transport

1386 *Headline finding: While fossil fuels continue to dominate the transport sector, the use of*
1387 *electricity rose by 18.1% from 2016 to 2017, and the global electric vehicle fleet increased to*
1388 *more than 5.1 million in 2018 (rising by 2 million in only 12 months).*

1389 The transition to ultra-low emissions vehicles is another essential component of climate
1390 change mitigation. In addition, policies that reduce overall vehicle use and increase walking
1391 and cycling will yield the greatest benefits in terms of reductions in GHG emissions and air
1392 pollution, as well as the health benefits of increased physical activity.[172] Well-designed
1393 public transport and active travel infrastructure can also help reduce inequality and improve
1394 mobility for those who otherwise have limited travel options.[173] For the 2020 report, global
1395 trends in fuel use for road transport are monitored, with methods and data available in the
1396 Appendix.[174]

1397 Global per-capita road transport fuel use increased by 0.5% from 2016 to 2017, with the
1398 rate of growth slowing slightly from previous years (Figure 16). Although fossil fuels
1399 continue to contribute the vast majority of total fuel use, the use of clean fuels is growing at
1400 a much faster pace. Total fossil fuel use for transport increased by 1.7% between 2016 and
1401 2017, compared with 18.1% growth in electricity. From 2017 to 2018, the global electric
1402 vehicle fleet grew by an enormous 64.5%, rising above 5.1 million in 2018. In line with this

1403 rapid growth, there are now more than 5.2 million charging stations available for passenger
1404 vehicles and another 157,000 fast-chargers available for buses worldwide.

1405
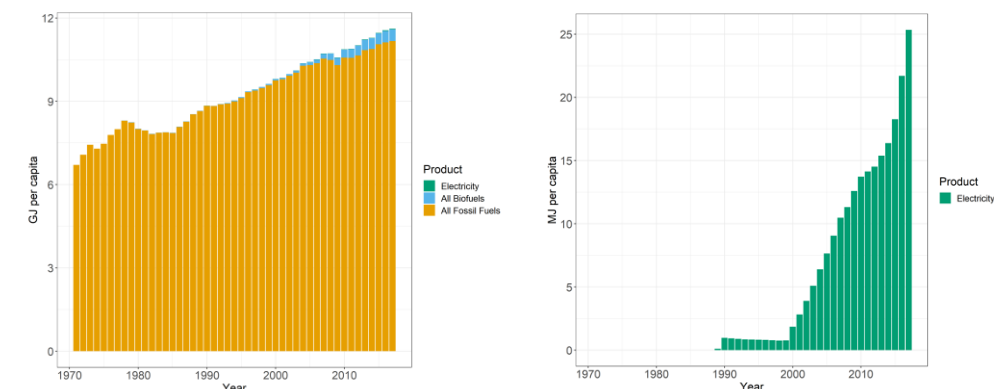
1406
1407 *Figure 16: Per capita fuel use for road transport: A) All fossil fuels, biofuels, electricity; B) Electricity*
1408 *only. NB. The varying scales in y-axes.*

1409

1410

1411 ## 3.5 Food, Agriculture, and Health

1412 ### Indicator 3.5.1: Emissions from Agricultural Production and Consumption

1413 *Headline finding: Ruminant livestock continue to dominate agriculture's contribution to*
1414 *climate change, responsible for 56% of its total emissions, and 93% of all livestock emissions*
1415 *globally. This represents a 5.5% increase in the per capita emissions from beef consumption*
1416 *since 2000, which is particularly concerning, given the sharp rise in population over this time*
1417 *period, and the health impacts of excess red meat consumption.*

1418 The food system is responsible for 20-30% of global GHG emissions, with the majority
1419 originating from meat and dairy livestock.[175] Improved for the 2020 report, agricultural
1420 emissions from countries' production and consumption (adjusting for international trade)
1421 are tracked using data from the FAO, with a full description of methods and data provided in
1422 the Appendix.[176-178] While countries' emissions are typically measured on a production
1423 basis, it is their consumption that generates the demand, and results in diet-related health
1424 outcomes.

1425 Overall emissions from livestock production have increased by 16% since 2000 to over 3.2
1426 billion tonnes of CO_2e in 2017. Ruminants contribute 93% of total livestock emissions, with
1427 non-dairy cattle contributing 67% of this. Moving to consumption emissions, beef industry

1428   products dominate, both in absolute and per-capita terms (Figure 17). Average beef
1429   consumption emissions were 402 kg CO_2e per person in 2017, compared to 380 kg CO_2e per
1430   person in 2000.

1431   Ultimately, effective mitigation will maximise human health while reducing food and
1432   agricultural emissions, however no one diet is applicable everywhere, and there are
1433   important nuances and variations to be considered across regions and countries. Excessive
1434   consumption of red meat brings significant health consequences, as outlined below, and
1435   less emissions-intensive plant-based sources are important alternatives, particularly in
1436   Europe and the Americas, where per capita emissions are high. In other parts of the world,
1437   sustainable farming and agricultural practices are being implemented to meet the
1438   nutritional requirements of rapidly growing populations while also keeping emissions low.[179]
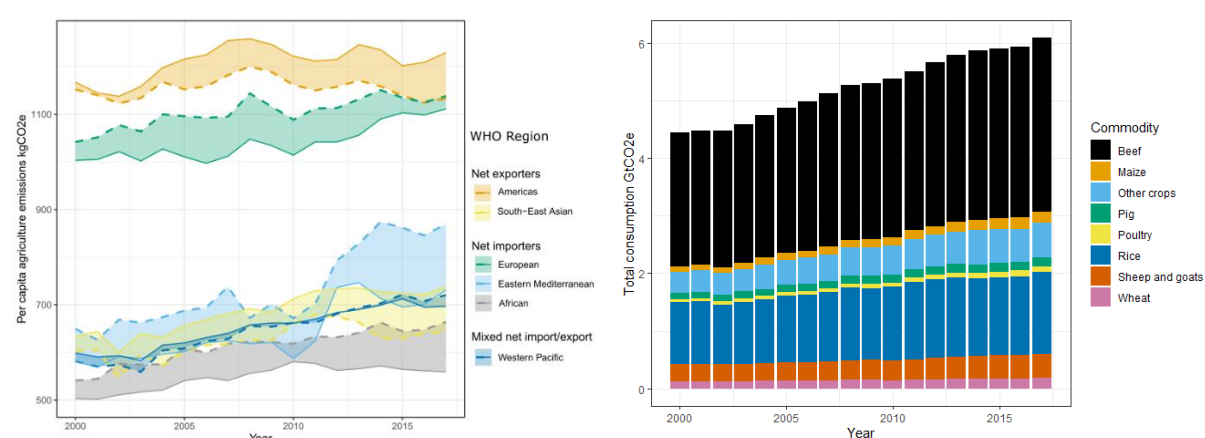
1439
1440 *Figure 17: Agricultural production and consumption emissions 2000-2017 calculated using FAO trade*
1441 *data: per capita production (solid line) and consumption (dotted line) emissions by WHO region (left);*
1442 *Global agricultural consumption emissions by commodity (right).*

1443

1444 Indicator 3.5.2: Diet and Health Co-Benefits

1445 *Headline finding: The global number of deaths due to excess red meat consumption has risen*
1446 *to 990,000 in 2017, a 72% increase since 1990.*

1447   Unhealthy diet is one of the leading risk factors for premature death, both globally and in
1448   most regions.[110] Combined with a range of food-system-wide interventions, it is possible to
1449   achieve dietary change consistent with the Paris Agreement and the SDGs, by reducing
1450   reliance on red meat consumption and prioritising healthier alternatives, with a variety of
1451   diets and choices available depending on the region, individual, and cultural context.[180,181]
1452   New to the 2020 report, this indicator presents the change in deaths attributable to dietary
1453   risks, by focusing in on one particular area – the consumption of excess red meat. Here, it

1454   links food consumption from the FAO's food balance sheets with dietary and weight-related
1455   risk factors, with a full description of methods and data presented in the Appendix.[112,182]

1456   Globally, diet and weight-related risk factors accounted for 8.8 million deaths in 2017, which
1457   represented 19% of total mortality, with little overall change since 1990. The regions with
1458   the largest ratio of diet-related deaths include the Eastern Mediterranean (28%), Europe
1459   (25%), and the Americas (22%).High red meat consumption was responsible for 990,000
1460   deaths globally in 2017 (Figure 18). The greatest contribution to this total came from the
1461   Western Pacific, where red meat consumption was responsible for an estimated 411,500
1462   deaths (3.3% of all deaths) and, while there has been an overall improvement in dietary risk
1463   factors in Europe, the share of all deaths attributable to red meat consumption still accounts
1464   for 3.4% (306,800 deaths) .

1465
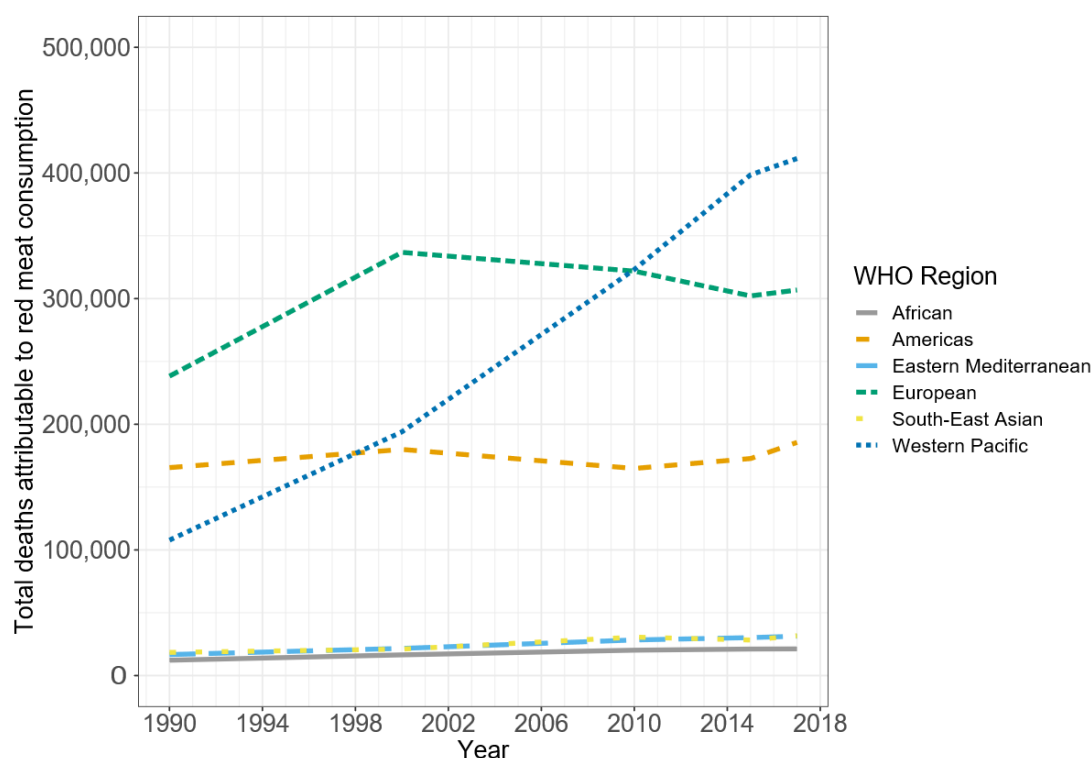
1466
1467   *Figure 18: Deaths attributable to high red meat consumption 1990-2017 by WHO region.*

1468

1469

Indicator 3.6: Mitigation in the Healthcare Sector

Headline finding: The healthcare sector was responsible for approximately 4.6% of global GHG emissions in 2017, with substantial variations in per capita emissions and healthcare access and quality.

Healthcare is among the most important sectors in managing the effects of climate change and, simultaneously, it has an important role to play in reducing its own carbon emissions (Panel 4). Emissions from the global healthcare sector are modelled using environmentally extended multi-region input-output (EE MRIO) models combined with WHO healthcare expenditure data.[183-187] Based on external review and feedback, the methodology improvements include adjustments in the EE MRIO satellite accounts that reflect recent shifts in emissions intensities, particularly in the energy sector, with a full description of methods and additional analysis in the Appendix.

In updated results to 2017, the healthcare sector contributed approximately 4.6% of global GHG emissions, a rise of 6.1% from 2016. On a per capita level, comparing emissions alone fails to capture vital differences in health outcomes among countries, including access to care. Similarly, increases in emissions in a single country over time may reflect additional healthcare spending that improves population health. Figure 19 plots per capita healthcare GHG emissions against the Healthcare Access and Quality (HAQ) Index.[184] There is a clear positive relationship between the two, up to 400 kgCO$_2$e per person. Above this point, countries achieve very similar HAQ levels with vastly different emissions profiles. For example, France, Japan, and the USA have very high HAQ attainment, with per capita emissions ranging from 350 kgCO$_2$e, through to 1,220 kgCO$_2$e, and 1,720 kgCO$_2$e respectively, suggesting that much of healthcare can achieve high-quality patient outcomes, with significantly reduced emissions.
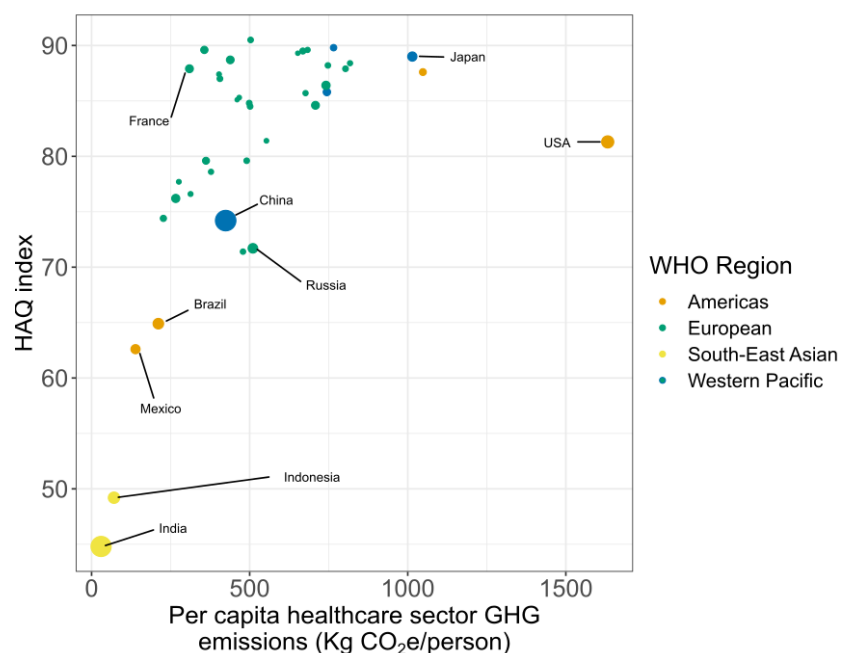
Figure 19: National per capita healthcare GHG emissions against the Healthcare Access and Quality Index for 2015.

1496
1497

1498

Panel 4: For a Greener NHS

With over 1.5 million employees, England's National Health Service (NHS England) is the largest single employer in Europe and is the largest single-payer healthcare system in the world, with an annual budget of £134 billion. While providing high-quality healthcare to a population of almost 56 million, NHS England contributes 4-5% of the country's total GHG emissions. Accountable to both NHS England and Public Health England, the Sustainable Development Unit was founded in 2008 to ensure the health service met its commitments under the UK Climate Change Act. Since then, the NHS has achieved impressive reductions in GHG emissions whilst maintaining high standards of care and reducing costs.[188] In January 2020, NHS England announced its commitment to become the world's first 'net zero health system', alongside its new campaign "For a greener NHS".[189] A new baseline of NHS England's current carbon footprint was quantified, identifying the different sources of emissions using a hybrid model of bottom-up measurements of direct emissions (on-site fossil fuel use, fleet and transport, and anaesthetic gases) and energy use and top-down MRIO-based measurements to estimate other indirect emissions (including upstream energy system emissions, pharmaceutical procurement, and patient use of metered dose inhalers). NHS England is now working to develop a strategy for how and when Net Zero emissions can be achieved.

1499   Conclusion

1500   The trends over the past year show a concerning lack of progress in a number of sectors,
1501   including a continued failure to reduce the carbon intensity of the global energy system, a
1502   rise in the use of coal-fired power, and rising agricultural emissions and premature deaths
1503   from excess red meat consumption. This is in-part counteracted by the growth of renewable
1504   energy and improvements in low-carbon transport. While these continue to rise at a pace, it
1505   is important to consider that they are starting from a low baseline.

1506   In many cases, it is likely that 2020 will be an inflection point for a number of indicators
1507   presented over the coming decade, with the direction of future trends yet to be seen..
1508   Ensuring that the recovery from the pandemic is synergistic with the long-term public health
1509   imperative of responding to climate change will be vital in the coming months, years, and
1510   decades.

1511
1512

Section 4: Economics and Finance

Section 1 described the emerging human symptoms of climate change, while Sections 2 and 3 detailed efforts to adapt and mitigate against the worst of these effects. In turn, Section 4 examines the financial and economic dimensions of both the impacts of climate change, and efforts to respond.

The Intergovernmental Panel on Climate Change (IPCC) estimate limiting warming to 1.5°C would require annual investment in the energy system equivalent to around 2.5% of global GDP, through to 2035.[85] Such investment would both limit the cost of the damage from climate change (up to US$4 trillion per year by 2100 from a 3°C world as compared to a 2°C world) and generate a range of other economic benefits (including the creation of new technologies and industries) and health benefits from avoiding the effects of climate change current carbon-intensive activities. Once such factors are considered, the overall economic implications of limiting warming to 1.5°C are likely to be positive – particularly if policy responses are accelerated as soon as possible to a level commensurate with the scale of the challenge. Recent estimates suggest that investment to "bend the curve" from the world's current path, to a limited temperature rise of 1.5°C by 2100, would generate global net benefit of US$264-610 trillion (3.1-7.2 times of the size of the global economy in 2018).[12]

The global economy will look substantially different following the recovery from the COVID-19 pandemic. As governments around the world grapple with the challenge of restarting their economies, it will be important to ensure these efforts are aligned with the response to climate change. If the enormous fiscal stimulus that will be required is directed away from high-carbon, and towards low-carbon infrastructure and activities, an opportunity to permanently bend the curve presents itself. Metrics examining these core concepts are currently tracked in this report, allowing future data to reveal the long-term effect of COVID-19 on the low-carbon economy.

The nine indicators in this section fall into two broad domains. The first is the health and economic costs of climate change and its mitigation (Indicators 4.1.1 to 4.1.4). This includes two new indicators for the 2020 report, on the economics of heat-related mortality and the potential reduction in earnings from heat-related labour capacity loss (Indicators 4.1.2 and 4.1.3). The second domain examines the economics of the transition to zero-carbon economies (Indicators 4.2.1 to 4.2.5), which is fundamental to the improvement of human health and wellbeing. This theme also includes a new indicator, (Indicator 4.2.5), which merges three indicators presented in previous reports (on fossil fuel subsidies, the strength and coverage of carbon prices, and carbon pricing revenues) to examine the "net" carbon prices in place around the world.

1549   ## 4.1 Health and Economic Costs of Climate Change and Benefits from Mitigation

1550   ### Indicator 4.1.1: Economic Losses due to Climate-Related Extreme Events

1551   *Headline finding: Economic losses from climate-related extreme events in 2019 were nearly*
1552   *five times greater in low-income economies than high-income economies, and with just 4%*
1553   *of these losses insured, compared to 60% in high-income economies.*

1554   Section 1 presented the evidence linking the impacts of climate change to human health
1555   and wellbeing. The loss of physical infrastructure (agricultural land, homes, health
1556   infrastructure) due to such events will further exacerbate these health impacts. This
1557   indicator tracks the total annual economic losses (insured and uninsured) that result from
1558   climate-related extreme events. The methodology is described in full in the Appendix, which
1559   has changed compared to previous years.[190,191]

1560   In 2019 there were 236 recorded climate-related extreme events, with absolute economic
1561   losses totalling US$132 billion. Although most of these losses occurred in high-income
1562   economies, when normalised by GDP, the value of total economic losses in low-income
1563   countries is nearly five times greater. In addition, while 60% of losses in high-income
1564   economies were insured, this reduces to 3-5% for other income groups. It is important to
1565   note that, when normalised by GDP, relative economic losses have been decreasing, while
1566   the number of total extreme events is increasing, suggesting that adaptation and prevention
1567   are reducing their impacts.[192]

1568

1569   ### Indicator 4.1.2: Costs of Heat-Related Mortality
1570
1571   *Headline finding: In 2018, the monetised value of global heat-related mortality reached*
1572   *0.37% of Gross World Product, compared to 0.23% in 2000. Europe suffered the most in*
1573   *2018, with costs equal to the average income of 11 million of its citizens, and 1.2% Gross*
1574   *National Income.*

1575   As Indicator 1.1.3 highlights, rising temperatures and extremes of heat are resulting in
1576   worsening morbidity and mortality for populations around the world. The 2020 report
1577   introduces a new indicator, which considers the economic impact of this, by tracking the
1578   monetised value of global heat-related mortality. To do so, it makes use of the value of a
1579   statistical life (VSL), drawing on estimates produced for the Organisation for Economic Co-
1580   operation and Development (OECD) for those countries, making use of a fixed ratio of VSL to
1581   gross national income (GNI) for non-OECD countries, and applying this to the heat-related
1582   mortality data from Indicator 1.1.3.[193,194] To address any distributional effects, and more
1583   accurately capture the economic harm that climate change presents to low- and middle-
1584   income countries, two indices have been calculated. The value of mortality is presented as a

1585 proportion of total GNI, and as the average income per person this loss would be equivalent
1586 to, in a given country and region. A full description of the methods, data, caveats and
1587 further analysis are described in the Appendix.

1588 As global heat-related mortality increased from 2000, so too did the monetised cost of
1589 these deaths. At a global level and represented as a proportion of Gross World Product
1590 (GWP), the cost increased from 0.23% in 2000 to 0.37% in 2018. Due the high number of
1591 heat-related deaths, Europe was the worst affected, reaching a cost equivalent to the
1592 income of 11 million of its citizens in 2018 (led by Germany at 1.9 million, Figure 20), and
1593 1.2% of regional GNI. While the value in terms of proportion of GNI for the Western Pacific
1594 and South East Asia were comparatively low at 0.43% and 0.19% respectively, these impacts
1595 are more substantial when considered against the average income in those regions.

1596
1597
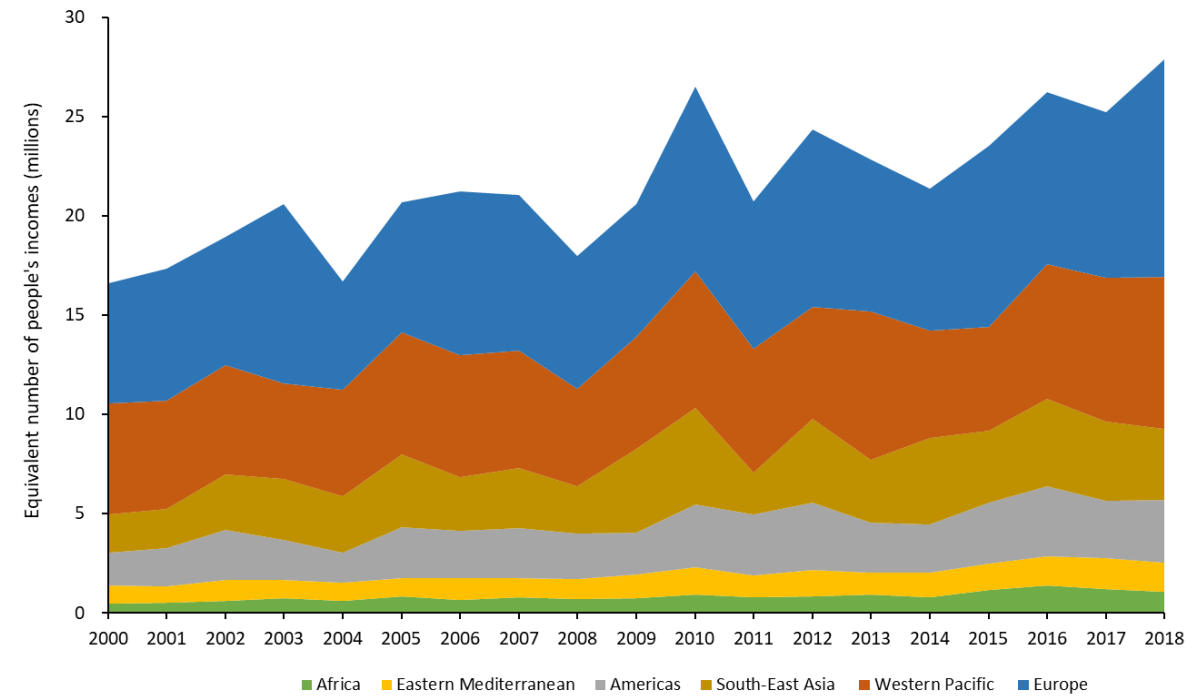
1598
1599 *Figure 20: Monetised value of heat-related mortality represented as the number of people to whose*
1600 *income this value is equivalent, on average, for each WHO region.*

1601

1602 Indicator 4.1.3: Loss of Earnings from Heat-Related Labour Capacity Reduction

1603 *Headline finding: Rising temperatures make outdoor labour increasingly difficult, often*
1604 *resulting in public health and economic consequences for a wide range of occupations. If*

1605 *borne out, the heat related reduction in labour capacity experienced would result in earnings*
1606 *losses equivalent to an estimated 4-6% of GDP in lower-middle income countries tracked.*

1607 Higher temperatures, driven by climate change, are affecting people's ability to work
1608 (Indicator 1.1.4). This new indicator considers the loss of earnings that could result from
1609 such reduced capacity, compounding the initial cause of ill health and impacting on
1610 wellbeing. It adopts the outputs of Indicator 1.1.4 for 25 countries, selected by the impact
1611 their workers experience and for geographical coverage, and combines these with data on
1612 average earnings by country and sector held in the International Labor Organization (ILO)
1613 databases.[42] These estimates will be modified by a variety of factors, ranging from whether
1614 or not sick leave was taken, the presence of workers sick pay rights, and the availability of
1615 shade. A full description of the methods and additional analysis is provided in the Appendix.

1616 When taken as a share of GDP, low- and lower middle-income countries are the hardest hit,
1617 with losses predominantly seen in agriculture, despite this being on average the lowest paid
1618 of the sectors considered. By 2015, averaged estimated earnings losses reached the
1619 equivalent of 4-6% of GDP for lower-middle income countries tracked including Indonesia,
1620 India, and Cambodia, and between 0.6-1% for upper-middle income countries, including
1621 China, Brazil, and Mexico.

1622

1623 Indicator 4.1.4: Economics of the Health Impacts of Air Pollution
1624
1625 *Headline finding: Across Europe, ongoing reductions in particulate air pollution from human*
1626 *activity were seen from 2015 to 2018. If held constant, this improvement alone would lead*
1627 *to an annual average reduction in years of life lost to the current population worth $8.8*
1628 *billion.*

1629 As described in Indicator 3.3, global mortality due to ambient $PM_{2.5}$ pollution has risen from
1630 around 2.95 million in 2015 to 3.01 million in 2018. However, due to improvements in air
1631 quality, including the closure of coal power stations, premature mortality due to air
1632 pollution in Europe has decreased over the same period. This indicator captures the cost of
1633 that change in the European Union (EU) by placing an economic value on the Years of Life
1634 Lost (YLL) that result from exposure to $PM_{2.5}$ from anthropogenic sources, with the methods
1635 and data described in full in the Appendix.[195]

1636 If the population of the EU in 2015 were to experience anthropogenic $PM_{2.5}$ emissions at
1637 2018 levels instead of levels experienced in 2015, consistently over the course of their lives,
1638 the total average economic value of the reduction in YLLs would be around $8.8 billion
1639 (€9.85 billion), every year. Despite this, 2018 $PM_{2.5}$ levels are still damaging to
1640 cardiovascular and respiratory systems, and the total annual average cost to the current
1641 population would still be $116 billion (€129 billion). Based on 2018 levels of air pollution,

1642 the average life lost per person in the EU is 5.7 months, but this loss of life is estimated at
1643 over 8 months per person for Poland, Romania, Hungary, Italy and Belgium (Figure 21).

1644

1645
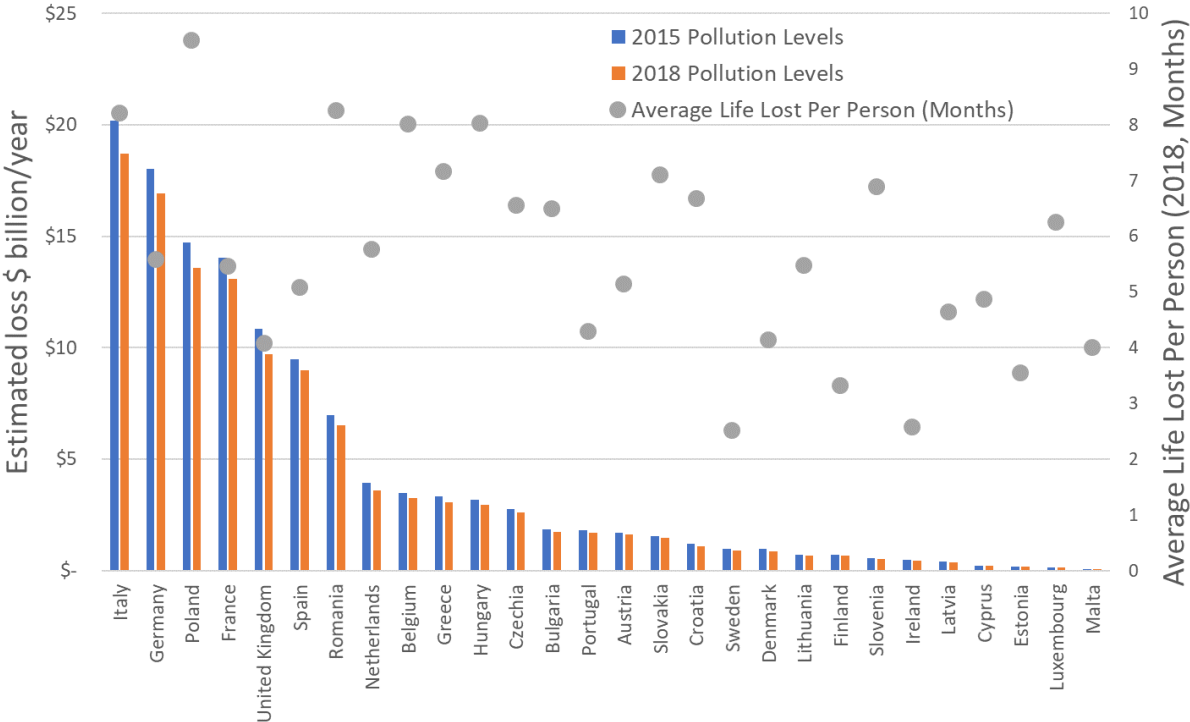
1646
1647 *Figure 21: Annual monetised value of YLLs due to anthropogenic PM2.5 exposure, and average*
1648 *months of life lost per person (2018 pollution levels).*

1649

4.2 The Economics of the Transition to Zero-Carbon Economies

Indicator 4.2.1: Investment in New Coal Capacity

Headline finding: Largely driven by China, investment in new coal capacity has been declining since 2011 and reduced by 6% from 2018 to 2019. Despite this, global coal capacity continues to increase, with fewer coal plant retirements than additions for every year tracked.

As identified in Section 3, coal phase-out is essential, not only for the mitigation of climate change, but also for the reduction of premature mortality due to air pollution. Taking data from the IEA, this indicator points to future coal use, tracking investment in new coal-fired power generation. The data represents 'ongoing' capital spending, with investment in a new plant spread evenly from the year new construction begins, to the year it becomes operational.[196] For the 2020 report, data is presented for key countries and regions, alongside the global trend. Further details on the methods and data are found in the Appendix.

Following the trend since 2011, global investment reduced a further 6% between 2018 and 2019. With a 27% reduction in investments over these two years, China has been driving this decline. Final Investment Decisions (FIDs, the point at which the project's future development is approved) have reached their lowest point in 40 years, with a further 11% reduction in investment forecast for 2020 – driven by declining investment in Asia, in part as a result of COVID-19. However, despite a substantial decline in actual investment, FIDs in China increased in 2019 compared to 2018, and, with the approval of 8 GW of new capacity, reached 2019 levels by March 2020. Additionally, with fewer coal plant retirements than additions in 2019 (and in every year presented), there was an overall increase in global capacity.
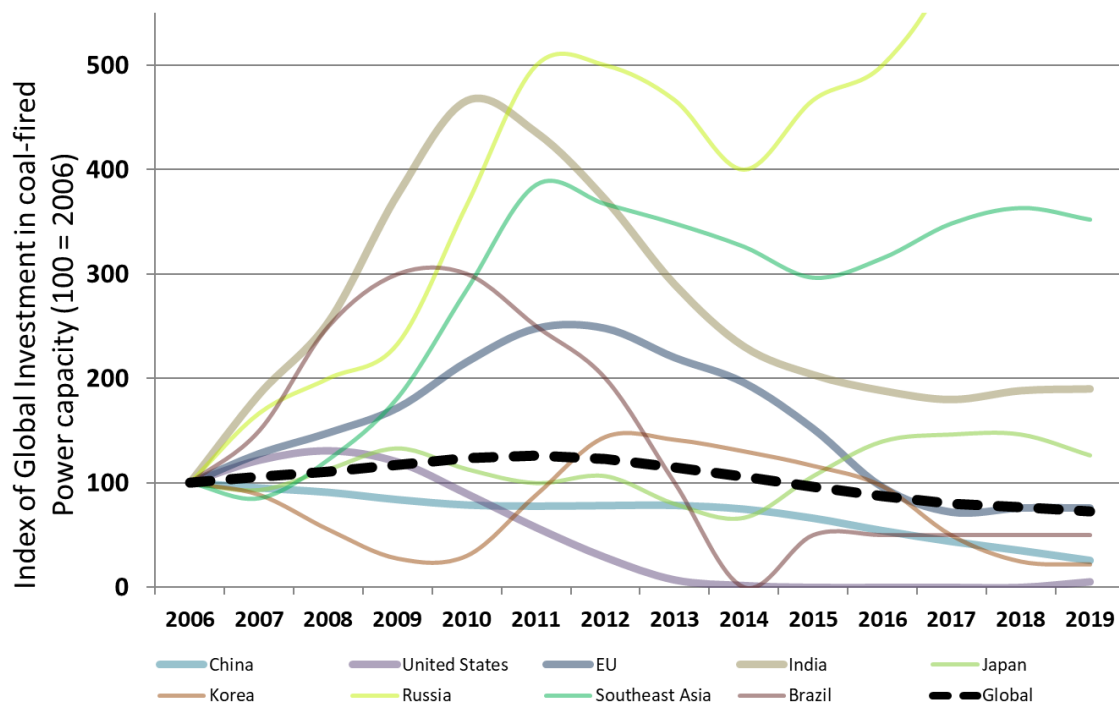
Figure 22: Annual investment in coal-fired capacity 2006-2019 (an index score of 100 corresponds to 2006 levels).

Indicator 4.2.2: Investments in Zero-Carbon Energy and Energy Efficiency

Headline finding: Progress towards zero-carbon energy has stalled in recent years, and investments in zero-carbon energy and energy efficiency have not risen since 2016, and are a long way from the doubling by 2030 required to be consistent with the Paris Agreement.

This indicator monitors annual global investment in these areas, as well as investment in all fossil fuels, complementing and providing a wider context to Indicator 4.2.1, above. Data is sourced from the IEA, and the methodology remains the same as the 2019 report of Lancet Countdown, with hydropower now considered separately and all values presented in US$2019.[196]

Since 2016, investment in global energy supply and energy efficiency has remained relatively stable at just under US$1.9 trillion, with fossil fuel supply consistently accounting for around half this value, and all renewables and energy efficiency combined maintaining a share of 32%. For a pathway consistent with 1.5°C of warming this century, annual investments must increase to US$4.3 trillion by 2030, with investment in renewable electricity, electricity networks and storage, and energy efficiency accounting for at least 50%.[197]

1694 As a result of the COVID-19 pandemic, short-term disruption and long-term reassessments
1695 of likely returns mean that total energy investment is estimated to reduce by 20% in 2020 –
1696 the largest fall ever recorded – with oil and gas supply investment to be reduced by a third.
1697 Renewable investment is likely to fare better than fossil fuel capacity, with investment in
1698 zero-carbon energy (nuclear, hydropower and other renewables) and energy efficiency
1699 projected to jump from 32% to 37% of investment in 2020, due to falling investments in
1700 fossil fuels.[196] Stimulus plans focussed on boosting energy efficiency and renewable energy
1701 will be essential to ensure that the power generation system is on track to meet the SDGs
1702 and the goals of the Paris Agreement.[163]

1703

1704
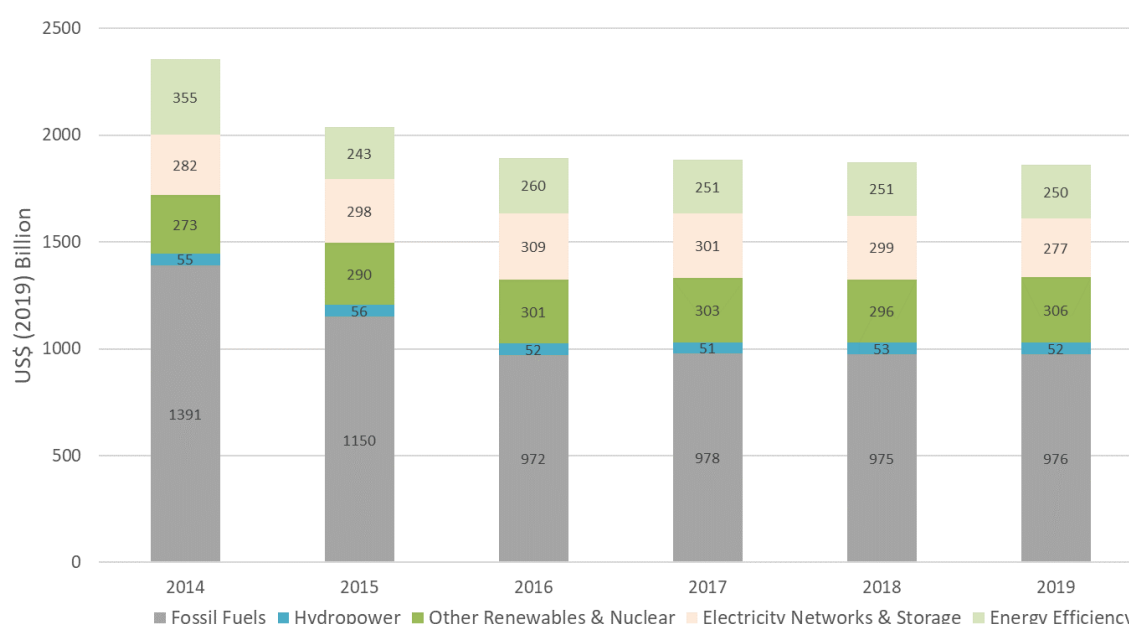
1705 *Figure 23: Annual Investment in energy supply and efficiency.*

1706

1707 Indicator 4.2.3: Employment in Renewable and Fossil Fuel Energy Industries

1708 *Headline finding: Renewable energy provided 11 million jobs in 2018, a 4.2% rise from 2017.*
1709 *Whilst still employing more people overall, employment in fossil fuel extraction declined by*
1710 *3% from 2018 to 2019.*

1711 There is mounting evidence that employees in some fossil-fuel extractive industries,
1712 particularly coal mining, and populations living in close proximity, suffer a greater incidence
1713 of certain illnesses, such as chronic respiratory diseases, cancers and congenital

68

1714 anomalies.[198,199] Combined with increased job certainty, a managed transition of
1715 employment opportunities away from fossil fuel-related industries, and towards low-carbon
1716 industries will result in improved occupational health of employees within the energy
1717 sector. This indicator tracks global direct employment in fossil fuel extraction industries
1718 (coal mining and oil and gas exploration and production) and direct and indirect (supply
1719 chain) employment in renewable energy for the most recent year available, with a full
1720 description of the methods and data available in the Appendix.[200-202]

1721 Around 11 million people globally were employed directly or indirectly by the renewable
1722 energy industry in 2018, representing an increase of 4.2% from 2017. Solar photovoltaic
1723 (PV) continues to provide the largest share of jobs, at over 3.6 million, with employment
1724 also rising in wind, bioenergy, and other technologies. Fossil fuel extraction industries
1725 continue to employ more people globally than all renewable energy industries, although the
1726 number of jobs in 2019 are slightly lower than in 2018, at 12.7 million compared with 13.1
1727 million.

1728 As the demand for fossil fuels declines, planned efforts, including retraining and job
1729 placement is important to ensure the ongoing employment of those currently working in
1730 fossil fuel extraction industries. The same will be true as part of the response to COVID-19,
1731 with structured re-training and deployment programmes for renewable energy potentially
1732 forming an important component of a recovery plan. Indeed, the IEA estimates that such a
1733 strategy, which accelerates the deployment of low-carbon electricity sources, expands
1734 electricity grid access and energy efficiency, and delivers cleaner transport, would create an
1735 additional nine million jobs a year, globally over the next three years.[163]

1736

1737 Indicator 4.2.4: Funds Divested from Fossil Fuels

1738 *Headline finding: The global value of new funds committed to fossil fuel divestment in 2019*
1739 *was US$4.01 trillion, of which health institutions accounted for around US$19 million. This*
1740 *represents a cumulative sum of US$11.51 trillion since 2008, with health institutions*
1741 *accounting for US$42 billion.*

1742 By encouraging investors to reduce their financial interests in the fossil fuel industry,
1743 divestment efforts both remove the 'social license to operate' and guard against the risk of
1744 losses due to 'stranded assets' in a world in which demand for fossil fuels rapidly
1745 reduces.[203,204] This indicator tracks the total global value of funds divested from fossil fuels,
1746 and the value of divested funds coming from health institutions, using data provided by
1747 350.org, with annual data and full methodology described in the Appendix.[205]

1748 From 2008 to the end of 2019, 1,157 organisations, with cumulative assets worth at least
1749 US$11.51 trillion have committed to fossil fuel divestment. Of these, only 23 are health

1750 institutions, including the World Medical Association, the British Medical Association, the
1751 Canadian Medical Association, the UK Faculty of Public Health, the Royal College of General
1752 Practitioners, the Royal Australasian College of Physicians, Gundersen Health System, the
1753 Berlin Doctors Pension Fund, and the Royal College of Emergency Medicine, with total
1754 assets of approximately US$42 billion. The annual value of new funds committed to
1755 divesting increased from US$2.14 trillion in 2018 to US$4.01 trillion in 2019. However,
1756 divestment from health institutions has slowed, with US$19 million divested in 2019,
1757 compared to US$867 million in 2018, owing primarily to divestment from particularly large
1758 institutions in previous years.

1759
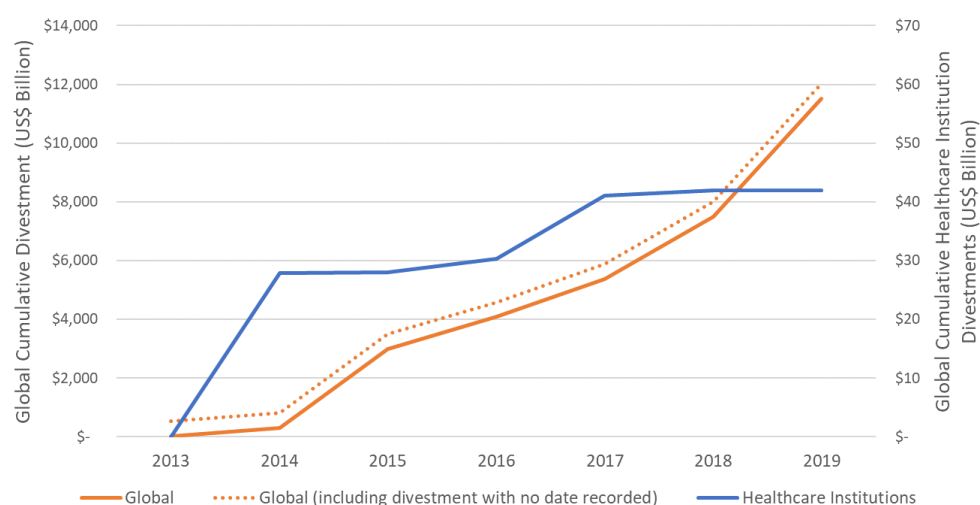
1760
1761 *Figure 24: Cumulative divestment – Global total and in healthcare institutions.*

1762

1763 Indicator 4.2.5: Net Value of Fossil Fuel Subsidies and Carbon Prices

1764 *Headline finding: 58 out of 75 countries reviewed were operating with a net-negative carbon*
1765 *price in 2017. The resulting net loss of revenue was in many cases equivalent to substantial*
1766 *proportions of the national health budget.*

1767 Placing a price on GHG emissions provides an incentive to drive the transition towards a
1768 low-carbon economy.[206,207] It also allows for a closer reflection of the true cost of emissions-
1769 intensive practices, particularly fossil fuel use, capturing some of the negative externalities
1770 resulting from their impact on health. However, not all countries explicitly set carbon prices,
1771 and in some cases the strength of any carbon price may be undermined by the opposing
1772 influence of subsidies on fossil fuel production and consumption.[208,209]

1773 Indicator 4.2.5 has been created for the 2020 report by combining previous indicators on
1774 fossil fuel subsidies and carbon pricing. It calculates "net" economy-wide average carbon
1775 prices and associated net carbon revenue to government. The calculations are based on the
1776 value of overall fossil fuel subsidies, the revenue from carbon pricing mechanisms, and the
1777 total CO_2 emissions of the economy. Data on fossil fuel subsidies are calculated based on
1778 analysis from the IEA and OECD.[210,211] Together these sources cover 75 countries and
1779 account for around 92% of global CO_2 emissions. Carbon prices and revenues are derived
1780 from data in the World Bank Carbon Pricing Dashboard and include international, national
1781 and subnational mechanisms within countries, 38 of which overlap with those covered by
1782 subsidy data and thus form part of this analysis.[212] A full description of the methodology,
1783 other data sources, and the methods for integrating them, can be found in the Appendix.

1784 Most of the 75 countries in 2016 and 2017 had net-negative carbon prices (61 and 58
1785 respectively), and only 25% with a price above zero in both years, resulting from substantial
1786 subsidies for fossil fuel production and consumption (Figure 25). The median net carbon
1787 revenue was negative – a pay-out of US$0.7 billion, with some countries providing net fossil
1788 fuel subsidies in the tens of billions of dollars each year. In many cases these subsidies are
1789 equivalent to substantial proportions of the national health budget – greater than 100% in
1790 eight of the 75 countries in 2017. Of the 38 countries that had formal carbon pricing
1791 mechanisms in place in 2017, 21 nonetheless had net-negative carbon prices.

1792
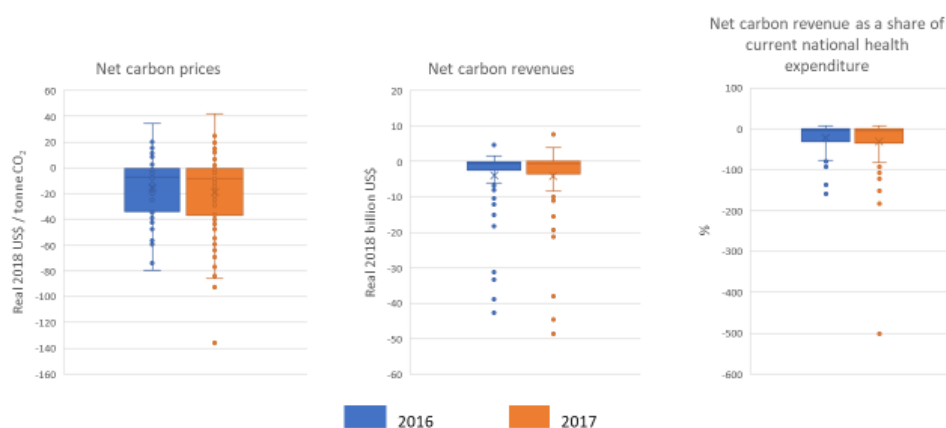
1793
1794 *Figure 25: Net carbon prices; net carbon revenues; and net carbon revenue as a share of current*
1795 *national health expenditure, across 75 countries, 2016 and 2017. Boxes show the interquartile range*
1796 *(IQR), horizontal lines inside the boxes showing the medians. The means are shown by crosses. The*
1797 *brackets represent the range from minimum to maximum, however points are represented as*
1798 *outliers beyond this range if they are 1.5 times the IQR below the 1st quartile, or above the 3rd*
1799 *quartile.*

1800

Conclusion

1801 **Conclusion**

1802 The economic and financial dimensions of public health and climate change are central to
1803 any comprehensive mitigation and adaptation effort. This section has covered both the
1804 health and economic costs of climate change, as well as indicators of progress underlying a
1805 transition to a low-carbon economy. It has developed a number of new metrics to inform
1806 this and will continue to expand the geographical coverage and reach of these in
1807 subsequent reports.

1808 The outlook presented here is mixed. On the one hand, investment in new coal capacity
1809 continues to decline, and employment in renewable energy continues to rise. On the other
1810 hand, composite indicators of net carbon pricing reveal that government policies are often
1811 mis-coordinated, resulting in inefficiencies and disrupted price signals. The full economic
1812 impacts of COVID-19 will continue to play out over the course of a number of years, leaving
1813 a lasting impact on the world. Indeed, the nature and extent of the economic impact and
1814 response to this pandemic will play a defining role in determining whether or not the world
1815 meets its commitments under the Paris Agreement. It is for this reason that strong
1816 investment in mitigation and adaptation technologies and interventions is more important
1817 now than ever before, leading to healthier and more prepared hospitals, economies, and
1818 populations.

Section 5: Public and Political Engagement

1819

1820 As previous sections make clear, the health impacts of climate change are multiplying,
1821 hitting hardest those who have contributed least to rising global temperatures. The public
1822 are voicing concern as individuals, and as members of Indigenous communities, and new
1823 social movements, urging greater ambition from those with the power to curb carbon
1824 emissions.[213-220]

1825 This section tracks engagement in health and climate change across multiple parts of
1826 society, including the media, by individuals, scientists, governments, and the corporate
1827 sector. For each of these, methods used in previous Lancet Countdown reports have been
1828 enhanced, increasing the sensitivity and specificity of health and climate change
1829 engagement in each.

1830 The media, and national newspapers in particular, are central to shaping public perceptions
1831 of climate change.[221-224] The media indicator (Indicator 5.1) tracks newspaper coverage of
1832 health and climate change in 36 countries, with additional analysis provided for China's
1833 *People's Daily,* the official voice of the government and China's most influential newspaper,
1834 and content analysis of newspaper coverage in India and the USA.[225,226]

1835 Individual engagement (Indicator 5.2) is tracked through the use of Wikipedia, an online
1836 information source that has outpaced traditional encyclopaedias in terms of reach, coverage
1837 and comprehensiveness.[227-231]

1838 Reintroduced in 2020 with a revised methodology, the scientific indicator (Indicator 5.3)
1839 tracks academic engagement with health and climate change in peer-reviewed journals, the
1840 premier source of high-quality research that provides evidence used by the media,
1841 government, and the public.[228,232,233]

1842 The fourth indicator (Indicator 5.4) focuses on the governmental domain, a key arena for
1843 driving the global response to climate change. It tracks government engagement in health
1844 and climate change at the UN General Assembly, where the UN General Debate provides a
1845 platform for national leaders to address the global community.[234,235] New to the 2020
1846 report, it also examines engagement with health in the NDCs which underpin the UN
1847 Framework Convention on Climate Change (UNFCCC) 2015 Paris Agreement.[4,236,237]

1848 The final indicator (Indicator 5.5) focuses on the corporate sector, which, through its
1849 behaviour and wider political influence is central to the transition to a low-carbon
1850 economy.[238-240] This indicator tracks engagement with health and climate change in
1851 healthcare companies within the UN Global Compact, the world's biggest corporate
1852 sustainability framework.[241]

73

Indicator 5.1 Media Coverage of Health and Climate Change

1853

1854 *Headline finding: While total climate change coverage increased substantially from 2018 to*
1855 *2019, the rise was even greater for health and climate change coverage, which increased by*
1856 *96% over this period, and has increased substantially from 2007 to 2019.*

1857 This indicator tracks coverage of health and climate change from 2007 to 2019 in 36
1858 countries, together with separate analyses of China's People's Daily and the content of
1859 coverage in leading newspapers in India and the USA. Full descriptions of the methods, data
1860 sources and further analyses are presented in the Appendix.

1861 Across the 36 countries, an increasing proportion of newspaper articles on climate change
1862 refer to human health. From 2018 to 2019, health and climate change coverage increased
1863 by 96%, outpacing the increase in overall climate change coverage (74%). From 2007 to
1864 2019, the average monthly number of newspaper articles on health and climate change
1865 increased by 57% compared to a 23% increase in articles on climate change. Overall, the
1866 coverage for health and climate change only makes up 16% of all climate change coverage in
1867 the 2007-19 period (Figure 26).

1868 Coverage of health and climate change peaked in months that coincided with COP15 in 2009
1869 (Copenhagen) and COP21 in 2015 (Paris). It rose again in late 2018 and remained high across
1870 2019, corresponding with the time of the rise of the School Climate Strikes and a series of
1871 extreme weather events, including the Californian and southern Australian wildfires.

1872 The analysis was based on key word searches for health and climate change in 61
1873 newspapers (English, German, Portuguese, Spanish) selected to provide a global spread of
1874 higher-circulation papers. The search strategy was revised for the 2020 report in order to
1875 exclude false positives whilst retaining true positive articles.

1876

1877
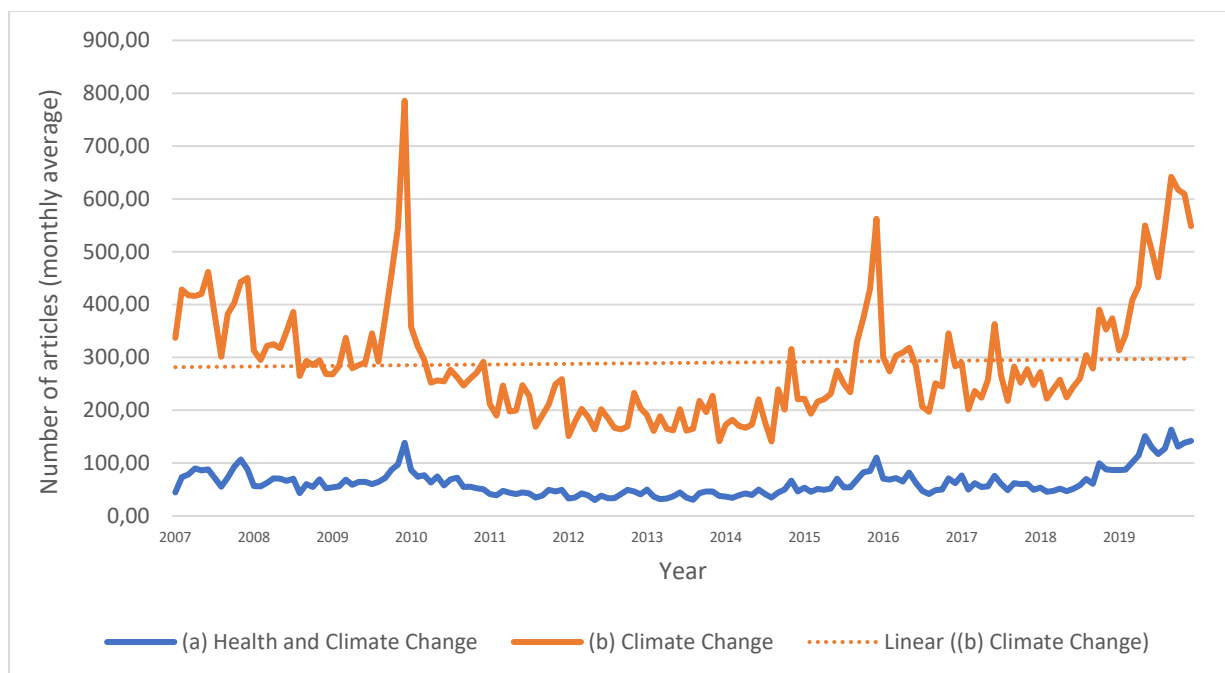
Figure 26: Average monthly coverage of (a) health and climate change and (b) climate change in 61
newspapers (36 countries), 2007-2019.

Additionally, coverage of health and climate change in *Renmin Ribao*, the Chinese language
edition of *People's Daily,* was tracked using keyword searches, algorithm-based natural
language processing and manual screening. Between 2008 and 2019, 2% of articles on
climate change were related to health. Health-related coverage spiked in 2013 with
coverage of the health threats of air pollution and heatwaves.[242]

The content of coverage of health and climate change was analysed in India (the *Times of
India* and the *Hindustan Times*) and the USA (the *New York Times* and the *Washington Post*)
from July-September and November-December 2019, chosen to include periods of extreme
weather (monsoons, drought) and COP25.[30] The newspapers form part of the 'elite press'
which, via their influence on the country's political and economic elites, have an influence
on the policy agenda.[243-248]

Three broad themes were identified in articles linking health and climate change. The
dominant theme was the health impacts of climate change, discussed in 68% of articles.
References were often to broad health impacts (e.g. "few countries are likely to suffer from
the health effects of climate change as much as India", *Hindustan Times*, 14 November).
More specific connections were also made to climate-related stressors (e.g. extreme
weather events, wildfires, population displacement) and health sequelae (e.g. vector-borne
disease, mental ill-health).

1900 The second theme relates to the common causes and co-benefits of addressing climate
1901 change and health, discussed in 39% of articles. Air pollution was the most frequently
1902 highlighted. Co-benefits of lifestyle changes to protect health and reduce emissions were
1903 also noted. The third theme focused on adaptation, discussed in 12% of articles. For
1904 example, the *Times of India*, 10 December, noted that "all levels of government need to
1905 prioritize building health system resilience to climate change". In addition, a small group of
1906 articles (six across the corpus) made a link between health and climate change with respect
1907 to activism and protest.

1908 The relative prominence of the three main themes in the 2019 analysis matches that for
1909 2018 and the *Times of India* again gave greater emphasis to common causes and co-benefits
1910 than the other newspapers.[30]

1911 For this indicator, articles were searched by health and climate change keywords and
1912 manually screened; the final sample of 209 articles was independently coded using the
1913 template developed for the 2018 analysis.[30,249]

1914

1915

1916 Indicator 5.2: Individual Engagement in Health and Climate Change

1917 *Headline finding: Individual information-seeking about health and climate change increased*
1918 *by 24% from 2018 to 2019, driven primarily by initial interest in health.*

1919 Wikipedia usage provides a digital footprint of individual information-seeking.[250,251] This
1920 indicator tracks individuals' engagement in health and climate change, by capturing visits to
1921 pairs of articles, for example, an individual clicking from a page on human health to one on
1922 climate change. Using data from the Wikimedia Foundation on the English version of
1923 Wikipedia (representing around 50% of global traffic to all Wikipedia language editions), this
1924 indicator is based on 6,902 articles related to health and 1,837 articles related to climate
1925 change.[252,253] Methods, data sources and further analyses are described in the Appendix.

1926 In both 2018 and 2019, individuals typically visited articles on either health or climate
1927 change, with little co-click activity between them, and when they were linked, the majority
1928 (75%) of co-visits started from a health-related page. While the overall number of health
1929 and climate change co-views is low, it increased by 24% across from 2018 to 2019, pointing
1930 to a rising individual engagement in the links between these two topics. In both years, co-
1931 clicks increased in months coinciding with key events in climate politics. As well as the 2019
1932 COP, co-clicks from articles on climate change to health in 2019 spiked in September at the
1933 time of Greta Thunberg's speech at the UN's Climate Action Summit.[254]

1934

Indicator 5.3: Coverage of Health and Climate Change in Scientific Journals

1935

1936 *Headline finding: There was a nine-fold increase in original research on health and climate*
1937 *change between 2007 and 2019, a trend driven by research led by scientists in high-income*
1938 *countries.*

1939 Between 2007 and 2019, 5,579 published academic articles referred to links between
1940 climate change and health. The period saw a nine-fold increase in original research (primary
1941 studies and evidence reviews) and a three-fold increase in research-related articles
1942 (editorials, reviews, comments, letters). Since 2011, original research has now surpassed
1943 research-related articles, with new research representing 61% of total scientific output in
1944 2019 (Figure 27).

1945 Consistent with observations in Section 1 (see Panel 3), the overall increase in research on
1946 health and climate change was primarily led by scientists based in high-income countries.
1947 USA-led and UK-led research made up 27% and 15% of the total output for 2007 to 2019,
1948 and respectively, 26% and 15% in 2019. Major contributions to 2019 output also come from
1949 the Netherlands (8%) and Switzerland (7%). Increases were also evident for China, South
1950 Africa, and India.

1951 Across the period, articles on health and climate change represented only a small
1952 proportion (9%) of total articles on climate change. However, the increase in articles relating
1953 to health and climate change was greater than for overall climate change output.

1954 This indicator is based on key word searches for health and climate change in OVID Medline
1955 and OVID Embase using the comprehensive indexing systems and thesaurus of Medical
1956 Subject Headings (MeSH) for Medline and Emtree for Embase. Methods, data sources and
1957 further analyses are described in the Appendix.
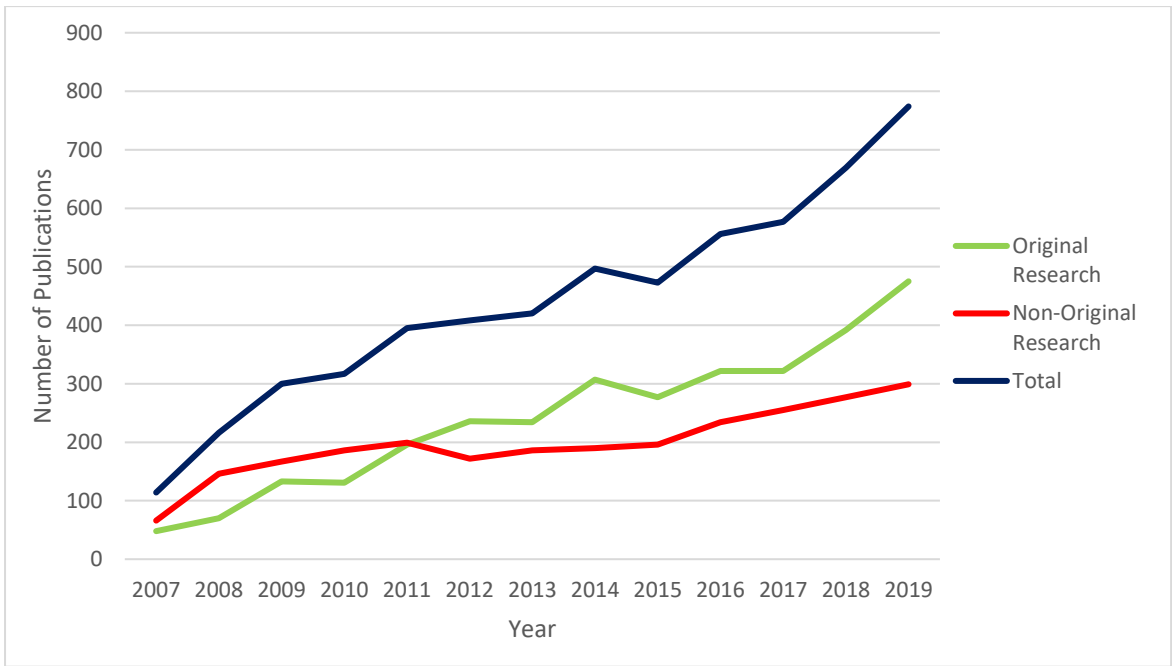
Figure 27: Scientific journal articles relating to health and climate change, 2007-2019.

Indicator 5.4: Government Engagement in Health and Climate Change

Headline finding: National governments are increasingly paying attention to health and
climate change. Small island developing states are leading this trend at the UN General
Debate, and poorer and more climate-vulnerable countries are more likely to reference
health in their NDCs, with 95% of the least developed countries making these references.

This indicator examines engagement with health and climate change in the UN General
Debate (UNGD) and with health in the NDCs committed to as part of the 2015 Paris
Agreement.[4,234] The indicator is based on a key word search of the United Nations General
Debate corpus, with algorithm-based natural language processing applied to the official
English versions of the statements.[255,256] References to health-related terms (e.g. 'health',
'illness', 'disease' and 'malnutrition') and climate-related health exposures were examined
in the 185 countries registering their NDCs in the UNFCCC repository by March 2020, with a
total of 2,159 pages of text analysed. Building on previous analyses, this indicator analyses
not only references, but the prominence they are given in the text.[237,257] Methods, data
sources and further analyses are described in the Appendix.

1978　As part of the annual UN General Assembly, the UNGD provides a global forum for national
1979　leaders to discuss issues they consider important. Health has been a long-standing issue,
1980　whilst engagement with climate change was limited until the late 1980s (**Error! Reference**
1981　**source not found.**). From the mid-2000s, national leaders began to focus on the
1982　connections between health and climate change, with the proportion rising rapidly from
1983　2007 and peaking in 2014 at 24%.

1984　Engagement in health and climate change continues to be led by the small island developing
1985　states (SIDS), particularly in the Western Pacific Region. In contrast, engagement remained
1986　low among the more powerful global actors, particularly those with the highest CO_2
1987　emissions (USA, China, and the EU). For the third consecutive year, President Donald
1988　Trump's statement on behalf of the USA failed to make a single reference to climate change,
1989　let alone to climate change and health linkages. However, 2019 did see growing
1990　engagement with climate change and health by other high-income nations (including
1991　Australia, Canada, Germany, and Spain) and by low-income countries, particularly in the
1992　African Region (for example Burkina Faso, Botswana, Côte d'Ivoire, Niger, and Togo).

1993　At the 2019 UNGD, the majority of health and climate change references focused on the
1994　health impacts of climate change. For example, Dominica highlighted the impacts of climate
1995　change on SIDS', including "rising sea levels, violent tropical storms and hurricanes, periods
1996　of severe drought alternating with floods and forest fires, new plant diseases, and vector-
1997　borne disease such as chikungunya and Zika present an existential threat." Similarly, Tonga's
1998　UNGD statement discussed how extreme weather events linked to climate change "are
1999　increasingly more intense, inflicting damage and destruction on our communities and
2000　ecosystems and putting the health of our peoples at risk."

2001　The 2019 UNGD also saw discussion of adaptation and resilience to "upgrade and climate-
2002　proof our health-care facilities" (Nauru), improve "the quality of health care and the
2003　durability of health-care systems in the face of the climate crisis" (Palau) and build "climate
2004　change resilience in our sectoral policies and strategies for health, transport, agriculture and
2005　pastoral production" (Niger).

2006　The second part of this indicator focuses on health within the NDCs, assessing both the
2007　references and their prominence within the text. Here, some 73% of NDCs included
2008　considerations of public health. At the WHO regional level, all countries in the South East
2009　Asian and Eastern Mediterranean Regions discuss these links (Figure 28). At the country
2010　level, references to health are particularly common among Least Developed Countries
2011　(95%). In contrast, the European Union (representing the contributions of 28 countries) and
2012　the USA NDCs have none.

2013
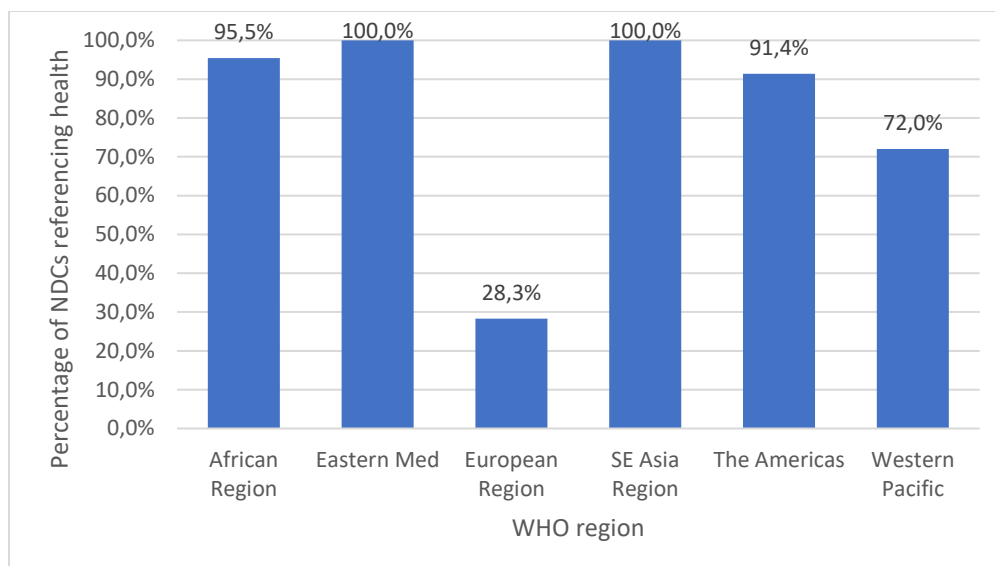
Figure 28: Reference to health in the NDCs by WHO region. The European region (which consists of 53 countries) is adjusted for the single NDC representing 28 EU countries; treating the EU as one country would increase the regional proportion to 60%.

A range of health dimensions were highlighted in the NDCs, including the direct impacts of climate change on health and health-related infrastructure. For example, in their respective NDCs, Morocco notes that climate change would increase deaths "by 250,000 annually between 2030 and 2050 due to malnutrition, malaria, diarrhea and heat-related stress" and Cambodia discusses the effects of climate change on "death, injury, psychological disorders and damage to public health infrastructure". There are also references to the co-benefits of interventions; for example, Saint Lucia refers to "human health benefits" among "co-benefits associated with its mitigation efforts".

Among the NDCs considering health and climate change, extreme weather events (e.g. floods, drought) and food security were most commonly cited, with 52% discussing these links. The proportion was highest in the NDCs from countries in South East Asia, and lowest in Europe. Examples include Sri Lanka's NDC, which warns of its "water borne diseases" which "can increase due to extreme heat and drought" and Nepal's NDC which describes "an increased frequency of extreme weather events such as landslides, floods and droughts resulting to the loss of human lives".

2036   Indicator 5.5: Corporate Sector Engagement in Health and Climate change

2037   *Headline finding: engagement in health and climate change increased to 24% in 2019*
2038   *among healthcare companies in the UN Global Compact, although this engagement*
2039   *continues to lag behind other sectors.*

2040   The UN Global Compact (UNGC) is a UN-supported platform, created to promote
2041   environmental and social responsibility in the business sector.[258] It represents over 10,000
2042   companies from more than 160 countries.[241] Focusing on the healthcare sector, Figure 29
2043   tracks engagement in health and climate change in the UNGC Communication on Progress
2044   reports that companies submit each year.

2045   Analysis was based on key word searches of health-related and of climate change-related
2046   terms in 20,775 annual reports in the UNGC database, and engagement in health and
2047   climate change was identified using natural language processing. [241] Methods, data sources
2048   and further analyses are described in the Appendix.

2049   This indicator points to an increase in healthcare sector engagement in 2019, with 24% of
2050   companies referring to the links between climate change and health (Figure 29). However,
2051   other sectors have higher levels of engagement, including the energy sector and real estate
2052   investment sector.

2053
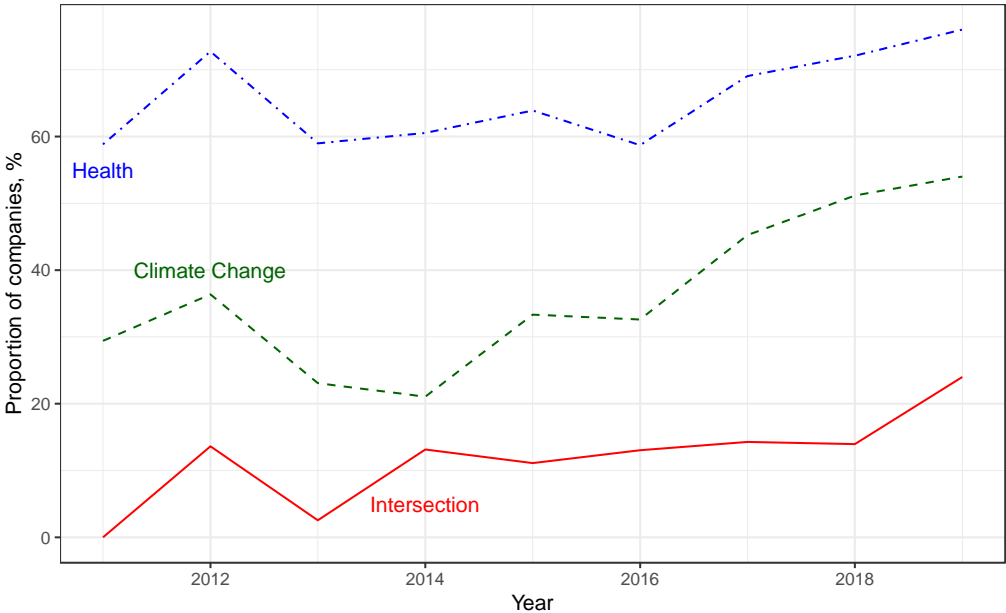
2054
2055   *Figure 29: Proportion of healthcare sector companies referring to climate change, health, and the*
2056   *intersection of health and climate change in Communication on Progress reports, 2011-2019.*

Conclusion

Public and political engagement is essential to curb fossil fuel consumption and hold global temperature rise to below 1.5°C.[259] Section Five has examined indicators of engagement relating to the media, the public, the scientific community, national government and the corporate sector. Taken together, the analyses point to two broad trends.

Firstly, engagement with health and climate change continues to increase. Between 2007 and 2019, newspaper coverage increased by over 50% and scientific journal output by over 500%. Across 2018 and 2019, the proportion of Wikipedia users searching for articles that linked health and climate change also increased. There is evidence of dynamic and reinforcing relationships between these domains. Media coverage increased at times of heightened political engagement and public engagement. September 2019, and Greta Thunberg's speech at the UN Climate Action Summit in particular, also saw a spike in individual engagement in health and climate change, as captured by Wikipedia use.

However, beneath these trends are persisting inequalities in wealth and political influence. In both the UNGD and the NDCs, engagement in health and climate change is led by countries and regions that are suffering most from a changing climate to which they have contributed least. At the same time, the science of health and climate change continues to be led by higher-income, high-emitting countries, which are the most responsible for climate change.[218,260]

Secondly, in absolute terms, climate change continues to be framed in ways that pay little attention to its health dimensions. One in six newspaper articles on climate change discuss its health dimensions; less than one in ten scientific articles do so; as do less than one in four healthcare companies signed up to sustainable business practices. In the political domain, health and climate change are rarely connected by government leaders in their speeches at the UN's major global forum and, while most NDCs refer to health, countries with high per capita carbon emissions – including EU countries and the USA – do not. Nonetheless, in key domains of engagement, the health dimensions of climate change are increasingly recognised, with media and scientific coverage increasing more rapidly than for climate change as a whole.

In conclusion, despite the fact that underlying inequalities in the drivers and impacts of climate change remain, there is evidence that health is becoming increasingly central to public and political engagement.

Conclusion: The 2020 Report of the Lancet Countdown

2089

2090 With global average temperature rise having reached 1.2°C above pre-industrial times, the
2091 indicators contained in the 2020 report provide insights into the health impacts of climate
2092 change today, and in the future. Extremes of heat hit vulnerable populations the hardest,
2093 with some 296,000 deaths occurring as a result of high temperatures in 2018 (Indicator
2094 1.1.3)

2095 The climate suitability for the transmission of a range of infectious diseases – dengue fever,
2096 malaria, and *Vibrio* bacteria– have demonstrated sustained rises across the world (Indicator
2097 1.3.1). This is occurring at the same time as crop yield potential is falling for each of the
2098 major crops tracked, with dire consequences anticipated for food-insecure populations
2099 (Indicator 1.4.1).

2100 And yet, the global response has remained muted. The carbon intensity of the global energy
2101 system has remained flat over the past three decades, and global coal use for energy has
2102 increased by 74% over the same period (Indicators 3.1.1 and 3.1.2). This has resulted in an
2103 estimated 390,000 deaths from particulate air pollution generated by coal fired power, with
2104 total global deaths for all ambient sources exceeding 3.01 million in 2018 (Indicator 3.3). In
2105 the agricultural sector, emissions from livestock grew by 16% from 2000 to 2017, with some
2106 990,000 deaths occurring globally from excess red meat consumption in 2017 (Indicators
2107 3.5.1 and 3.5.2).

2108 In the face of this, the response from the health profession continues to gain momentum.
2109 Spending on health system adaptation continued its previous upward trend, rising by 5.3%
2110 in 2019, to $18.4 billion (Indicator 2.4). A nine-fold increase in original research on health
2111 and climate change has occurred in just over 10 years, and, in half that time, health
2112 institutions with total assets of $42 billion have divested their holdings from fossil fuel
2113 industries (Indicators 5.3 and 4.2.3). Led by low-income countries, more governments are
2114 linking health and climate change in their annual UN General Debate speeches and their
2115 NDCs under the Paris Agreement.

2116 The public health and financial effects of COVID-19 will be felt for years to come, and efforts
2117 to protect and rebuild local communities and national economies will need to be robust and
2118 sustained. Despite concerning indicators across each section of this report, the 2021 UN
2119 climate change conference presents an opportunity for course correction, and revitalised
2120 Nationally Determined Contributions. The window of opportunity is narrow, and if the
2121 response to COVID-19 is not fully and directly aligned with countries' national climate
2122 change strategies, the world will be unable to meet its commitments under the Paris
2123 Agreement, damaging health and health systems today, and in the future.
2124

References

1.   McMichael AJ, Haines JA, Slooff R, et al. Climate change and human health: an assessment / prepared by a Task Group on behalf of the World Health Organization, the World Meteorological Association and the United Nations Environment Programme; editors: A. J. McMichael ... [et al.]. Geneva: World Health Organization; 1996.

2.   NASA Goddard Institute for Space Studies. GISS Surface Temperature Analysis (GISTEMP v4). 2020. https://data.giss.nasa.gov/gistemp/ (accessed 28 April 2020).

3.   Smith KR, Woodward A, Campbell - Lendrum D, et al. Human Health: Impacts, Adaptation, and Co-Benefits. 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, United Kingdom and New York, New York: Cambridge University Press; 2014: 709-54.

4.   United Nations Framework Convention on Climate Change. Decision1/CP.21, Adoption of the Paris Agreement, FCCC/CP/2015/10/Add.1 (January 29, 2016), paras 23 and 24. 2016. http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf (accessed April 6, 2020.

5.   Herring SC, Christidis N, Hoell A, Hoerling MP, Stott PA. Explaining Extreme Events of 2017 from a Climate Perspective. *Bulletin of the American Meteorological Society* 2019; **100**(1): S1-S117.

6.   Herring SC, Christidis N, Hoell A, Hoerling MP, Stott PA. Explaining Extreme Events of 2018 from a Climate Perspective. *Bulletin of the American Meteorological Society* 2020; **101**(1): S1-S128.

7.   Herring SC, Christidis N, Hoell A, Kossin JP, III CJS, Stott PA. Explaining Extreme Events of 2016 from a Climate Perspective. *Bulletin of the American Meteorological Society* 2018; **99**(1): S1-S157.

8.   Herring SC, Hoell A, Hoerling MP, Kossin JP, III CJS, Stott PA. Explaining Extreme Events of 2015 from a Climate Perspective. *Bulletin of the American Meteorological Society* 2016; **97**(12): S1-S145.

9.   World Economic Forum. The Global Risks Report 2020. Cologny, Switzerland: World Economic Forum, 2020.

10.   Ecosystems and Human Well-being: Current State and Trends, Volume 1. In: Hassan R, Scholes R, Ash N, eds. The Millennium Ecosystem Assessment Series. Washington, DC and Covelo, CA, USA, and London, UK: Island Press; 2005.

11.   United Nations General Assembly. Resolution adopted by the General Assembly on 25 September 2015 Transforming our world: the 2030 Agenda forSustainable Development New York, NY, USA: United Nations; 2015.

12.   Wei Y-M, Han R, Wang C, et al. Self-preservation strategy for approaching global warming targets in the post-Paris Agreement era. *Nature communications* 2020; **11**(1): 1-13.

13.   Kjellstrom T, Briggs D, Freyberg C, Lemke B, Otto M, Hyatt O. Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. *Annu Rev Public Health* 2016; **37**: 97-112.

14.   Sampedro J, Smith SJ, Arto I, et al. Health co-benefits and mitigation costs as per the Paris Agreement under different technological pathways for energy supply. *Environ Int* 2020; **136**: 105513.

15.   Vandyck T, Keramidas K, Kitous A, et al. Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nat Commun* 2018; **9**(1): 4939.

16.   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.

17.   Johns Hopkins Center for Systems Science and Engineering. COVID-19 Dashboard. 2020. https://coronavirus.jhu.edu/map.html (accessed 31 July 2020).

18.   Strauss D. BoE is financing UK's coronavirus measures, Bailey acknowledges. Financial Times. 2020.

19.   Hopman J, Allegranzi B, Mehtar S. Managing COVID-19 in Low- and Middle-Income Countries. *JAMA* 2020; **323**(16): 1549-50.

2173   20.   Ji Y, Ma Z, Peppelenbosch MP, Pan Q. Potential association between COVID-19 mortality and
2174   health-care resource availability. *The Lancet Global Health* 2020; **8**(4): e480.
2175   21.   Raju E, Ayeb-Karlsson S. COVID-19: How do you self-isolate in a refugee camp? *International*
2176   *Journal of Public Health* 2020.
2177   22.   IEA. Global Energy Review 2020. Paris, France: International Energy Agency, 2020.
2178   23.   Hallegatte S, Hammer S. Thinking ahead: For a sustainable recovery from COVID-19. 2020.
2179   https://www.preventionweb.net/news/view/71103 (accessed 23 May 2020).
2180   24.   WHO. Operational framework for building climate resilient health systems. Geneva,
2181   Switzerland: World Health Organization, 2015.
2182   25.   Audia C, Visman E, Fox G, et al. Decision-making heuristics for managing climate-related risks:
2183   The FREE framework. In: Conway D, ed. Climate Risk in Africa: Adaptation and Resilience. London, UK:
2184   Palgrave Macmillan; 2020.
2185   26.   Ranger N, Reeder T, Lowe J. Addressing 'deep'uncertainty over long-term climate in major
2186   infrastructure projects: four innovations of the Thames Estuary 2100 Project. *EURO Journal on*
2187   *Decision Processes* 2013; **1**(3-4): 233-62.
2188   27.   IPCC. Climate Change 2014. Impacts, Adaptation, and Vulnerability. Working Group II
2189   Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
2190   Cambridge and New York, 2014.
2191   28.   Lord Deben, Baroness Brown of Cambridge. Building a resilient recovery from the COVID-19
2192   crisis. 2020 (accessed 23 March 2020).
2193   29.   NHS. GP online consultations. 2020. https://www.nhs.uk/using-the-nhs/nhs-services/gps/gp-
2194   online-and-video-consultations/ (accessed 23 May 2020).
2195   30.   Watts N, Amann M, Arnell N, et al. The 2019 report of The *Lancet* Countdown on health and
2196   climate change: ensuring that the health of a child born today is not defined by a changing climate.
2197   *The Lancet* 2019; **394**(10211): 1836-78.
2198   31.   Szekely M, Carletto L, Garami A. The pathophysiology of heat exposure. *Temperature (Austin,*
2199   *Tex)* 2015; **2**(4): 452.
2200   32.   Xu Z, FitzGerald G, Guo Y, Jalaludin B, Tong S. Impact of heatwave on mortality under different
2201   heatwave definitions: A systematic review and meta-analysis. *Environment International* 2016; **89-90**:
2202   193-203.
2203   33.   Campbell S, Remenyi TA, White CJ, Johnston FH. Heatwave and health impact research: A
2204   global review. *Health & place* 2018; **53**: 210-8.
2205   34.   NASA Socioeconomic Data and Applications Center (SEDAC) Gridded Population of the World
2206   (GPWv4). Available at https://beta.sedac.ciesin.columbia.edu/data/collection/gpw-v4. 2020.
2207   35.   The Inter-Sectoral Impact Model Intercomparison Project (ISIMP). Input data set: Historical,
2208   gridded   population.   Available   at   https://www.isimip.org/gettingstarted/input-data-bias-
2209   correction/details/31/. 2020.
2210   36.   Copernicus Climate Change Service (C3S). ERA5 hourly data on single levels from 1979 to
2211   present. Available at https://doi.org/10.24381/cds.adbb2d47. 2020.
2212   37.   Honda Y, Kondo M, McGregor G, et al. Heat-related mortality risk model for climate change
2213   impact projection. *Environ Health Prev Med* 2014; **19**(1): 56-63.
2214   38.   WHO. Quantitative risk assessment of the effects of climate change on selected causes of
2215   death, 2030s and 2050s. 2014.
2216   39.   Guo Y, Gasparrini A, Armstrong BG, et al. Temperature Variability and Mortality: A Multi-
2217   Country Study. *Environ Health Perspect* 2016; **124**(10): 1554-9.
2218   40.   Sera F, Armstrong B, Tobias A, et al. How urban characteristics affect vulnerability to heat and
2219   cold: a multi-country analysis. *International Journal of Epidemiology* 2019; **48**(4): 1101-12.

41. 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.

42. ILO. ILOSTAT database. Geneva, Switzerland: International Labour Organization; 2020.

43. Hempel S, Frieler K, Warszawski L, Schewe J, Piontek F. A trend-preserving bias correction– the ISI-MIP approach. 2013.

44. Lange S. EartH2Observe, WFDEI and ERA-Interim data Merged and Bias-corrected for ISIMIP (EWEMBI). *GFZ Data Services* 2016.

45. Lange S. Bias correction of surface downwelling longwave and shortwave radiation for the EWEMBI dataset. 2018.

46. Black C, Tesfaigzi Y, Bassein JA, Miller LA. Wildfire smoke exposure and human health: Significant gaps in research for a growing public health issue. *Environmental toxicology and pharmacology* 2017; **55**: 186-95.

47. Copernicus Climate Change Service (C3S). Fire danger indices historical data from the Copernicus Emergency Management Service. Available at https://doi.org/10.24381/cds.0e89c522. 2020.

48. NASA EarthData. Active Fire Data. Available at https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data. 2020.

49. Dai A. Drought under global warming: a review. *WIREs Climate Change* 2011; **2**(1): 45-65.

50. Stanke C, Kerac M, Prudhomme C, Medlock J, Murray V. Health effects of drought: a systematic review of the evidence. *PLoS currents* 2013; **5**.

51. Du W, FitzGerald GJ, Clark M, Hou X-Y. Health Impacts of Floods. *Prehospital and Disaster Medicine* 2010; **25**(3): 265-72.

52. Mukherjee S, Mishra A, Trenberth KE. Climate Change and Drought: a Perspective on Drought Indices. *Current Climate Change Reports* 2018; **4**(2): 145-63.

53. Centre for Research on the Epidemiology of Disasters. EM-DAT The International Disaster Database. Available at https://emdat.be/. 2020.

54. World Health Organization. Global Health Observatory. Available at https://apps.who.int/nha/database/Select/Indicators/en. 2020.

55. World Weather Attribution. European heatwave, July 2015. 2015. https://www.worldweatherattribution.org/european-heat-wave-july-2015/ (accessed 27 April 2020).

56. World Weather Attribution. 2015 – a record breaking hot year. 2015. https://www.worldweatherattribution.org/record-hot-year-2015/ (accessed 27 April 2020).

57. King A, Kirkpatrick S, Oldenborgh GJv. Extreme heat in southeast Australia, February 2017. 2017. https://www.worldweatherattribution.org/extreme-heat-australia-february-2017/ (accessed 16 April 2020).

58. Otto F, Oldenborgh GJv, Vautard R, Schwierz C. Record June temperatures in western Europe. 2017. https://www.worldweatherattribution.org/european-heat-june-2017/ (accessed 2020 2020).

59. Oldenborgh GJv, Philip S, Kew S, et al. Human contribution to record-breaking June 2019 heatwave in France. 2019. https://www.worldweatherattribution.org/human-contribution-to-record-breaking-june-2019-heatwave-in-france/ (accessed 16 April 2020).

60. Vautard R, Boucher O, Oldenborgh GJv, et al. Human contribution to the record-breaking July 2019 heatwave in Western Europe. 2019. https://www.worldweatherattribution.org/human-contribution-to-the-record-breaking-july-2019-heat-wave-in-western-europe/ (accessed 16 April 2020).

61. van Oldenborgh GJ, Krikken F, Lewis S, et al. Attribution of the Australian bushfire risk to anthropogenic climate change. *Nat Hazards Earth Syst Sci Discuss* 2020; **2020**: 1-46.

2267 62.   World Weather Attribution. Record high temperatures in India, 2016. 2016.
2268 https://www.worldweatherattribution.org/india-heat-wave-2016/ (accessed 27 April 2020).

2269 63.   Oldenborgh GJv, Vries Hd, Vecchi G, Otto F, Tebaldi C. A cold winter in North America,
2270 December 2017 to January 2018. 2018. https://www.worldweatherattribution.org/winter-in-north-
2271 america-is-cold-dec-2017-jan-2018/ (accessed 16 April 2020).

2272 64.   Otto FEL, Wolski P, Lehner F, et al. Likelihood of Cape Town water crisis tripled by climate
2273 change. 2018. https://www.worldweatherattribution.org/the-role-of-climate-change-in-the-2015-
2274 2017-drought-in-the-western-cape-of-south-africa/ (accessed 16 April 2020).

2275 65.   Otto FEL, Haustein K, Uhe P, et al. Factors Other Than Climate Change, Main Drivers of
2276 2014/15 Water Shortage in Southeast Brazil. *Bulletin of the American Meteorological Society* 2015;
2277 **96**(12): S35-S40.

2278 66.   World Weather Attribution. Ethiopia drought, 2015 – a livelihood crisis. 2015.
2279 https://www.worldweatherattribution.org/ethiopia-drought-2015/ (accessed 27 April 2020).

2280 67.   Oldenborgh GJv, Wiel Kvd, Philip S, et al. Rapid analysis of drought in Somalia, 2016. 2017.
2281 https://www.worldweatherattribution.org/somalia-drought-2016-2017/ (accessed 27 April 2020).

2282 68.   Uhe P, Philip S, Kew S, et al. Attributing drivers of the 2016 Kenyan drought. *International
2283 Journal of Climatology* 2018; **38**(S1): e554-e68.

2284 69.   van Oldenborgh GJ, Philip S, Aalbers E, et al. Rapid attribution of the May/June 2016 flood-
2285 inducing precipitation in France and Germany to climate change. *Hydrol Earth Syst Sci Discuss* 2016;
2286 **2016**: 1-23.

2287 70.   van der Wiel K, Kapnick SB, van Oldenborgh GJ, et al. Rapid attribution of the August 2016
2288 flood-inducing extreme precipitation in south Louisiana to climate change. *Hydrol Earth Syst Sci* 2017;
2289 **21**(2): 897-921.

2290 71.   Oldenborgh GJv, Otto F, Singh R, Tebaldi C, Kew S, Philip S. Extreme rainfall in Japan, 2018 – a
2291 quick look. 2018. https://www.worldweatherattribution.org/a-quick-look-at-the-extreme-rainfall-in-
2292 japan/ (accessed 16 April 2020).

2293 72.   Philip S, Sparrow S, Kew SF, et al. Attributing the 2017 Bangladesh floods from meteorological
2294 and hydrological perspectives. *Hydrol Earth Syst Sci* 2019; **23**(3): 1409-29.

2295 73.   Mishra V, Shah HL. Hydroclimatological Perspective of the Kerala Flood of 2018. *Journal of the
2296 Geological Society of India* 2018; **92**(5): 645-50.

2297 74.   Otto FEL, Wiel Kvd, Oldenborgh GJv, et al. Climate change increases the probability of heavy
2298 rains in Northern England/Southern Scotland like those of storm Desmond—a real-time event
2299 attribution revisited. *Environmental Research Letters* 2018; **13**.

2300 75.   Zhang W, Vecchi GA, Murakami H, et al. Influences of Natural Variability and Anthropogenic
2301 Forcing on the Extreme 2015 Accumulated Cyclone Energy in the Western North Pacific. *Bulletin of
2302 the American Meteorological Society* 2016; **97**(12): S131-S5.

2303 76.   van Oldenborgh GJ, van der Wiel K, Sebastian A, et al. Attribution of extreme rainfall from
2304 Hurricane Harvey. *Environmental Research Letters* 2017; **12**.

2305 77.   Reed KA, Stansfield AM, Wehner MF, Zarzycki CM. Forecasted attribution of the human
2306 influence on Hurricane Florence. *Science Advances* 2020; **6**(1): eaaw9253.

2307 78.   Oldenborgh GJv, Wiel Kvd, Philip S, et al. Rapid attribution of the extreme rainfall in Texas
2308 from Tropical Storm Imelda. 2019. https://www.worldweatherattribution.org/rapid-attribution-of-
2309 the-extreme-rainfall-in-texas-from-tropical-storm-imelda/ (accessed 16 April 2020).

2310 79.   Vautard R, Oldenborgh GJv, Otto F, et al. Stormy January over western Europe, 2018. 2018.
2311 https://www.worldweatherattribution.org/the-stormy-month-of-january-2018-over-western-
2312 europe/ (accessed 16 April 2020).

2313   80.   World   Weather   Attribution.   Great   Barrier   Reef   bleaching,   2016.   2016.
2314   https://www.worldweatherattribution.org/great-barrier-reef-bleaching-march-2016/ (accessed   18
2315   May 2020).
2316   81.   Oldenborgh GJv, Macias-Fauria M, King A, et al. Unusually high temperatures at the North
2317   Pole, winter 2016. 2016. https://www.worldweatherattribution.org/north-pole-nov-dec-2016/
2318   (accessed 28 April 2020).
2319   82.   Bindoff N, PA S, AchutaRao KM ea. Detection and Attribution of Climate Change: from Global
2320   to Regional. Climate Change 2013: The Physical Science Basis Contribution of Working Group I to the
2321   Fifth Assessment Report of the Intergovernmental Panel on Climate Change; 2013.
2322   83.   Ebi KL, Ogden NH, Semenza JC, Woodward A. Detecting and attributing health burdens to
2323   climate change. *Environmental health perspectives* 2017; **125**(8): 085004.
2324   84.   Stone D, Auffhammer M, Carey M, et al. The challenge to detect and attribute effects of
2325   climate change on human and natural systems. *Climatic Change* 2013; **121**(2): 381-95.
2326   85.   IPCC. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of
2327   1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context
2328   of strengthening the global response to the threat of climate change. Geneva, Switzerland: World
2329   Meteorological Organization, 2018.
2330   86.   Stabeno PJ, Bell SW. Extreme Conditions in the Bering Sea (2017–2018): Record-Breaking Low
2331   Sea-Ice Extent. *Geophysical Research Letters* 2019; **46**(15): 8952-9.
2332   87.   Thoman RL, Bhatt US, Bieniek PA, et al. The Record Low Bering Sea Ice Extent in 2018: Context,
2333   Impacts, and an Assessment of the Role of Anthropogenic Climate Change. *Bulletin of the American*
2334   *Meteorological Society* 2020; **101**(1): S53-S8.
2335   88.   Bethel Search and Rescue Report. 2017.
2336   89.   Macarthur A. Father's body recovered, five rescued after family falls through Kuskokwim on
2337   New Year's Eve. 2018.
2338   90.   Waldholz R. In western Alaska, there's water where there should be ice. 2018.
2339   91.   World Weather Attribution. Heatwave in northern Europe, summer 2018. 2018.
2340   92.   Åström C, Bjelkmar P, Forsberg B. High mortality during the 2018 heatwave in Sweden.
2341   *Lakartidningen* 2019; **116**.
2342   93.   BBC.   Summer   heat   killed   nearly   1,500   in   France,   officials   say.   2019.
2343   https://www.bbc.co.uk/news/world-europe-49628275 (accessed 20 May 2020).
2344   94.   Meijer B. Heatwave caused nearly 400 more deaths in Netherlands: stats agency. 2019.
2345   https://www.reuters.com/article/us-weather-netherlands/heatwave-caused-nearly-400-more-
2346   deaths-in-netherlands-stats-agency-idUSKCN1UZ0GA?il=0 (accessed 20 May 2020).
2347   95.   Imada Y, Watanabe M, Kawase H, Shiogama H, Arai M. The July 2018 high temperature event
2348   in Japan could not have happened without human-induced global warming. *SOLA* 2019: 15A-002.
2349   96.   Shimpo A, Takemura K, Wakamatsu S, et al. Primary factors behind the heavy rain event of
2350   July 2018 and the subsequent heat wave in Japan. *SOLA* 2019: 15A-003.
2351   97.   Harris I, Osborn TJ, Jones P, Lister D. Version 4 of the CRU TS monthly high-resolution gridded
2352   multivariate climate dataset. *Scientific Data* 2020; **7**(1): 109.
2353   98.   Koninklijk Nederlands Meteorologisch Instituut. KNMI Climate Explorer. Available at
2354   https://climexp.knmi.nl/. 2020.
2355   99.   Lyon B, Dinku T, Raman A, Thomson MC. Temperature suitability for malaria climbing the
2356   Ethiopian Highlands. *Environmental Research Letters* 2017; **12**(6): 064015.
2357   100.   Martinez-Urtaza J, Trinanes J, Abanto M, et al. Epidemic Dynamics of Vibrio parahaemolyticus
2358   Illness in a Hotspot of Disease Emergence, Galicia, Spain. *Emerging Infectious Diseases* 2018; **24**(5):
2359   852-9.

2360 101. Martinez-Urtaza J, van Aerle R, Abanto M, et al. Genomic Variation and Evolution of Vibrio
2361 parahaemolyticus ST36 over the Course of a Transcontinental Epidemic Expansion. *mBio* 2017; **8**(6).

2362 102. Wang H, Tang X, Su YC, Chen J, Yan J. Characterization of clinical Vibrio parahaemolyticus
2363 strains in Zhoushan, China, from 2013 to 2014. *PLoS One* 2017; **12**(7): e0180335.

2364 103. Ebi KL, Nealon J. Dengue in a changing climate. *Environmental Research* 2016; **151**: 115-23.

2365 104. Semenza JC, Sewe MO, Lindgren E, et al. Systemic Resilience to Cross-border Infectious
2366 Disease Threat Events in Europe. *Transboundary and emerging diseases* 2019.

2367 105. WHO. International Health Regulations (2005): implementation status of IHR core capacities,
2368 2010-2017. Geneva, Switzerland: World Health Organization, 2018.

2369 106. FAO. The state of food security and nutrition in the world. Rome, Italy: Food and Agriculture
2370 Organization of the United Nations, 2020.

2371 107. Porter JR, Xie L, Challinor AJ, et al. Food Security and Food Production Systems. Climate
2372 Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects Contribution
2373 of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate
2374 Change. Cambridge, United Kingdom and New York, NY, USA; 2014.

2375 108. Craufurd PQ, Wheeler TR. Climate change and the flowering time of annual crops. *Journal of
2376 Experimental Botany* 2009; **60**(9): 2529-39.

2377 109. FAO. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable
2378 development goals. Rome: Food and Agriculture Organization of the United Nations, 2018.

2379 110. GBD 2017 Diet Collaborators, Afshin A, Sur PJ, et al. Health effects of dietary risks in 195
2380 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet
2381 (London, England)* 2019; **0**(0).

2382 111. FAO. Impact of climate change on fisheries and aquaculture: synthesis of current knowledge,
2383 adaptation and mitigation options. Rome, Italy: Food and Agriculture Organization of the United
2384 Nations, 2018.

2385 112. FAO. New Food Balance Sheets. 2020. http://www.fao.org/faostat/en/#data/FBS (accessed
2386 19 February 2020).

2387 113. NASA NEO NEO. Sea surface temperature (1 month – AQUA/MODIS). 2017.
2388 https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MYD28M (accessed 23 September 2019).

2389 114. NOAA. NOAA Coral Reef Watch Version 3.1 Daily Global 5-km Satellite Coral Bleaching Degree
2390 Heating Week Product. Washington DC: National Oceanic and Atmospheric Administration; 201.

2391 115. McMichael C. Climate change-related migration and infectious disease. *Virulence* 2015; **6**(6):
2392 548-53.

2393 116. Schwerdtle P, Bowen K, McMichael C. The health impacts of climate-related migration. *BMC
2394 medicine* 2018; **16**(1): 1.

2395 117. Kulp SA, Strauss BH. New elevation data triple estimates of global vulnerability to sea-level
2396 rise and coastal flooding. *Nature communications* 2019; **10**(1): 1-12.

2397 118. Lindsey R. Climate Change: Global Sea Level. 2019.

2398 119. Bright EA, Rose AN, Urban ML, McKee J. LandScan 2017 High-Resolution Global Population
2399 Data Set: Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States), 2018.

2400 120. Kulp SA, Strauss BH. CoastalDEM: a global coastal digital elevation model improved from SRTM
2401 using a neural network. *Remote sensing of environment* 2018; **206**: 231-9.

2402 121. Hauer ME, Fussell E, Mueller V, et al. Sea-level rise and human migration. *Nature Reviews
2403 Earth & Environment* 2019: 1-12.

2404 122. Luber G, Knowlton K, Balbus J, et al. Human health. *Climate change impacts in the United
2405 States: the third National Climate Assessment* 2014: 220-56.

2406 123. Ayeb-Karlsson S, Kniveton D, Cannon T. Trapped in the prison of the mind: Notions of climate-
2407 induced (im)mobility decision-making and wellbeing from an urban informal settlement in
2408 Bangladesh. *Palgrave Communications* 2020: forthcoming.
2409 124. Dannenberg AL, Frumkin H, Hess JJ, Ebi KL. Managed retreat as a strategy for climate change
2410 adaptation in small communities: public health implications. *Climatic change* 2019; **153**(1-2): 1-14.
2411 125. Schütte S, Gemenne F, Zaman M, Flahault A, Depoux A. Connecting planetary health, climate
2412 change, and migration. *The Lancet Planetary Health* 2018; **2**(2): e58-e9.
2413 126. Page LA, Hajat S, Kovats RS. Relationship between daily suicide counts and temperature in
2414 England and Wales. *The British Journal of Psychiatry* 2007; **191**(2): 106-12.
2415 127. Thompson R, Hornigold R, Page L, Waite T. Associations between high ambient temperatures
2416 and heat waves with mental health outcomes: a systematic review. *Public health* 2018; **161**: 171-91.
2417 128. Cunsolo A, Ellis NR. Ecological grief as a mental health response to climate change-related
2418 loss. *Nature Climate Change* 2018; **8**(4): 275.
2419 129. Legido-Quigley H, Asgari N, Teo YY, et al. Are high-performing health systems resilient against
2420 the COVID-19 epidemic? *The Lancet* 2020; **395**(10227): 848-50.
2421 130. Phillips CA, Caldas A, Cleetus R, et al. Compound climate risks in the COVID-19 pandemic.
2422 *Nature Climate Change* 2020; **10**(7): 586-8.
2423 131. UNEP. The Adaptation Gap Report 2018. Health Report. Nairobi: United Nations Environment
2424 Program, 2018.
2425 132. Mimura N, Pulwarty RS, Duc DM, et al. 2014:Adaptation planning and implementation. In:
2426 Field CB, Barros VR, Dokken DJ, et al., eds. Climate Change 2014: Impacts,Adaptation, and Vulnerability
2427 Part A: Global and Sectoral Aspects Contribution of Working Group II to the Fifth Assessment Report
2428 of the Intergovernmental Panel on Climate Change

2429 Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014: 869-98.
2430 133. CDP. Annual Cities Survey Data. In: CDP, editor. London, UK; 2020.
2431 134. WHO. WHO Health and Climate Change Survey Report: Tracking Global Progress. Geneva,
2432 Switzerland: World Health Organization, 2019.
2433 135. WBG. Urban Development. 2020.
2434 https://www.worldbank.org/en/topic/urbandevelopment/overview (accessed 28 April 2020).
2435 136. Watts N, Amann M, Arnell N, et al. The 2018 report of the Lancet Countdown on health and
2436 climate change: shaping the health of nations for centuries to come. *The Lancet* 2018; **392**(10163):
2437 2479-514.
2438 137. WMO. Country Profile Database. 2019.
2439 138. Kandel N, Chungong S, Omaar A, Xing J. Health security capacities in the context of COVID-19
2440 outbreak: an analysis of International Health Regulations annual report data from 182 countries. *The
2441 Lancet* 2020; **395**(10229): 1047-53.
2442 139. Bouchama A, Dehbi M, Mohamed G, Matthies F, Shoukri M, Menne B. Prognostic factors in
2443 heat wave related deaths: a meta-analysis. *Archives of internal medicine* 2007; **167**(20): 2170-6.
2444 140. Salamanca F, Georgescu M, Mahalov A, Moustaoui M, Wang M. Anthropogenic heating of the
2445 urban environment due to air conditioning. *Journal of Geophysical Research: Atmospheres* 2014;
2446 **119**(10): 5949-65.
2447 141. Waite M, Cohen E, Torbey H, Piccirilli M, Tian Y, Modi V. Global trends in urban electricity
2448 demands for cooling and heating. *Energy* 2017; (127): 786-802.
2449 142. Abel DW, Holloway T, Harkey M, et al. Air-quality-related health impacts from climate change
2450 and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary
2451 modeling study. *PLOS Medicine* 2018; **15**(7): e1002599.

2452   143.   Hospers L, Smallcombe JW, Morris NB, Capon A, Jay O. Electric fans: A potential stay-at-home
2453   cooling strategy during the COVID-19 pandemic this summer? *Science of The Total Environment* 2020:
2454   141180.
2455   144.   Miettinen OS. Proportion of disease caused or prevented by a given exposure, trait or
2456   intervention. *American journal of epidemiology* 1974; **99**(5): 325-32.
2457   145.   Markevych I, Schoierer J, Hartig T, et al. Exploring pathways linking greenspace to health:
2458   Theoretical and methodological guidance. *Environmental Research* 2017; **158**: 301-17.
2459   146.   Fong KC, Hart JE, James P. A Review of Epidemiologic Studies on Greenness and Health:
2460   Updated Literature Through 2017. *Current Environmental Health Reports* 2018; **5**(1): 77-87.
2461   147.   Sreetheran M, Van Den Bosch CCK. A socio-ecological exploration of fear of crime in urban
2462   green spaces–A systematic review. *Urban Forestry & Urban Greening* 2014; **13**(1): 1-18.
2463   148.   Wolch JR, Byrne J, Newell JP. Urban green space, public health, and environmental justice:
2464   The challenge of making cities 'just green enough'. *Landscape and urban planning* 2014; **125**: 234-44.
2465   149.   NASA LP DAAC. MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m.
2466   150.   Florczyk AJ, Melchiorri M, Corbane C, et al. Description of the GHS Urban Centre Database
2467   2015. Brussels, Belgium: European Commission - DG Joint Research Centre, 2019.
2468   151.   kMatrix Ltd. Adaptation and Resilience to Climate Change dataset. 2020.
2469   152.   Fisk M, Livingstone A, Pit SW. Telehealth in the Context of COVID-19: Changing Perspectives
2470   in Australia, the United Kingdom, and the United States. *J Med Internet Res* 2020; **22**(6): e19264.
2471   153.   UNEP. Emissions Gap Report 2019. Nairobi: United Nations Environment Programme, 2019.
2472   154.   WBG. Global Economic Prospects: Slow Growth, Policy Challenges. Washington, DC, USA:
2473   World Bank Group; 2020.
2474   155.   Le Quéré C, Jackson RB, Jones MW, et al. Temporary reduction in daily global CO2 emissions
2475   during the COVID-19 forced confinement. *Nature Climate Change* 2020.
2476   156.   Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. The contribution of outdoor air pollution
2477   sources to premature mortality on a global scale. *Nature* 2015; **525**(7569): 367.
2478   157.   Sellers S, Ebi KL, Hess J. Climate change, human health, and social stability: addressing
2479   interlinkages. *Environmental health perspectives* 2019; **127**(04): 045002.
2480   158.   IEA. World Energy Outlook 2019. Paris: IEA, 2019.
2481   159.   IEA. IEA Statistical Report. Paris: IEA, 2020.
2482   160.   Peters GP, Marland G, Le Quéré C, Boden T, Canadell JG, Raupach MR. Rapid growth in CO2
2483   emissions after the 2008–2009 global financial crisis. *Nature Climate Change* 2012; **2**(1): 2-4.
2484   161.   IEA. World Extended Energy Balances. UK Data Service; 2020.
2485   162.   Bergen T. Sweden and Austria close their last coal plants. 2020.
2486   https://inhabitat.com/sweden-and-austria-close-their-last-coal-plants/.
2487   163.   IEA. Sustainable Recovery: World Energy Outlook Special Report. Paris, France: International
2488   Energy Agency, 2020.
2489   164.   Roth GA, Abate D, Abate KH, et al. Global, regional, and national age-sex-specific mortality for
2490   282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global
2491   Burden of Disease Study 2017. *The Lancet* 2018; **392**(10159): 1736-88.
2492   165.   WHO. Burden of disease from Household Air Pollution for 2016. Geneva, Switzerland: World
2493   Health Organization, 2018.
2494   166.   Hajat A, Hsia C, O'Neill MS. Socioeconomic Disparities and Air Pollution Exposure: a Global
2495   Review. *Current environmental health reports* 2015; **2**(4): 440-50.
2496   167.   WHO. Ambient air pollution database, 2018 update. Geneva, Switzerland: World Health
2497   Organization, 2018.

2498 168. Amann M, Bertok I, Borken-Kleefeld J, et al. Cost-effective control of air quality and
2499 greenhouse gases in Europe: Modeling and policy applications. *Environmental Modelling & Software*
2500 2011; **26**(12): 1489-501.
2501 169. IEA. World Energy Outlook 2018. Paris, France: International Energy Agency, 2018.
2502 170. Zhang Q, Zheng Y, Tong D, et al. Drivers of improved $PM_{2.5}$ air quality in China from 2013 to
2503 2017. *Proceedings of the National Academy of Sciences* 2019; **116**(49): 24463-9.
2504 171. IEA. SDG7: Data and Projections. Paris: International Energy Institute, 2019.
2505 172. Milner J, Hamilton I, Woodcock J, et al. Health benefits of policies to reduce carbon emissions.
2506 *BMJ* 2020; **368**: l6758.
2507 173. International Transport Forum. Income Inequality, Social Inclusion and Mobility. Paris, France:
2508 Organisation for Economic Co-operation and Development, 2017.
2509 174. IEA. Global EV Outlook. Paris: International Energy Institute, 2019.
2510 175. Food Climate Research Network Foodsource: Food systems and greenhouse gas emissions.
2511 2020. https://foodsource.org.uk/31-what-food-system%E2%80%99s-contribution-global-ghg-
2512 emissions-total (accessed 30 April 2020).
2513 176. Carlson KM, Gerber JS, Mueller ND, et al. Greenhouse gas emissions intensity of global
2514 croplands. *Nature Climate Change* 2017; **7**(1): 63-8.
2515 177. FAO. FAOSTAT. 2020.
2516 178. Herrero M, Havlík P, Valin H, et al. Biomass use, production, feed efficiencies, and greenhouse
2517 gas emissions from global livestock systems. *Proceedings of the National Academy of Sciences* 2013;
2518 **110**(52): 20888-93.
2519 179. Global Alliance for Improved Nutrition. GAIN Briefing Paper Series 2 - Animal-source foods for
2520 human and planetary health. Geneva, Switzerland: Global Alliance for Improved Nutrition (GAIN),
2521 2020.
2522 180. Springmann M, Clark M, Mason-D'Croz D, et al. Options for keeping the food system within
2523 environmental limits. *Nature* 2018; **562**(7728): 519-25.
2524 181. Willett W, Rockstrom J, Loken B, et al. Food in the Anthropocene: the EAT-Lancet Commission
2525 on healthy diets from sustainable food systems. *The Lancet* 2019; **393**(10170): 447-92.
2526 182. FAO. Food balance sheets: a handbook. Rome, Italy: Food and Agriculture Organization of the
2527 United Nations; 2001.
2528 183. Dietzenbacher E, Los B, Stehrer R, Timmer M, De Vries G. The construction of world input–
2529 output tables in the WIOD project. *Economic Systems Research* 2013; **25**(1): 71-98.
2530 184. Fullman N, Yearwood J, Abay SM, et al. Measuring performance on the Healthcare Access and
2531 Quality Index for 195 countries and territories and selected subnational locations: a systematic
2532 analysis from the Global Burden of Disease Study 2016. *The Lancet* 2018; **391**(10136): 2236-71.
2533 185. Stadler K, Wood R, Bulavskaya T, et al. EXIOBASE 3: Developing a time series of detailed
2534 environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology* 2018;
2535 **22**(3): 502-15.
2536 186. WBG. Consumer price index (2010 = 100). 2020.
2537 https://data.worldbank.org/indicator/FP.CPI.TOTL?end=2017&locations=US&start=2000.
2538 187. WHO. Current health expenditure by financing schemes, in Global Health Expenditure
2539 Database. In: Organization WH, editor.; 2020.
2540 188. NHS England, Public Health England. Reducing the use of natural resources in health and social
2541 care. London: NHS England, 2018.
2542 189. NHS England. Greener NHS campaign to tackle climate 'health emergency'. 2020.
2543 https://www.england.nhs.uk/2020/01/greener-nhs-campaign-to-tackle-climate-health-emergency/
2544 (accessed 26 April 2020).
2545 190. Swiss Re Institute. Sigma explorer. Zurich, Switzerland: Swiss Re; 2020.

191. WBG. World Development Indicators. Washington, DC, USA: World Bank Group, 2020.

192. NatCatSERVICE. Relevant weather-related loss events worldwide 1990-2018. Munich, Germany: Munich Re, 2020.

193. OECD. Mortality Risk Valuation in Environment, Health and Transport Policies. OECD Publishing; 2012.

194. WBG. GNI (current US$). Washington, DC, USA: World Bank Group; 2020.

195. European Commission. Part III: Annexes to Impact Assessment Guidelines. Brussels, Belgium: European Commission, 2009.

196. IEA. World Energy Investment 2020. In: IEA, editor. Paris, France; 2020.

197. IRENA. Transforming the energy system. Abu Dhabi: International Renewable Energy Agency, 2019.

198. Balise VD, Meng C-X, Cornelius-Green JN, Kassotis CD, Kennedy R, Nagel SC. Systematic review of the association between oil and natural gas extraction processes and human reproduction. *Fertility and Sterility* 2016; **106**(4): 795-819.

199. Cortes-Ramirez J, Naish S, Sly PD, Jagals P. Mortality and morbidity in populations in the vicinity of coal mining: a systematic review. *BMC public health* 2018; **18**(1): 721.

200. IBISWorld. IBISWorld Industry Report: Global Coal Mining. Los Angeles, CA: IBISWorld, 2019.

201. IBISWorld. IBISWorld Industry Report: Global Oil & Gas Exploration & Production. Los Angeles, CA: IBISWorld, 2020.

202. IRENA. Renewable Energy and Jobs: Annual Review 2020. Abu Dhabi, United Arab Emirates: International Renewable Energy Agency, 2020.

203. Halcoussis D, Lowenberg AD. The effects of the fossil fuel divestment campaign on stock returns. *The North American Journal of Economics and Finance* 2019; **47**: 669-74.

204. Hunt C, Weber O. Fossil fuel divestment strategies: Financial and carbon-related consequences. *Organization & Environment* 2019; **32**(1): 41-61.

205. 350.org. Divestment Commitments. 2020. https://gofossilfree.org/divestment/commitments/ (accessed 14 April 2019).

206. Stiglitz JE. Addressing climate change through price and non-price interventions. *European Economic Review* 2019; **119**: 594-612.

207. Zapf M, Pengg H, Weindl C. How to Comply with the Paris Agreement Temperature Goal: Global Carbon Pricing According to Carbon Budgets. *Energies* 2019; **12**(15): 2983.

208. Coady D, Parry I, Le N, Shang B. Global fossil fuel subsidies remain large: an update based on country-level estimates: International Monetary Fund, 2019.

209. Gençsü I, McLynn M, Runkel M, et al. Phase-out 2020: Monitoring Europe's fossil fuel subsidies: ODI and Climate Action Network,, 2017.

210. IEA. Fossil fuel subsidies. 2019. https://www.iea.org/weo/energysubsidies/ (accessed 25th November 2019).

211. OECD. OECD Companion to the Inventory of Support Measures for Fossil Fuels 2018. Paris, France: OECD Publishing; 2018.

212. WBG. Carbon Pricing Dashboard. 2019. https://carbonpricingdashboard.worldbank.org/ (accessed 25th November 2019).

213. Berkes F. Sacred ecology. New York, NY: Routledge; 2008.

214. Duyck S, Lennon E. National Human Rights Institutions and the 2018 Talanoa Dialogue: showcasing that climate action should be human rights-based. 2018. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-59529-7 (accessed April 5, 2020.

215. Jamison A. Climate change knowledge and social movement theory. *Wiley Interdisciplinary Reviews: Climate Change* 2010; **1**(6): 811-23.

216. Pew Research Center. Climate change still seen as the top global threat, but cyberattacks a rising concern. 2019. https://www.pewresearch.org/global/2019/02/10/climate-change-still-seen-as-the-top-global-threat-but-cyberattacks-a-rising-concern/ (accessed April 5, 2020.

217. Poortinga W, Whitmarsh L, Steg L, Böhm G, Fisher S. Climate change perceptions and their individual-level determinants: A cross-European analysis. *Global environmental change* 2019; **55**: 25-35.

218. Ripple WJ, Wolf C, Newsome TM, Barnard P, Moomaw WR. World scientists' warning of a climate emergency. *BioScience* 2019; **70**(1): 8-12.

219. Thackeray SJ, Robinson SA, Smith P, et al. Civil disobedience movements such as School Strike for the Climate are raising public awareness of the climate change emergency. *Global Change Biology,* 2020; **26**: 1042-4.

220. United Nations Framework Convention on Climate Change. Local communities and indigenous peoples platform: Proposals on operationalization based on the open multi-stakeholder dialogue and submissions [online]. 2017. http://unfccc.int/resource/docs/2017/sbsta/eng/06.pdf (accessed April 5, 2020.

221. Boykoff MT. Who speaks for the climate?: Making sense of media reporting on climate change. Cambridge: Cambridge University Press; 2011.

222. Carvalho A, Burgess J. Cultural circuits of climate change in UK broadsheet newspapers, 1985–2003. *Risk Analysis: An International Journal* 2005; **25**(6): 1457-69.

223. Gavin NT. Addressing climate change: a media perspective. *Environmental Politics* 2009; **18**(5): 765-80.

224. Happer C, Philo G. The role of the media in the construction of public belief and social change. *Journal of social and political psychology* 2013; **1**(1): 321-36.

225. Hassid J. Controlling the Chinese Media: An Uncertain Business. *Asian Survey* 2008; **48**(3): 414-30.

226. 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.

227. Alexander DD. The top 500 sites on the Web. 2018. https://www.alexa.com/topsites.

228. Bornmann L. Scientific peer review. *Annual review of information science and technology* 2011; **45**(1): 197-245.

229. 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 Wikipedia. *Journal of the Association for Information Science and Technology* 2015; **66**(2): 219-45.

230. Schroeder R, Taylor L. Big data and Wikipedia research: social science knowledge across disciplinary divides. *Information, Communication & Society* 2015; **18**(9): 1039-56.

231. Wikimedia Statistics. https://stats.wikimedia.org/v2/#/all-projects (accessed April 5, 2020.

232. Lewis J, Williams A, Franklin B. A compromised fourth estate? UK news journalism, public relations and news sources. *Journalism studies* 2008; **9**(1): 1-20.

233. Molek-Kozakowska K. Popularity-driven science journalism and climate change: A critical discourse analysis of the unsaid. *Discourse, Context & Media* 2018; **21**: 73-81.

234. General Assembly of the United Nations. United Nations General Debate of the 74th session of the General Assembly 24-27 September 2019. 2019. https://gadebate.un.org/generaldebate74/en/ (accessed April 7, 2020.

235. Peterson MJ. General Assembly. In: Weiss TG, Daws S, eds. The Oxford Handbook on the United Nations. Oxford, UK: Oxford University Press; 2018.

236. Brandi C, Dzebo A, Janetschek H, Lambert C, Savvidou G. NDC-SDG Connections. 2017. https://klimalog.die-gdi.de/ndc-sdg (accessed April 5, 2020.

2640   237.   Wiley E, Tcholakov Y, Pétrin-Desrosiers C, Al-Qodmani L. Health in intended nationally
2641   determined   contributions   (INDCS).   2015.
2642   https://www.researchgate.net/publication/289451213_health_in_intended_nationally_determined
2643   _contributions_indcs_executive_summary/citation/download (accessed April 5, 2020.
2644   238.   Jeswani HK, Wehrmeyer W, Mulugetta Y. How warm is the corporate response to climate
2645   change? Evidence from Pakistan and the UK. *Business Strategy and the Environment* 2008; **17**(1): 46-
2646   60.
2647   239.   World Economic Forum. Two Degrees of Transformation. Businesses are coming together to
2648   lead on climate change. Will you join them? 2019. https://www.weforum.org/reports/two-degrees-
2649   of-transformation-businesses-are-coming-together-to-lead-on-climate-change-will-you-join-them.
2650   240.   Wright C, Nyberg D. Climate change, capitalism, and corporations: Cambridge University
2651   Press; 2015.
2652   241.   United Nations Global Compact. https://www.unglobalcompact.org/ (accessed 13.04.19.
2653   242.   State Council of China. Air pollution prevention and control action plan. 2013.
2654   http://www.gov.cn/jrzg/2013-09/12/content_2486918.htm (accessed April 1, 2020.
2655   243.   Auerbach Y, Bloch-Elkon Y. Media framing and foreign policy: The elite press vis-a-vis US policy
2656   in Bosnia, 1992–95. *Journal of Peace Research* 2005; **42**(1): 83-99.
2657   244.   Billett S. Dividing climate change: global warming in the Indian mass media. *Climatic change*
2658   2010; **99**(1-2): 1-16.
2659   245.   Boykoff MT, Boykoff JM. Balance as bias: global warming and the US prestige press. *Global
2660   environmental change* 2004; **14**(2): 125-36.
2661   246.   Nagarathinam S, Bhatta A. Coverage of climate change issues in Indian newspapers and policy
2662   implications. *Current Science* 2015; **108**(11): 1972-3.
2663   247.   Schäfer MS, Ivanova A, Schmidt A. What drives media attention for climate change? Explaining
2664   issue attention in Australian, German and Indian print media from 1996 to 2010. *International
2665   Communication Gazette* 2014; **76**(2): 152-76.
2666   248.   Shehata A, Hopmann DN. Framing Climate Change. *Journalism Studies* 2012; **13**(2): 175-92.
2667   249.   Brooks J, McCluskey S, Turley E, King N. The Utility of Template Analysis in Qualitative
2668   Psychology Research. *Qualitative Research in Psychology* 2015; **12**(2): 202-22.
2669   250.   Segev E, Sharon AJ. Temporal patterns of scientific information-seeking on Google and
2670   Wikipedia. *Public Understanding of Science* 2017; **26**(8): 969-85.
2671   251.   Yoshida M, Arase Y, Tsunoda T, Yamamoto M. Wikipedia page view reflects web search trend.
2672   Proceedings of the ACM Web Science Conference; 2015; 2015. p. 1-2.
2673   252.   Wulczyn E, Taraborelli D. Wikipedia clickstream. figshare. 2015.
2674   253.   Zachte E. WikiStats. Page Views for Wikipedia, Both Sites, Normalized. 2019.
2675   https://stats.wikimedia.org/EN/TablesPageViewsMonthlyCombined.htm. (accessed April 5, 2020.
2676   254.   United   Nations.   UN   Climate   Action   Summit   2019.   2019.
2677   https://www.un.org/en/climatechange/un-climate-summit-2019.shtml (accessed April 5, 2020.
2678   255.   Baturo A, Dasandi N, Mikhaylov SJ. Understanding state preferences with text as data:
2679   Introducing the UN General Debate corpus. *Research & Politics* 2017; **4**(2): 2053168017712821.
2680   256.   Jankin Mikhaylov S, Baturo A, Dasandi N. United Nations General Debate Corpus. In: Jankin
2681   Mikhaylov S, editor. V5 ed: Harvard Dataverse; 2017.
2682   257.   World Health Organization. Health in the NDCs. Geneva, Switzerland: World Health
2683   Organization, 2019.
2684   258.   United Nations Global Compact. Corporate sustainability in the world economy. New York:
2685   UN Global Compact, 2008.

2686   259.   Institute for Global Environmental Strategies Allto University, D-mat Ltd. 1.5-Degree
2687   Lifestyles: Targets and options for reducing lifestyle carbon footprints. Technical Report. 2019.
2688   https://www.iges.or.jp/en/pub/15-degrees-lifestyles-2019/en (accessed April 5, 2020.
2689   260.   Pretty J. The consumption of a finite planet: well-being, convergence, divergence and the
2690   nascent green economy. *Environmental and Resource Economics* 2013; **55**(4): 475-99.

2691