

The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future

Article

Accepted Version

Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., Kennard, H., Lampard, P., Solano Rodriguez, B., Arnell, N. ORCID: <https://orcid.org/0000-0003-2691-4436>, Ayeb-Karlsson, S., Belesova, K., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Chu, L., Ciampi, L. ORCID: <https://orcid.org/0000-0003-1240-7695>, Dalin, C., Dasandi, N., Dasgupta, S., Davies, M., Dominguez-Salas, P., Dubrow, R., Ebi, K. L., Eckelman, M., Ekins, P., Escobar, L. E., Georgeson, L., Grace, D., Graham, H., Gunther, S. H., Hartinger, S., He, K., Heaviside, C., Hess, J., Hsu, S.-C., Jankin, S., Jimenez, M. P., Kelman, I., Kiesewetter, G., Kinney, P. L., Kjellstrom, T., Kniveton, D., Lee, J. K. W., Lemke, B., Liu, Y., Liu, Z., Lott, M., Lowe, R., Martinez-Urtaza, J., Maslin, M., McAllister, L., McMichael, C., Mi, Z., Milner, J., Minor, K., Mohajeri, N., Moradi-Lakeh, M., Morrissey, K., Munzert, S., Murray, K. A., Neville, T., Nilsson, M., Obradovich, N., Sewe, M. O., Oreszczyn, T., Otto, M., Owfi, F., Pearman, O., Pencheon, D., Rabbaniha, M., Robinson, E., Rocklöv, J., Salas, R. N., Semenza, J. C., Sherman, J., Shi, L., Springmann, M., Tabatabaei, M., Taylor, J., Trinanes, J., Shumake-Guillemot, J., Vu, B., Wagner, F., Wilkinson, P.,

Winning, M., Yglesias, M., Zhang, S., Gong, P., Montgomery, H., Costello, A. and Hamilton, I. (2021) The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. *The Lancet*, 398 (10311). pp. 1619-1662.
ISSN 0140-6736 doi: 10.1016/S0140-6736(21)01787-6
Available at <https://centaur.reading.ac.uk/100869/>

It is advisable to refer to the publisher's version if you intend to cite from the work. See [Guidance on citing](#).

Published version at: <https://www.sciencedirect.com/science/article/pii/S0140673621017876>

To link to this article DOI: [http://dx.doi.org/10.1016/S0140-6736\(21\)01787-6](http://dx.doi.org/10.1016/S0140-6736(21)01787-6)

Publisher: Elsevier

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the [End User Agreement](#).

www.reading.ac.uk/centaur

CentAUR

Central Archive at the University of Reading

Reading's research outputs online

The 2021 Report of The *Lancet* Countdown on Health and Climate Change

Marina Romanello, Alice McGushin, Claudia Di Napoli, Paul Drummond, Nick Hughes, Louis Jamart, Harry Kennard, Pete Lampard, Baltazar Solano Rodriguez, Nigel Arnell, Sonja Ayeb-Karlsson, Kristine Belesova, Wenjia Cai, Diarmid Campbell-Lendrum, Stuart Capstick, Jonathan Chambers, Lingzhi Chu, Luisa Ciampi, Carole Dalin, Niheer Dasandi, Shouro Dasgupta, Michael Davies, Paula Dominguez-Salas, Robert Dubrow, Kristie L. Ebi, Matthew Eckelman, Paul Ekins, Luis E. Escobar, Lucien Georgeson, Delia Grace, Hilary Graham, Samuel H. Gunther, Stella Hartinger, Kehan He, Clare Heaviside, Jeremy Hess, Shih-Che Hsu, Slava Jankin, Marcia P. Jimenez, Ilan Kelman, Gregor Kiesewetter, Patrick Kinney, Tord Kjellstrom, Dominic Kniveton, Jason K.W. Lee, Bruno Lemke, Yang Liu, Zhao Liu, Melissa Lott, Rachel Lowe, Jaime Martinez-Urtaza, Mark Maslin, Lucy McAllister, Celia McMichael, Zhifu Mi, James Milner, Kelton Minor, Nahid Mohajeri, Maziar Moradi-Lakeh, Karyn Morrissey, Simon Munzert, Kris A. Murray, Tara Neville, Maria Nilsson, Nick Obradovich, Maquins Odhiambo Sewe, Tadj Oreszczyn, Matthias Otto, Fereidoon Owfi, Olivia Pearman, David Pencheon, Mahnaz Rabbaniha, Elizabeth Robinson, Joacim Rocklöv, Renee N. Salas, Jan C. Semenza, Jodi Sherman, Liuhua Shi, Marco Springmann, Meisam Tabatabaei, Jonathon Taylor, Joaquin Trinanes, Joy Shumake-Guillemot, Bryan Vu, Fabian Wagner, Paul Wilkinson, Matthew Winning, Marisol Yglesias, Shihui Zhang
Peng Gong^a, Hugh Montgomery^a, Anthony Costello^a, Ian Hamilton*
[Insert institutional logos for inside cover]

^a Co-Chair

* Executive Director and Corresponding Author

[Word Count: 17,822]

Table of Contents

List of Figures, Tables and Panels.....	3
List of Figures.....	3
List of Panels.....	4
List of Abbreviations.....	5
Executive Summary	7
Deepening inequities in a warming world.....	7
An inequitable response leaves the most vulnerable behind and fails all of us Error! Bookmark not defined.	
An unprecedented opportunity to ensure a healthy future for all.....	10
Introduction	12
Five years of tracking progress on health and climate change.....	13
Section 1: Climate Change Impacts, Exposures, and Vulnerability	17
1.1 Health and Heat	18
Indicator 1.1.1: Vulnerability to the Extremes of Heat	18
Indicator 1.1.2: Exposure of Vulnerable Populations to Heatwaves	18
Indicator 1.1.3: Heat and Physical Activity	20
Indicator 1.1.4: Change in Labour Capacity.....	21
Indicator 1.1.5: Heat and Sentiment.....	22
Indicator 1.1.6: Heat-Related Mortality	25
1.2 Health and Extreme Weather Events	26
Indicator 1.2.1: Wildfires.....	26
Indicator 1.2.2: Drought	27
Indicator 1.2.3: Lethality of Extreme Weather Events.....	28
1.3 Climate-Sensitive Infectious Diseases	28
Indicator 1.3.1: Climate Suitability for Infectious Disease Transmission	28
Indicator 1.3.2: Vulnerability to Mosquito-Borne Diseases	30
1.4 Food Security and Undernutrition.....	31
Indicator 1.4.1: Terrestrial Food Security and Undernutrition.....	31
Indicator 1.4.2: Marine Food Security.....	32
1.5 Migration, Displacement, and Rising Sea Levels	33
Conclusion	35
Section 2: Adaptation, Planning, and Resilience for Health	36
2.1: Adaptation Planning and Assessment	36
Indicator 2.1.1: National Adaptation Plans for Health.....	36
Indicator 2.1.2: National Assessments of Climate Change Impacts, Vulnerability, and Adaptation for Health.....	37
Indicator 2.1.3: City-level Climate Change Risk Assessments.....	38
Indicator 2.2: Climate Information Services for Health.....	39
2.3: Adaptation Delivery and Implementation	39
Indicator 2.3.1: Detection, Preparedness and Response to Health Emergencies	39
Indicator 2.3.2: Air Conditioning: Benefits and Harms	40
Indicator 2.3.3: Urban Green Space	43
Indicator 2.4: Health Adaptation-Related Global Funding and Financial Transactions.....	45
Conclusion	46
Section 3: Mitigation Actions and Health Co-Benefits	48
Indicator 3.1: Energy System and Health	48
Indicator 3.2: Clean Household Energy	50

Indicator 3.3: Mortality from Ambient Air Pollution by Sector	52
Indicator 3.4: Sustainable and Healthy Road Transport.....	54
3.5: Food, Agriculture, and Health	54
Indicator 3.5.1: Emissions from Agricultural Production and Consumption	54
Indicator 3.5.2: Diet and Health Co-Benefits.....	56
Indicator 3.6: Healthcare Sector Emissions	57
Conclusion	59
Section 4: Economics and Finance	61
4.1 The Economic Impact of Climate Change and its Mitigation	61
Indicator 4.1.1: Economic Losses due to Climate-Related Extreme Events	61
Indicator 4.1.2: Costs of Heat-Related Mortality.....	62
Indicator 4.1.3: Loss of Earnings from Heat-Related Labour Capacity Reduction	63
Indicator 4.1.4: Costs of the Health Impacts of Air Pollution	64
4.2 The Economics of the Transition to Zero-Carbon Economies.....	66
Indicator 4.2.1: Coal and Clean Energy Investment.....	67
Indicator 4.2.2: Employment in Low-Carbon and High-Carbon Industries	68
Indicator 4.2.3: Funds Divested from Fossil Fuels	69
Indicator 4.2.4: Net Value of Fossil Fuel Subsidies and Carbon Prices.....	70
Indicator 4.2.5: Production- and Consumption-Based Attribution of CO ₂ and PM _{2.5} Emissions	71
Conclusion	73
Section 5: Public and Political Engagement	75
Indicator 5.1 Media Coverage of Health and Climate Change.....	76
Indicator 5.2: Individual Engagement in Health and Climate Change.....	77
Indicator 5.3: Coverage of Health and Climate Change in Scientific Journals	78
Indicator 5.4: Government Engagement in Health and Climate Change	80
Indicator 5.5: Corporate Sector Engagement in Health and Climate change.....	83
Conclusion	84
Conclusion: the 2021 Report of the <i>Lancet</i> Countdown	86
References	90

List of Figures, Tables and Panels

List of Figures

Figure 1. Change in person-days of heatwave exposure relative to the 1986-2005 baseline.	19
Figure 2. Average potential activity hours lost per person per day by 2019 Human Development Index country group, 1980-2020.....	20
Figure 3. Heat-related potential hours of labour lost by sector and 2019 country Human Development Index group, 1990-2000.....	22
Figure 4. Heatwaves and sentiment.	24
Figure 5. Heat-related mortality among the 65-and-older population in 2019, by country	25
Figure 6. Annual population-weighted mean changes in days of very high and extremely high fire danger from 2001-2004 to 2017-2020 for each country/territory.	26
Figure 7. Percentage of land area affected by drought events per month	27
Figure 8. Change in climate suitability for infectious diseases.	30
Figure 9. Change in crop growth duration relative to the 1981–2010 baseline. The grey line represents the annual global area-weighted change.....	32

Figure 10. Global heat-related deaths averted by household air conditioning in the 65-and-older population (red line), proportion of households with air conditioning (blue line), and carbon dioxide emissions from air conditioning (green line), 2000-2019.....	41
Figure 11. Average urban population-weighted peak Normalized Difference Vegetation Index (NDVI) in urban centres of >500,000 inhabitants by country, for 2010 (A) and 2020 (B)	44
Figure 12. Per capita potential adaptation transactions in the health and health care sector (A) and health-relevant sectors (B) for financial years 2015/16 to 2019/20, by 2019 Human Development Index country group	46
Figure 13. The carbon intensity of the energy system for 1970-2018, by 2019 Human Development Index country group	50
Figure 14. Residential energy supply by 2019 Human Development Index country group for 2000 to 2019.....	52
Figure 15. Mortality attributable to ambient PM _{2.5} in 2015, 2018 and 2019 by source and by 2019 Human Development Index country group.	53
Figure 16. Per capita yearly greenhouse gas emissions associated with consumption of agri-food products, by 2019 Human Development Index country group and commodity, 2000-2018.	56
Figure 17. Deaths attributable to imbalanced diets and weight in 2018 by risk factor, sex, and 2019 Human Development Index country group.	57
Figure 18. National per capita healthcare greenhouse gas emissions for 2018 against 2019 country Human Development Index level. Dot size is proportional to population	59
Figure 19. Monetised cost of heat-related (in terms of expressed as the number of people whose average income the loss is equivalent to) by 2019 Human Development Index country group for 2000-2019	63
Figure 20 Average potential loss of earnings in the low Human Development Index country group as a result of potential labour loss due to heat exposure.	64
Figure 21. Economic cost of YLLs in 2015 and 2019, relative to the annual income of the average person and total GDP, by 2019 Human Development Index country group	65
Figure 22. Economic value of annual investment in renewable and fossil fuel energy supply and energy efficiency, 2014-2020.....	68
Figure 23. Net carbon prices (left), net carbon revenues (centre), and net carbon revenue as a share of current national health expenditure (right), across 84 countries in 2018, arranged by 2019 Human Development Index country group	71
Figure 24. The flows of embodied CO ₂ and PM _{2.5} emissions among different Human Development Index country groups in 2019	73
Figure 25. Aggregate monthly co-clicks on Wikipedia articles related to human health and climate change, 2018—2020.....	78
Figure 26. Scientific journal articles relating to health and climate change, 2007-2020, by 2019 country Human Development Index country group	79
Figure 27. Proportion of countries referring to climate change, health, and the intersection between the two in their UNGD statements, 1970-2020	81
Figure 28. Proportion of companies referring to climate change, health, and the intersection of health and climate change in their UN Global Compact Communication on Progress (GCCOP) reports, 2011-2020.	84

List of Panels

Panel 1. The Indicators of the 2021 Report of the <i>Lancet</i> Countdown.....	16
--	----

Panel 2. Gender, Health and Climate Change.....	34
Panel 3. The Urban Heat Island and the Impact of Cool Roofs.....	42
Panel 4. Recovering from Covid-19: Stimulus Measures for a Sustainable Economy.....	66
Panel 5. Compatibility of Fossil Fuel Company Strategies with Well Below 2°C-Consistent Emissions Trajectories.....	70
Panel 6. The place of Health in the Enhanced NDCs.....	82

List of Abbreviations

A&RCC – Adaptation & Resilience to Climate Change
 CDP – Carbon Disclosure Project
 CFU – Climate Funds Update
 CO₂ – Carbon Dioxide
 CO₂e – Carbon Dioxide Equivalent
 COP – Conference of the Parties
 ECMWF – European Centre for Medium-Range Weather Forecasts
 EE-MRIO – Environmentally Extended Multi-Region Input-Output
 EJ – Exajoule
 EM-DAT – Emergency Events Database
 ERA – European Research Area
 ETS – Emissions Trading System
 EU – European Union
 FAO – Food and Agriculture Organization of the United Nations
 GBD – Global Burden of Disease
 GDP – Gross Domestic Product
 GHG – Greenhouse Gas
 GNI – Gross National Income
 GtCO₂ – Gigatons of Carbon Dioxide
 GW – Gigawatt
 GWP – Gross World Product
 HIC – High Income Countries
 HDI – Human Development Index
 IEA – International Energy Agency
 IHR – International Health Regulations
 IPC – Infection Prevention and Control
 IPCC – Intergovernmental Panel on Climate Change
 IRENA – International Renewable Energy Agency
 LMICs – Low- and Middle-Income Countries
 LPG – Liquefied Petroleum Gas
 Mt – Metric Megaton
 MtCO₂e – Metric Megatons of Carbon Dioxide Equivalent
 MODIS – Moderate Resolution Imaging Spectroradiometer
 MRIO – Multi-Region Input-Output
 NAP – National Adaptation Plan
 NASA – National Aeronautics and Space Administration

NDCs - Nationally Determined Contributions
NHS – National Health Service
NO_x – Nitrogen Oxide
NDVI – Normalised Difference Vegetation Index
OECD – Organization for Economic Cooperation and Development
PM_{2.5} – Fine Particulate Matter
PV – Photovoltaic
SDG – Sustainable Development Goal
SDU – Sustainable Development Unit
SIDS – Small Island Developing States
SSS – Sea Surface Salinity
SST – Sea Surface Temperature
tCO₂ – Tons of Carbon Dioxide
tCO₂/TJ – Total Carbon Dioxide per Terajoule
TJ – Terajoule
TPES – Total Primary Energy Supply
TWh – Terawatt Hours
UN – United Nations
UNFCCC – United Nations Framework Convention on Climate Change
UNGA – United Nations General Assembly
UNGD – United Nations General Debate
VC – Vectorial Capacity
WHO – World Health Organization
WMO – World Meteorological Organization

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

Executive Summary

The Lancet Countdown: Tracking Progress on Health and Climate Change is an international collaboration which independently monitors the health consequences of a changing climate. Publishing updated, new and improved indicators each year, it represents the consensus of leading researchers from 38 academic institutions and UN agencies. The 44 indicators of the 2021 report of the Lancet Countdown expose an unabated rise in the health impacts of climate change, and the current health consequences of the delayed and uneven response of countries around the world – providing a clear imperative for accelerated action that puts the health of people and planet first.

This year's report coincides with the 26th UN Framework Convention on Climate Change Conference of the Parties (COP26), a moment when countries are facing pressure to realise the ambition of the Paris Agreement to keep global average temperature rise to 1.5 °C,¹ and mobilise the finance required for all countries to deliver an effective climate response. These negotiations unfold in the context of the COVID-19 pandemic – a global health crisis which has claimed millions of lives, affected livelihoods and communities around the globe and exposed deep fissures and inequities in the world's capacity to cope with, and respond to, health emergencies.²⁻⁴ Yet, in its response to both crises, the world is faced with an unprecedented opportunity to ensure a healthy future for all.

Deepening inequities in a warming world

Record temperatures in 2020 resulted in a new high of 3.1 billion more days of heatwave exposure among people over 65 and 626 million more exposures affecting children under 1 year old, as compared to a 1986-2005 baseline (indicator 1.1.2). Looking to 2021, people in these age groups, along with those facing social disadvantages, were the most affected by the record-breaking temperatures of over 40°C that affected the Pacific northwest areas of the USA and Canada in June 2021⁵ – an event that would have been virtually impossible without human-caused climate change.⁶ Although the tally will not be known for several months, hundreds of people prematurely died from the heat.^{7,8} Furthermore, populations in countries with low and medium levels of UN-defined Human Development Index (HDI)⁹ have experienced the biggest increase in heat vulnerability over the past 30 years, with risks to their health further exacerbated by the lower availability of cooling mechanisms and urban green space in these countries (indicators 1.1.1, 2.3.2 and 2.3.3).

Agricultural workers in countries with low and medium HDI were among the worst affected by exposure to extreme temperatures, bearing almost half the 295 billion potential work hours lost due to heat in 2020 (indicator 1.1.4). These lost work hours could have devastating economic consequences to these already vulnerable workers – data in this year’s report shows that potential earnings lost were equivalent to 4-8% of national GDP in the low HDI country group (indicator 4.1.3).

Through these impacts and alongside rising average temperatures and altered rainfall patterns, climate change is beginning to reverse years of progress in tackling the food and water insecurity that still affects the most underserved populations around the world, undermining a cornerstone of good health.¹⁰ In any given month in 2020, up to 19% of the global land surface was affected by extreme drought, a value that had not exceeded 13% from 1950 to 1999 (indicator 1.2.2). In parallel, warmer temperatures are affecting the yield potential of the world’s major staple crops: a 6.0% reduction for maize; 3.0% for winter wheat; 5.4% for soybean; and 1.8% for rice in 2020, relative to 1981-2010 (indicator 1.4.1); exposes the rising risk of food insecurity in a warming world.

Adding to these health hazards, the changing environmental conditions are also increasing the suitability for the transmission of many water-, air-, food-, and vector-borne pathogens. Although socioeconomic development, public health interventions, and advances in medicine have reduced the global burden of infectious disease transmission, climate change threatens to undermine eradication efforts.^{11,12}

The number of months with environmentally suitable conditions for the transmission of malaria (*Plasmodium falciparum*) rose by 39% from 1950-1959 to 2010-2019 in densely populated highland areas in the low HDI country group – threatening highly disadvantaged populations, previously comparably safe from this disease due to their geographical location (indicator 1.3.1). The epidemic potential for dengue, Zika and chikungunya, which currently affect primarily populations in Central and South America, the Caribbean, Africa and south Asia, increased globally by 13% for the transmission by *A. aegypti* and 7% higher for *A. albopictus* from the 1950s, with the biggest relative increase was seen in countries with very high HDI (indicator 1.3.1). However, it is people in the low HDI country group who are confronted with the highest vulnerability to these arboviruses (indicator 1.3.2).

Similar findings are observed in the environmental suitability for *Vibrio cholerae*, a pathogen estimated to cause almost 100,000 deaths annually, particularly among populations with poor access to safe water and sanitation.¹³ Between 2003 and 2019, the coastal areas suitable for *Vibrio cholerae* transmission increased significantly across all HDI country groups – but, with 98% of their coastline suitable to the transmission of *Vibrio cholerae* in 2020, it is people in the low HDI country group that face the highest environmental suitability for this disease (indicator 1.3.1).

The concurrent and interconnecting risks posed by extreme weather events, infectious disease transmission, and food, water and financial insecurity are overburdening the most vulnerable. Through multiple simultaneous and interacting health risks, climate change is threatening to reverse years of progress in public health and sustainable development.

Even with overwhelming evidence on the health impacts of climate change, countries are not delivering an adaptation response proportionate to rising risks their populations face. In 2020, 63% of all countries were yet to achieve a high level of implementation of national health emergency frameworks, leaving them unprepared to respond to pandemics and climate-related health emergencies (indicator 2.3.1). Importantly, only 55% of low HDI countries had reported at least medium-level of implementation of these frameworks, compared with 89% of very high HDI countries. In addition, only 37 of 70 countries reported having a national adaptation plan for health, with insufficient human and financial resources identified as the key barrier for their implementation (indicator 2.1.1). With a world facing unavoidable temperature rise, even under the most ambitious climate change mitigation, accelerated adaptation is essential to reduce vulnerabilities and protect the health of people around the world.

An inequitable response fails everyone

Six months into 2021, the world had failed to deliver global equitable access to the COVID-19 vaccine: more than 75% of all vaccine doses had been given to people in just 10 countries.¹⁴ Data in this report exposes similar inequities in the global climate change mitigation response.

To meet the Paris Agreement goals and prevent catastrophic levels of warming, global greenhouse gas emissions must halve within a decade.^{15,16} However, at the current pace, it would take over 150 years for the energy system to fully decarbonise (indicator 3.1), and the unequal response between countries is resulting in an uneven realisation of the health co-benefits of a low-carbon transition.

Partly responsible for the slow decarbonisation rate is the use of public funds to subsidise fossil fuels. Out of 84 countries reviewed, 65 were still providing an overall subsidy to fossil fuels in 2018, using funds in many cases equivalent to substantial proportions of the national health budget, and which could otherwise be redirected to deliver net benefits to health and wellbeing. Further, all the 19 countries whose carbon pricing policies did outweigh the effect of any fossil fuels subsidies came from the very high HDI group (indicator 4.2.4).

While countries in the very high HDI group have collectively made the greatest progress in energy system decarbonisation, they are still the main contributors to CO₂ emissions through their local production, accounting for 45% of the global total (indicator 4.2.5). Meanwhile, with a slower pace of decarbonisation and poorer air quality regulations, the medium and high HDI country groups produce the most PM_{2.5} emissions and have the highest rates of air

pollution-related mortality – about 50% higher than the total mortality in the very high HDI group (indicator 3.3). Turning to the low HDI country group, with comparatively lower levels of industrial activity, its local production contributes to only 0.7% of global CO₂ emissions, and it has the lowest mortality rate from ambient air pollution. However, with only 12% of its inhabitants relying on clean fuels and technologies for cooking, the health of these populations is still at risk from dangerously high concentrations of household air pollution (indicator 3.2). Importantly, even within the most affluent countries, people in the most deprived areas overwhelmingly bear the health burden from exposure to air pollution.^{17,18} These findings expose the health costs of the delayed and unequal mitigation response, and underscore the millions of lives to be saved annually through a low-carbon transition that prioritises the health of all populations.

However, the world is not on track to realising these health gains: current global decarbonisation commitments would lead to 2.7-3.1°C of warming by the end of the century,¹⁹ and present direction of post-COVID-19 spending is threatening to make this situation worse, with just 18% of all funds committed for recovery by the end of 2020 expected to reduce greenhouse gas emissions.^{20,21} Indeed, the economic recovery from the pandemic is already predicted to lead to an unprecedented 5% increase in GHG emissions in 2021, which will bring global anthropogenic emissions back to their peak levels.²²

In addition, the current economic recession is threatening to further undermine the target of mobilising US\$100 billion per year from 2020 onwards to promote low-carbon shifts and adaptation responses in the most underserved countries - even while this quantity is now dwarfed by the trillions allocated to COVID-19 recovery.^{23,24} The high levels of borrowing that lower income countries had to resort to during the pandemic could further erase their ability to deliver a green recovery, and maximise the health gains to their population of a low-carbon transition.^{25,26}

[An unprecedented opportunity to ensure a healthy future for all](#)

The overshoot in emissions resulting from a carbon-intensive COVID-19 recovery would irreversibly push the world off track meeting climate commitments and the Sustainable Development Goals – and lock in humanity to an increasingly extreme and unpredictable environment. Data in this report expose the health impact and health inequities of the current 1.2°C world and confirms that, on the current trajectory, climate change will become the defining narrative of human health.

However, by directing the trillions of dollars that will be committed to COVID-19 recovery towards the WHO's prescriptions for a healthy, green recovery, the world could meet the Paris Agreement goals, protect the natural systems that support wellbeing, and minimise inequities through reduced health impacts and maximised co-benefits of a universal low-carbon transition.²⁷ Promoting equitable climate change mitigation and universal access to

147 clean energies could save millions of lives annually from reduced exposure to air pollution,
148 healthier diets, and more active lifestyles, and contribute to reducing health inequities
149 globally.²⁸ This pivotal moment of economic stimulus represents a historical opportunity to
150 securing the health of present and future generations.

151 There is a glimpse of this story unfolding through several promising trends in this year's data:
152 electricity generation from renewable wind and solar energy has increased by an annual
153 average of 17% between 2013-2018 (indicator 3.1); investment in new coal capacity
154 decreased by 10% in 2020 (indicator 4.2.1); and the global number of electric vehicles reached
155 7.2 million in 2019 (indicator 3.4). Additionally, the global pandemic has driven increased
156 engagement in health and climate change across multiple domains in society, with 91 heads
157 of state making the connection in the 2020 UN General Debate, and newly widespread
158 engagement among very high HDI countries (indicator 5.4). Whether COVID-19 recovery
159 supports, or reverses these trends, is yet to be seen.

160 Neither SARS-CoV-2 nor climate change respect national borders. Without widespread,
161 accessible vaccination across all countries and societies, the virus and its new variants will
162 continue to put the health of everyone at risk. Likewise, tackling climate change requires all
163 countries to deliver an urgent and coordinated response, with COVID-19 recovery funds
164 allocated to support and ensure a just transition to a low carbon future and climate change
165 adaptation in all corners of the world. Leaders of the world have an unprecedented
166 opportunity to deliver a future of improved health, reduced inequity, and economic and
167 environmental sustainability. However, this will only be possible if the world acts together to
168 ensure no one is left behind.
169

170 Introduction

171 The COVID-19 pandemic has changed societies in ways previously unimaginable, with
172 deepening and widespread concerns about global health security, inequities, and
173 anthropogenic influences on the environment. As of the 11th of May 2021, the pandemic had
174 resulted in almost 191 million cases and 4.1 million deaths,^{2,3} and its multidimensional
175 impacts on health and wellbeing, together with its disruption to work, social, and leisure
176 activities, still continue. The overwhelming healthcare demand caused 94 of 105 countries
177 examined to experience disruptions to the delivery of essential health services, further
178 undermining health and wellbeing.²⁹ Adding to this, COVID-19 led to a worldwide economic
179 recession, an estimated 90 million people were pushed below the extreme poverty threshold
180 in 2020,^{30,31} and pandemic-induced borrowing by the World Trade Organization's 'developing'
181 countries amounted to US\$130 billion by July that year.²⁶

182 But while the world's attention has been diverted towards the ongoing acute health crisis,
183 the health effects of human-induced climate change continue to increase. Climate change
184 contributed to the unusually high temperatures seen during 2020 in the United Kingdom and
185 Siberia, to the record-breaking well-over 40°C heatwave that affected populations across the
186 Pacific northwest areas of the USA and Canada in June 2021 and caused over 1000 deaths,
187 with that number expected to increase, to an accelerated glacier retreat that is putting the
188 city of Huaraz (Peru) under imminent flooding risk, and to Australia's devastating 2019/2020
189 bushfire season.^{6,32-35} Over a six month period in 2020, 84 disasters from floods, droughts,
190 and storms affected 51.6 million people in countries already struggling with COVID-19,³⁶ with
191 the escalating impacts threatening their ability to respond to health emergencies. Meanwhile,
192 climate impacts may undermine the capacity of countries to repay their debts, further
193 hindering their progress towards the Sustainable Development Goals (SDGs).^{25,37} As with
194 COVID-19, the health impacts of climate change are inequitable, with disproportionate effects
195 on the most vulnerable in every society, including the poor, members of minority groups,
196 women, children, older adults, people with chronic diseases and disabilities, and outdoor
197 workers.³⁸ Such interrelationships between climate change and COVID-19 provide ongoing
198 evidence of the interconnectedness of the world, and of the health consequences of
199 inequities. The 2021 report of the *Lancet* Countdown depicts the synergies and interactions
200 between these two crises.

201 The world is now 1.2°C warmer than in the pre-industrial period, the past seven years rank
202 as the hottest seven on record, and 2020 tied with 2016 as the hottest yet.³⁹⁻⁴¹ Atmospheric
203 CO₂ concentrations have reached a concerning milestone – now 50% higher than in the pre-
204 industrial era.⁴² Changes such as reduced soil moisture could limit the Earth's carbon
205 reuptake, resulting in further CO₂ in the atmosphere.⁴³ Furthermore, some climate tipping
206 points are close to or may have surpassed critical thresholds and could interact to further
207 destabilise the Earth's climate system.^{44,45} While the dramatic reductions in transport and
208 industrial manufacturing during the pandemic resulted in energy-related emissions for 2020
209 falling by 5.8%, the largest annual percentage decline since World War II, this was short-lived

210 and emissions have risen in 2021.^{22,46,47} Without an adequate response, the health effects of
211 climate change will worsen throughout the coming decades.

212 The world now turns with hope to the 2021 UN Framework Convention on Climate Change
213 (UNFCCC) conference in Glasgow (COP26), originally scheduled for 2020. Over the past year,
214 the world has seen more ambitious climate targets from governments and businesses, and
215 73% of global emissions are now covered by net zero emissions targets announced by May
216 2021. Nevertheless, these announcements are non-binding, and even with their full
217 implementation the world would be on track to ~2.4°C (1.9-3.0°C) of warming by 2100.⁴⁸

218 These climate announcements are being made against the backdrop of huge investments in
219 economic recovery from COVID-19. Depending on their consistency with climate targets,
220 these investments could take the world in one of two directions – either driving it towards
221 the goals of the Paris Agreement, or locking it into increased emissions and climate change
222 that will damage the health of current and future generations. As humanity faces a critical
223 turning point, the indicators in this report provide the health evidence to inform a global
224 response to the impacts of climate change, and identify the considerable health,
225 environmental and economic benefits that would result if a ‘green recovery’ from COVID-19
226 was prioritised.

227

228 [Five years of tracking progress on health and climate change](#)

229 The *Lancet* Countdown is an independent, international, and multidisciplinary collaboration
230 that monitors the health impacts of climate change, and progress – or lack thereof – in the
231 world’s response. It draws on the expertise of climate scientists, economists, energy and
232 transport experts, social and political scientists, public health experts and health professionals
233 among others, spanning 38 academic and UN institutions. Together, they report on 44
234 indicators, organised within five domains: climate change impacts, exposures, and
235 vulnerabilities; adaptation, planning, and resilience for health; mitigation actions and health
236 co-benefits; economics and finance; and public and political engagement. The 2021 report of
237 the *Lancet* Countdown is its sixth annual report, building on nine years of collaborative work.

238 The *Lancet* Countdown’s indicator domains were selected through an open, global
239 consultation process that identified scientifically documented links between health and
240 climate change, with indicators developed according to well-established methods, and to the
241 availability of reliable and regularly updated data with adequate geographical and temporal
242 scales.⁴⁹ Each year, the indicators have been improved upon through an open, iterative and
243 adaptive approach, and new indicators have been introduced to provide an increasingly
244 complete picture of the health dimensions of climate change. For the two most recent
245 reports, prior to the formal peer review, all new indicators underwent an independent
246 assessment process led by world experts in their respective domains, adding rigour and
247 transparency to the collaboration’s research. Existing indicators are undergoing a similar,

248 independent quality improvement process, aimed at ensuring they continue to use the best
249 available data and methods.

250 Three new important indicators are added to the 2021 report: the first incorporates
251 considerations of mental wellbeing by tracking the effect of heat on expressed online
252 sentiment; the second captures the influence of heat on safe physical activity; and the third
253 tracks consumption-based greenhouse gas and PM_{2.5} emissions. Most of the pre-existing
254 indicators underwent major improvements, with strengthened methods, datasets and
255 metrics, and expanded geographical and temporal coverage. All indicators, including their
256 methods, data sources, caveats, and plans for future improvements, are described in detail
257 in the appendix – an essential manual for this report. The final indicators for the 2021 report
258 are listed in panel 1.

259 Each indicator, wherever possible and appropriate, is disaggregated into very high, high,
260 medium, and low Human Development Index (HDI) country groups, as defined by the United
261 Nations Development Programme (UNDP), in the latest year for which data are available
262 (2019).⁹ This composite index captures three key dimensions: a long and healthy life (with life
263 expectancy as a proxy), education (captured by the mean of years of schooling for adults),
264 and standard of living (measured by per capita gross national income).⁹ In line with the
265 priorities of *The Lancet's* Diversity Board, gender disparities are also considered wherever
266 relevant. However, a stark lack of gender-disaggregated data, means that few indicators are
267 able to capture these differences quantitatively, and often do so using sex disaggregation as
268 a proxy for gender (see panel 2).

269 The COVID-19 pandemic will alter the trends of many of the indicators reported – some of
270 which can be identified in this report, and others which will become apparent in the coming
271 years. COVID-19 has also altered population demographics and mortality rates, as well as the
272 structure and size of the labour force. These changes are not reflected in the current
273 indicators, presenting methodological challenges in the assessment of the health impacts of
274 climate change. How this impacts the methods and assumptions of the *Lancet* Countdown's
275 indicators will become clearer in future reports, as more data become available.

276 The global reach of the *Lancet* Countdown is expanding. Two regional offices – in South
277 America (based at Universidad Peruana Cayetano Heredia, Lima, Peru) and in Asia (based at
278 Tsinghua University, Beijing, China) – were established in 2020. These regional collaborators
279 contributed indicators to the global 2021 report and are working on nationally- and
280 regionally-relevant health and climate change research, accompanied by local
281 communications and policy engagement. A third regional office, based at the University of
282 the West Indies, was established in September 2021, aiming to build on the network and
283 evidence base of health and climate change in Small Island Developing States (SIDS). The
284 *Lancet* Countdown is also working in collaboration with the European Environment Agency,
285 incorporating policy-relevant data from its indicators into the European Climate and Health
286 observatory.

287 National and regional reports were published for Australia (in partnership with the *Medical*
288 *Journal of Australia*), China, and SIDS.⁵⁰⁻⁵² For the third year now, the data underpinning each
289 of the *Lancet* Countdown's indicators have been shared through an online data visualisation
290 platform, where they can be explored at finer spatial and temporal scales.

291 The work of this collaboration is driven by the ongoing support from *The Lancet* and the
292 Wellcome Trust, the *Lancet* Countdown's scientific advisory group and higher-level advisory
293 board, and, importantly, the *Lancet* Countdown's authors and collaborators. The
294 collaboration welcomes further offers of support from new experts and new institutions,
295 willing to build on this analysis, as the *Lancet* Countdown monitors the world's response to
296 the health effects of climate change across this decade.

297

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 and Physical Activity
		1.1.4: Change in Labour Capacity
		1.1.5: Heat and Sentiment
		1.1.6: Heat-Related Mortality
	1.2: Health and Extreme Weather Events	1.2.1: Wildfires
		1.2.2: Drought
		1.2.3: Lethality of Extreme Weather Events
	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 Rising Sea Levels	
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: Health Adaptation-Related Global Funding and Financial Transactions	
Mitigation Actions and Health Co-Benefits	3.1: Energy System and Health	
	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 Economic Impact of Climate Change and its 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 Reduction
		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: Coal and Clean Energy Investment
		4.2.2: Employment in Low-Carbon and High-Carbon Industries
		4.2.3: Funds Divested from Fossil Fuels
		4.2.4: Net Value of Fossil Fuel Subsidies and Carbon Prices
	4.2.5: Production- and Consumption-Based Attribution of CO ₂ and PM _{2.5} Emissions	
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	

298 Panel 1. The Indicators of the 2021 report of the Lancet Countdown

299 Section 1: Climate Change Impacts, Exposures, and Vulnerability

300 Climate change threatens human health and wellbeing through impacts on weather,
301 ecosystems and human systems – increasing exposure to extreme events, changing the
302 environmental suitability for infectious disease transmission, altering population movements,
303 and undermining people’s livelihoods and mental health.⁵³⁻⁵⁷ The resulting strains on health
304 and social systems are felt disproportionately by the most disadvantaged in society, with
305 climate change amplifying inequities.^{53,54}

306 Section 1 of the 2021 report monitors the health impacts of climate change, with indicators
307 tracking climate hazards, human exposure and vulnerabilities, and the resulting health
308 outcomes. The first group of indicators addresses the direct implications of rising
309 temperatures for health, exploring changes in the exposure and vulnerabilities of world
310 populations to extreme heat, as well as its impacts on health and wellbeing (indicators 1.1.1–
311 1.1.6, see panel 1). Each of these indicators takes gridded heat data as a starting point, and
312 overlays them with relevant exposure and vulnerability data to reflect health outcomes. Two
313 new indicators are introduced: one examines how heat is reducing the possibility to
314 undertake outdoor exercise safely (indicator 1.1.3); the other approaches the challenge of
315 assessing the influence of extreme heat on sentiment, using Twitter data to capture people’s
316 online expressions (indicator 1.1.5).⁵⁸

317 The second group of indicators in this section sheds light on climate-sensitive extreme events,
318 tracking exposure to wildfire and wildfire risk (indicator 1.2.1), the incidence of droughts
319 (indicator 1.2.2), and the lethality of extreme weather events (indicator 1.2.3). Capturing the
320 influence of environmental changes on ecological niches for human pathogens, the section
321 also models the changing suitability for the transmission of climate-sensitive infectious
322 diseases, expanding the analysis from previous years to capture three new diseases of global
323 public health relevance (Zika, chikungunya and *Vibrio cholerae*), and improving models to
324 reflect the reproduction number for arbovirus transmission. With health outcomes of vector-
325 borne disease transmission strongly influenced by socioeconomic factors and healthcare
326 access, indicator 1.3.2 incorporates considerations of implemented adaptation measures to
327 capture the changing vulnerability to arboviruses. This is followed by indicators of
328 environmental pressure on terrestrial and marine food productivity, this year extending the
329 analysis to assess the association between heat stress and severe food insecurity (indicators
330 1.4.1 and 1.4.2). The final indicator in this section focuses on exposure to sea level rise and its
331 implications for human mobility (indicator 1.5).

332

333 1.1 Health and Heat

334 Indicator 1.1.1: Vulnerability to the Extremes of Heat

335 *Headline finding: although vulnerability to heat in the low and medium Human Development*
336 *Index country groups remains 27-38% lower than that of the very high Human Development*
337 *Index group, it is increasing rapidly and is today 19% and 20% higher than in 1990, respectively*

338 Exposure to extreme heat poses an acute health hazard, with individuals over 65 years of
339 age,⁵⁹⁻⁶¹ urban populations,^{60,61} and those with underlying health conditions^{59,60} particularly
340 at risk. Heat disproportionately affects the marginalised or under-resourced that have limited
341 access to cooling mechanisms and healthcare, amplifying health and social inequities.⁶²⁻⁶⁵

342 This indicator tracks vulnerability to extreme heat, through an index that combines the
343 proportion of the population older than 65 years, the prevalence of relevant chronic diseases
344 (respiratory disease, cardiovascular disease, and diabetes) in that group, and the proportion
345 of the total population living in urban areas.

346 With aging populations, high prevalence of chronic diseases, and increasing urbanisation, the
347 very high HDI countries exhibited the highest vulnerability to extremes of heat. Vulnerability
348 is rising across all HDI groups, with countries of low and medium HDI experiencing the highest
349 increases from 1990 levels (19% and 20%, respectively). The heat indicators that follow each
350 present worsening trends, highlighting a great need to identify populations that are
351 vulnerable to the health impacts of heat, at the national and at the local level. Further work
352 will be done to capture other heat vulnerabilities within this indicator.

353

354 Indicator 1.1.2: Exposure of Vulnerable Populations to Heatwaves

355 *Headline finding: in 2020, compared with the 1986-2005 baseline, children under 1 and adults*
356 *over 65 were affected by 626 million and 3.1 billion more days of heatwave exposure,*
357 *respectively*

358 Young children and older persons are especially susceptible to the health risks of high
359 temperatures and heatwaves.⁶⁶ This indicator reports the total number of days adults aged
360 over 65 years and (for the first time) children from birth to 1 year, were exposed to life-
361 threatening heatwave events. In an improvement from previous years, the definition of a
362 heatwave now aligns with the World Meteorological Organization (WMO) and other scientific
363 literature.⁶⁷⁻⁶⁹ Additional details are given in the appendix (pp 5-7).

Results show a steady increase in the person-days of exposure for adults over 65 years, with the last 10 years seeing an annual average of 2.9 billion additional events and 3.1 billion more person-days of exposure (or an average of 4.1 days per person >65 years) in 2020, with respect to the 1986-2005 baseline (Figure 1). For children under 1 year, there were an estimated 626 million additional person-days of exposure (4.6 days per person <1 year) affecting this vulnerable group in 2020, compared with baseline years.

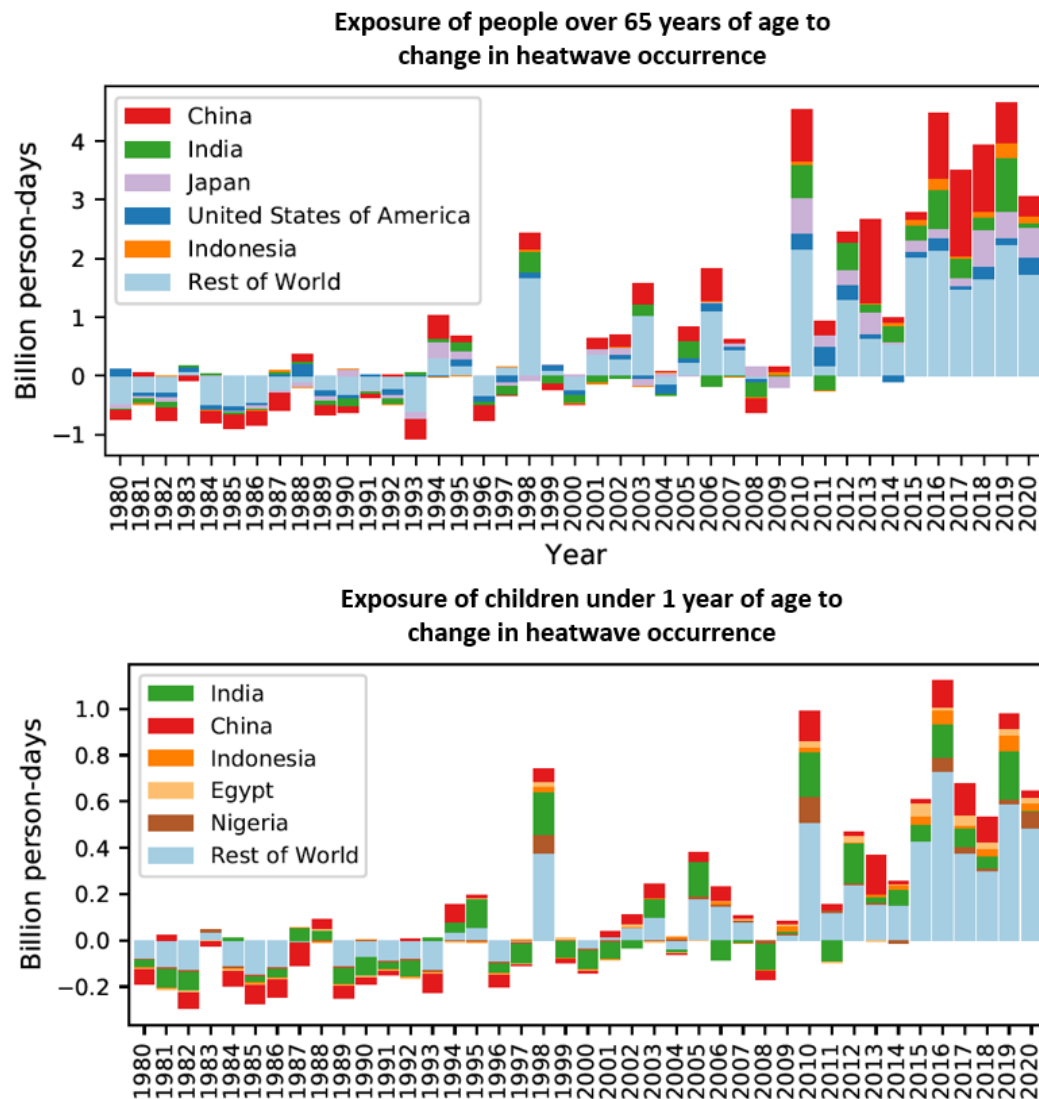


Figure 1. Change in person-days of heatwave exposure relative to the 1986-2005 baseline. A) in the population aged over 65 years; B) in the population aged under 1 year of age. In each case, the countries with the highest exposure averages over the past 5 years are highlighted.

Indicator 1.1.3: Heat and Physical Activity

Headline finding: the last four decades saw an increase in the number of daily hours in which temperatures were too high for safe outdoor exercise, with people in the medium Human Development Index country group experiencing an average loss of 4.4 hours of safe exercise per day in 2020

Physical exercise provides mental health benefits, and reduces the risk of cardiovascular disease, diabetes, cancer, cognitive decline and all-cause mortality.⁷⁰⁻⁷⁴ However, high temperatures can reduce the frequency and duration of physical activity, and the desire to engage in exercise,⁷⁵⁻⁷⁷ and even low levels of physical activity can pose a risk to health under high temperatures.⁷⁸ This indicator estimates the hours of physical activity potentially lost per person due to ambient temperature, humidity, and radiant heat, by tracking the number of hours per day during which the wet bulb globe temperature (WBGT) exceeds 28°C, a threshold above which national sports medicine authorities of the USA, Australia and Japan recommend outdoor physical activities to be conducted with discretion.^{79,80}

Due to rising temperatures, the loss in the number of hours available for safe physical activity per day increased in all four country HDI groups (Figure 2). The greatest rate occurred the medium HDI country group, with an average increase from 3.5 hours per person per day in 1980 to 4.4 hours per person per day in 2020.

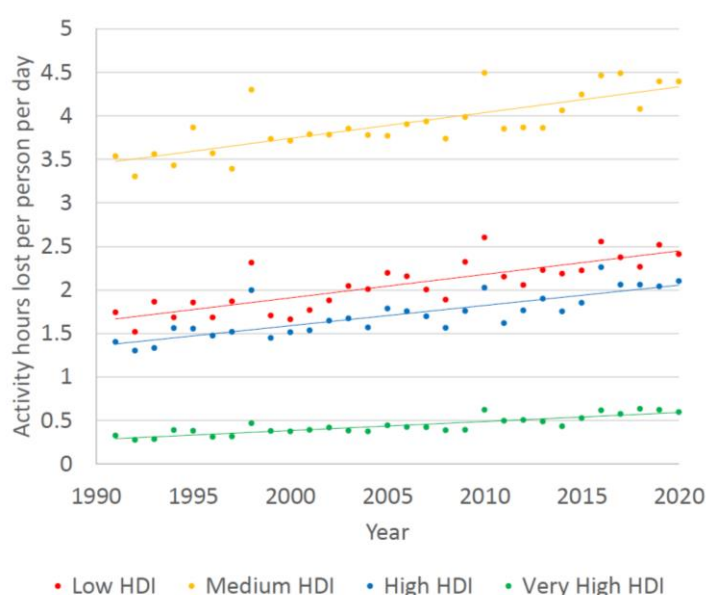


Figure 2. Average potential activity hours lost per person per day by 2019 Human Development Index country group, 1980-2020.

397 Indicator 1.1.4: Change in Labour Capacity

398 *Headline finding: in 2020 the world lost 295 billion potential work hours due to extreme heat*
399 *exposure, with 79% of all losses in countries of low Human Development Index level occurring*
400 *in the agricultural sector*

401
402 As well as through its direct impacts on health, high temperatures can also affect people's
403 ability to work.⁸¹ This indicator estimates the potential work hours lost as a result of heat
404 exposure, by linking WBGT with the power (metabolic rate) typically expended by a worker
405 within the construction, manufacturing, agriculture, and all other sectors.

406 In a rising trend, 295 billion potential work hours were lost across the globe in 2020 due to
407 heat exposure – equivalent to 88 work hours per employed person. The three most populous
408 countries with medium HDI levels, Pakistan, Bangladesh, and India experienced the greatest
409 losses (2.5-3 times the world average, equivalent to 216-261 hours lost per employed person
410 in 2020). In contrast, the three most populous countries with very high HDI levels (the USA,
411 Japan, and Russia) accounted for the smallest numbers of labour hours lost. With lockdowns
412 around the world, COVID-19 led to the loss of millions of hours of effective labour, particularly
413 within service, construction, and manufacturing sectors.⁸² The changes in labour structure
414 induced by COVID-19 are not currently accounted for by this indicator.

415 Almost half of the total potential work hours lost globally occurred in the agricultural sector
416 of low and medium HDI countries. Occupational heat exposure disproportionately affects
417 labourers in the agricultural sector of low HDI countries, with 79% (25.8 out of 32.6 billion
418 hours) of these countries' losses occurring in this sector, compared with only 12% (1.1 out of
419 9.3 billion hours) in very high HDI countries. The impacts could therefore extend to food
420 production. While heat affects labour capacity across all genders, differences in occupation
421 may drive gender disparity. Men make up 80% of the total employment in the construction
422 sector, and indigenous women and women in rural areas, who are highly dependent on local
423 natural resources for their livelihood would be particularly affected by the impacts of climate
424 change on labour capacity.⁸³⁻⁸⁵

425

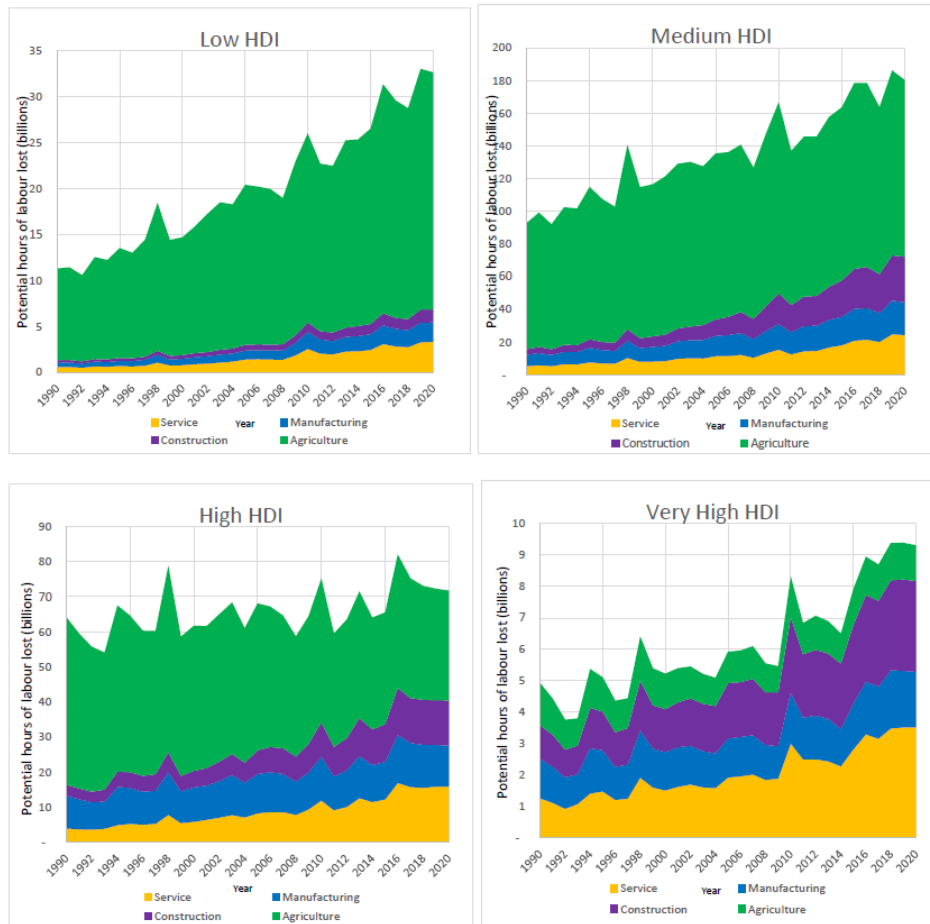


Figure 3. Heat-related potential hours of labour lost by sector and 2019 country Human Development Index group, 1990-2020

Indicator 1.1.5: Heat and Sentiment

Headline finding: Exposure to heatwave events significantly worsens expressed sentiment, with a 155% increase in negative expressions during heatwaves in 2020 relative to the 2015-2019 average

Climate change-related increases in heat extremes pose diverse risks to mental health globally, ranging from altered affective states to elevated mental health-related hospitalisations and suicidality.^{55-57,86-89} However, because the definition, acknowledgement, stigmatisation, and treatment of mental health varies across different regions and cultures,⁵⁸ capturing the mental health impacts of climate change still remains a challenge that the Lancet Countdown will work to address in upcoming years.

This indicator, new to the 2021 report, tracks the effect of heatwaves on the sentiment of expressions from Twitter users around the world, using previously published methods for estimating climate impacts.⁹⁰⁻⁹² Briefly, this indicator classifies the sentiment expressed in over six billion geolocated tweets collected between 2015 and 2020, using the Linguistic Inquiry Word Count (LIWC) sentiment classification tool.⁹⁴ It then deploys a multivariate ordinary least squares fixed effects model to estimate the annual effect of heatwaves on expressed sentiment. In this way, it compares sentiment expression during as-good-as-random heatwave days (as defined in indicator 1.1.2) with non-heatwave days in 40,000 unique localities for nearly one million individuals per day. Potential temporal and geographical confounders were adjusted for by taking into account the month, calendar date, and location of each tweet in the analysis. Further detail is provided in the appendix (pp 15-18). This indicator offers a glimpse into the influence of extremes of heat on sentiment of people around the world. However, since Twitter access and social media use are not evenly distributed, higher income countries are disproportionately represented.

Local heatwave exposure was found to significantly reduce positive expressions and increase negative expressions (Figure 4). In 2020, the percentage point increase in negative sentiment during a heatwave day rose to 0.20 (95% CI: 0.31-0.08), 155% higher than the 2015-2019 average effect. Compared to the recent 2015-2019 baseline, the magnitude of this additional increase was substantive, equivalent to three quarters of the total rise in negative sentiment observed during a benchmark flooding event (see appendix, p 18). In parallel the reduction in positive sentiment observed during 2020 was 11.9% smaller than that observed during 2015-2019.

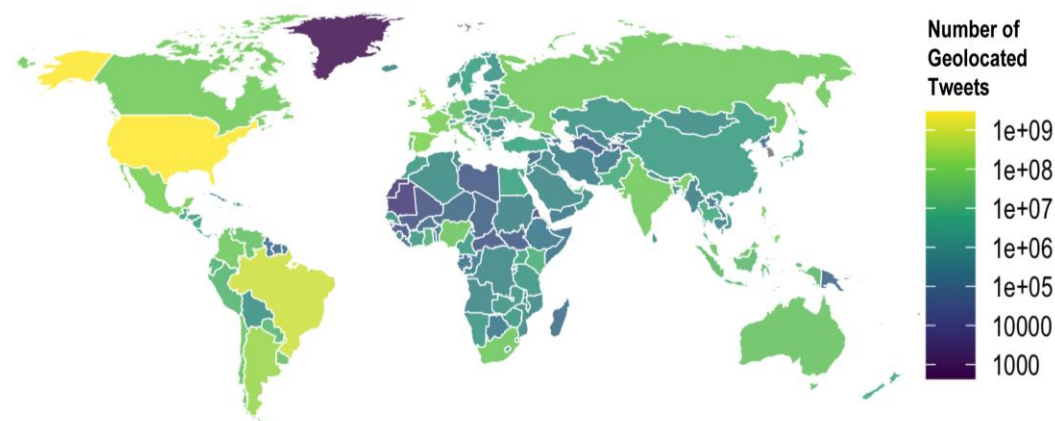
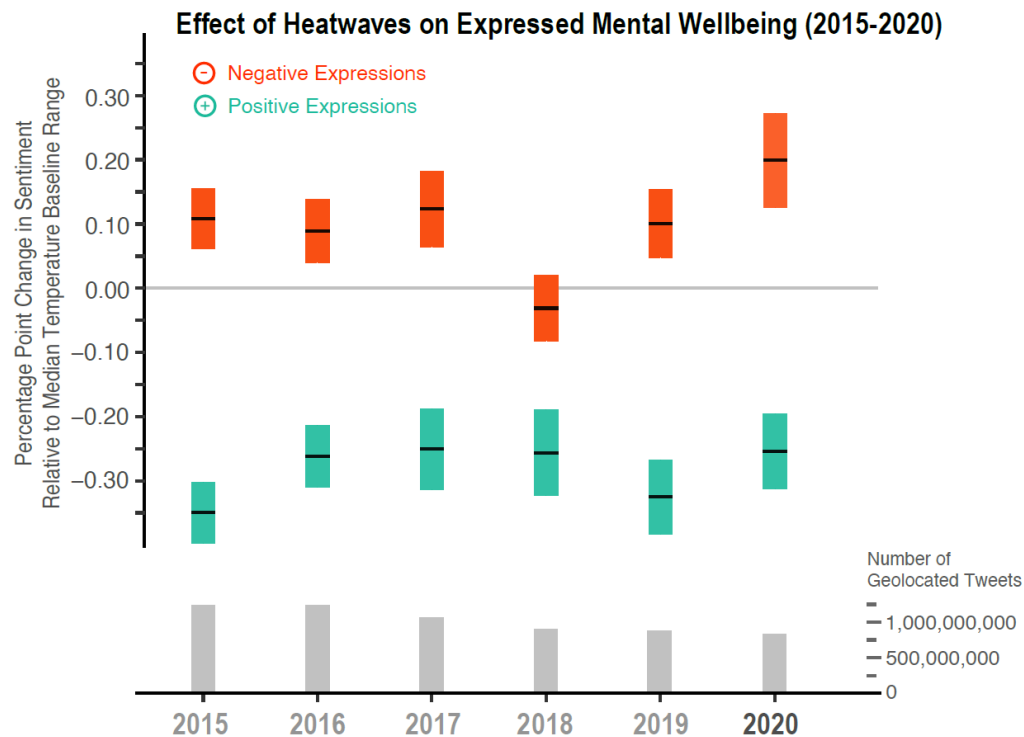


Figure 4. Heatwaves and sentiment. Top: Annual effect of heatwave exposure on the sentiment of online expressions from 2015-2020. Coloured intervals depict 95% CIs of the estimated average change in positive (green) and negative (orange) sentiment expressions during days with heatwaves, relative to the median daily maximum temperature baseline range for each location and year. Sentiment was extracted from Twitter posts using a dictionary-based approach across multiple languages. Grey bars depict the geolocated Tweet count by year of observation. Bottom: Country-level count of geolocated tweets for 2015-2020.

Indicator 1.1.6: Heat-Related Mortality

Headline finding: heat-related mortality in the ≥ 65 population reached a record high of an estimated 345,000 deaths in 2019. Between 2018 and 2019, all WHO regions except for Europe saw an increase in heat-related deaths in this vulnerable age group

Exposure to extreme heat increases risk of cardiovascular, cerebrovascular and respiratory mortality, as well as all-cause mortality.⁹⁵ As in the 2020 report, this indicator uses the exposure-response function and minimum mortality temperature defined by Honda and collaborators⁹⁶ to estimate deaths attributable to extremes of heat, with work ongoing to increase the accuracy of local estimates.^{96,97} Using life expectancy data from the Global Burden of Disease 2019 Study,⁹⁸ years of life lost (YLL) were also calculated to better reflect health burdens.

Heat-related mortality for the 65-and-older population increased throughout the period of study, reaching a record high of almost 345,000 deaths in 2019 (Figure 5) - 80.6% higher than in the 2000-2005 average. Between 2018 and 2019, India and Brazil experienced the biggest absolute increase in heat-related mortality. Although heat related mortality fell from 2018 to 2019 in the WHO European region (due to fewer attributable deaths in countries such as Germany, Russia, and the UK), this region still remains the most affected, with almost 108,000 deaths attributable to heat exposure in 2019.

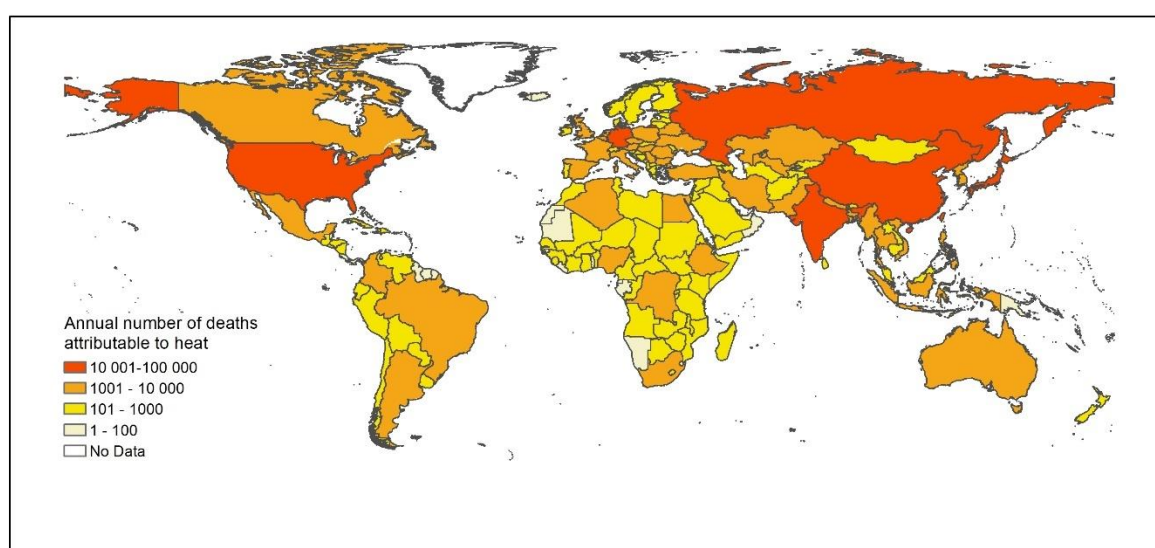


Figure 5. Heat-related mortality among the 65-and-older population in 2019, by country

1.2 Health and Extreme Weather Events

Indicator 1.2.1: Wildfires

Headline finding: nearly 60% of countries saw an increase in the number of days people were exposed to 'very high' or 'extremely high' fire danger in 2017-2020 compared to 2001-2004, and 72% experienced an increased human exposure to wildfires across the same period

Hotter and drier conditions caused by climate change increase the risk of wildfires and the extent of their damage.⁹⁹ As in previous years, this indicator tracks wildfire exposure by joining satellite-observed active fire spots,^{100,101} as well as human exposure to high and very high climatological wildfire danger by combining areas with a Fire Danger Index score of over 5 and population data.¹⁰² A full description of the methods can be found in the appendix (pp 22-23). This indicator does not yet quantify exposure to wildfire smoke, which can affect much greater populations and have large health consequences. For example, it is estimated that smoke from the 2019/2020 Australian fires affected 80% of Australia's population and resulted in hundreds of deaths and thousands of hospital presentations.¹⁰³

Globally, in 2017-2020, there was an additional annual average of 215,531 person-days of wildfire exposure compared to 2001-2004. Overall, 72.4% (134 out of 185) of countries experienced an increase in wildfire exposure over this time. But the increase was unequal: 83% (27 out of 32) of low HDI countries experienced an increase in wildfire exposure compared with 62.5% (40 out of 64) of very high HDI countries. The largest increases were observed in The Democratic Republic of the Congo, India, and China. Over the same time period, the climatological danger of wildfire increased in 110 countries, with the largest growth occurring in Lebanon, Gambia, and Lesotho (Figure 6).

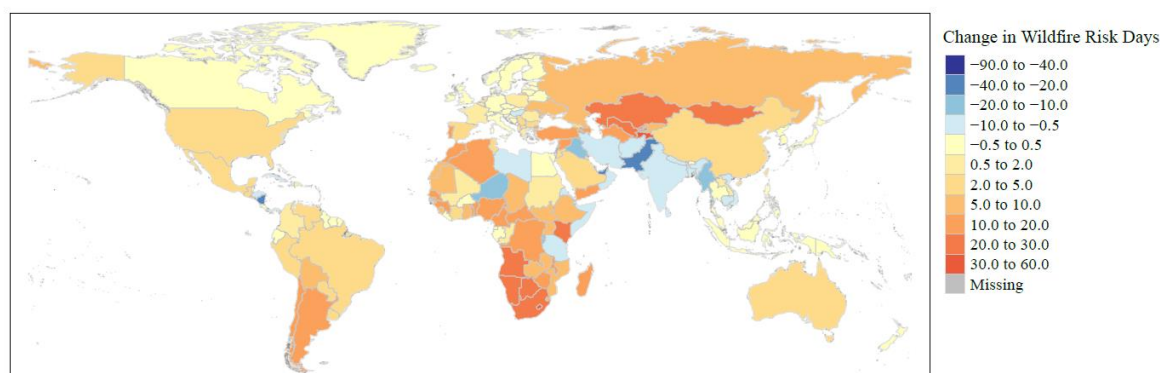


Figure 6. Annual population-weighted mean changes in days of very high and extremely high fire danger from 2001-2004 to 2017-2020 for each country/territory. Large urban areas with population density ≥ 400 persons/km² are excluded in the calculations of population-weighted mean values.

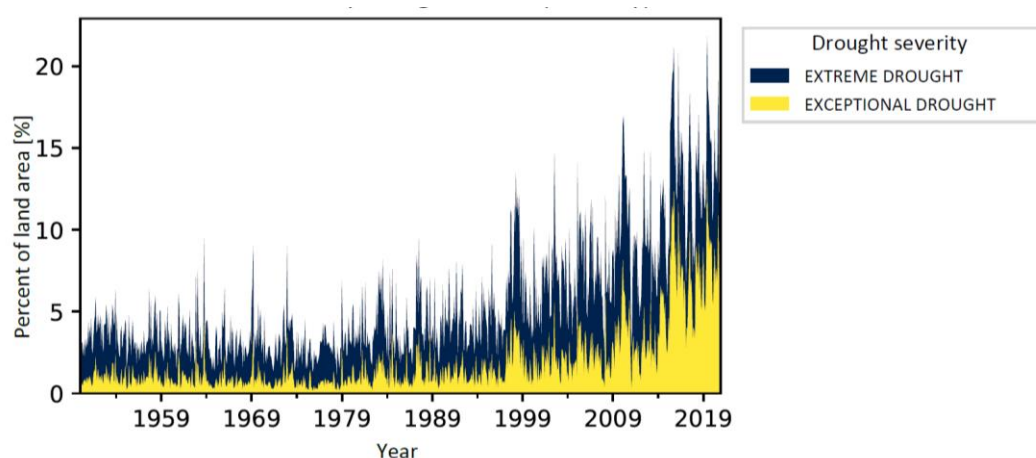
518 Indicator 1.2.2: Drought

519 *Headline finding: in 2020, up to of 19% of the global land surface was affected by extreme*
520 *drought in any given month*

521 Climate change is driving an increase in the frequency, intensity, and duration of drought
522 events. This is posing threats to water security, sanitation and food productivity, and
523 increasing the risk of wildfires and exposure to pollutants.^{53,104}

524 This indicator tracks the land area affected by extreme drought events using the Standardised
525 Precipitation-Evapotranspiration Index (SPEI), capturing the changes in precipitation and the
526 effect of temperature on evaporation and moisture loss.

527 The global land surface area affected by extreme drought conditions has consistently
528 increased over the past 30 years. The percentage of the world's land surface experiencing
529 extreme drought in a given month reached a maximum of 22% in the 2010-2019 decade, a
530 value that had only ever reached 13% in 1950-1999 (Figure 7). Furthermore, the 5 years with
531 the most area affected have all occurred since 2015, and the Horn of Africa, a region impacted
532 by recurrent extreme droughts and food insecurity,¹⁰⁵ was one of the most affected areas in
533 2020.



534
535 *Figure 7. Percentage of land area affected by drought events per month*

536 Indicator 1.2.3: Lethality of Extreme Weather Events

537 *Headline finding: the last 30 years have seen statistically significant increases in the number*
538 *of extreme weather events, yet only the low Human Development Index country group*
539 *experienced a statistically significant increase in the number of people affected by these*
540 *events*

541 This indicator tracks the number of occurrences of climate-sensitive weather-related
542 disasters, and the number of people affected and killed per event. Data is taken from the
543 Centre for Research on the Epidemiology of Disasters,¹⁰⁶ and presented as standardised
544 anomalies across the 1990-2020 period. The number of extreme weather events has seen a
545 consistent and statistically significant increase in all HDI country groups over the last 30 years,
546 with the very high HDI country group experiencing the highest increase (see appendix pp 27-
547 31). However, only the low HDI country group experienced a statistically significant increase
548 in the number of people affected per disaster event, a situation that might reflect greater
549 population shifts to high-risk areas or inequities in adaptive capacity and preparedness to
550 respond to worsening climate change hazards.

551

552 1.3 Climate-Sensitive Infectious Diseases

553 Indicator 1.3.1: Climate Suitability for Infectious Disease Transmission

554 *Headline finding: in the last decade, the area of coastline suitable for Vibrio bacterial*
555 *transmission has increased by 35% in the Baltic, 25% in the Atlantic Northeast, and 4% in the*
556 *Pacific Northwest. The number of months suitable for malaria transmission increased by 39%*
557 *between 1950-1959 and 2010-2019 in highland areas of the low Human Development Index*
558 *country group*

559 Climate change is affecting the distribution of arthropod-, food-, and water-borne
560 diseases.^{11,12} Together with global mobility and urbanisation, climate change is a major driver
561 of the increase in dengue cases,¹⁰⁷ which have doubled every decade since 1990.⁹⁸ Other
562 important emerging or re-emerging arboviruses, transmitted by the same vectors, are likely
563 similarly responsive to climate change.¹⁰⁸ This indicator tracks the environmental suitability
564 for the transmission of arboviruses (dengue, chikungunya and Zika) using an improved model
565 to capture the influence of temperature and rainfall on vectorial capacity and vector
566 abundance, and overlaying it with human population density data to estimate the R_0 (the
567 expected number of secondary infections resulting from one infected person). The R_0 for all
568 arboviral diseases tracked has increased rapidly from the 1950s, and, in 2020, was 13% higher
569 for the transmission by *A. aegypti* and 7% higher for *A. albopictus*, than in baseline years
570 (1950-1954). The largest increases in epidemic potential for dengue, Zika and chikungunya
571 were in countries with very high HDI, mainly driven by the ongoing expansion of *Aedes*
572 mosquitoes.

The influence of the changing climate on the length of the transmission season for *Plasmodium falciparum* malaria is also tracked, using a threshold-based model that incorporates precipitation accumulation, average temperature, and relative humidity.³⁶ There were significant changes in the number of months suitable for transmission of malaria in highland areas ($\geq 1,500$ m above sea level) between 2010-2019 compared to 1950-1959, with an increase of 39% in highlands within the low HDI country group, and an increase of 15% in those within medium HDI group. The difference between high and medium HDI areas is even more marked at a sub-national level. This suggests that climate change might make malaria eradication efforts increasingly difficult in already disadvantaged areas.

Finally, this indicator monitors the environmental suitability for the transmission of *Vibrio* bacteria in coastal waters. *Vibrio* pathogens can cause gastroenteritis and life-threatening cholera, as well as severe wound infections and sepsis.³⁷ Driven by changes in sea surface temperature and sea surface salinity, the environmental area of coastline showing suitable conditions for the transmission of non-*cholerae* *Vibrio* species at any one point during the year increased by 56% (from 7.0% to 10.9% of the coastline) in northern latitudes (40-70° N) in 2020 compared to a 1980s baseline. From the 1980s to the most recent decade, the area of coastline suitable for these bacteria at any point during the year has risen from 47.5% to 82.4% in the Baltic, 29.9 to 54.9% in the Atlantic Northeast, and 1.2 to 5.1% in the Pacific Northwest (Figure 8). Between 2003 and 2019, there was an increase in the proportion of coastline with suitable conditions for *Vibrio cholerae* across all HDI country groups, with the low HDI country group being having the highest suitability on average, at 98.6% of countries' coastlines in 2019. However, it was the high HDI country group that showed the biggest increase in suitable coastline area during this period, at a rate of almost an additional 1% of their coastline becoming suitable each year ($r^2=0.78$, $df=15$, $p<0.01$).

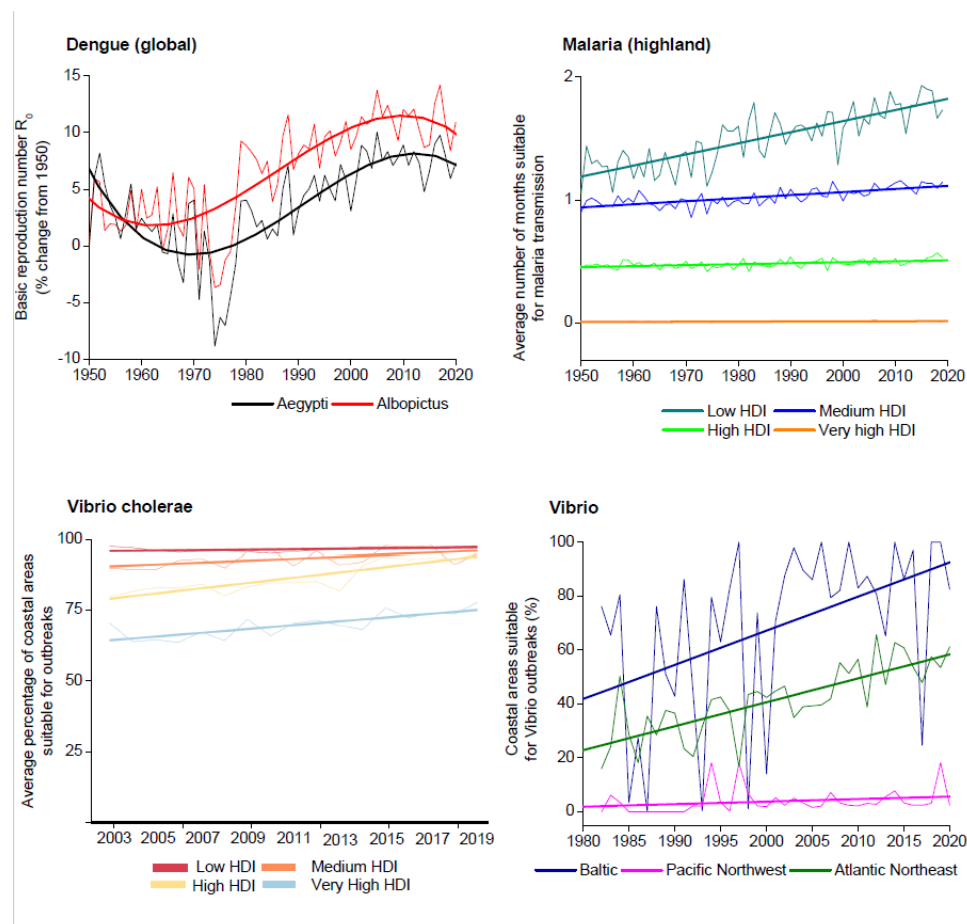


Figure 8. Change in climate suitability for infectious diseases. Solid lines represent the annual change. Straight lines represent the trend since 1950 (for dengue and malaria), 1982 (for Vibrio bacteria), and 2003 (for Vibrio cholerae)

Indicator 1.3.2: Vulnerability to Mosquito-Borne Diseases

Headline finding: while vulnerabilities to arboviruses transmitted by *A. albopictus* and *A. aegypti* have decreased across all countries since the year 2000, countries in the low Human Development Index group remain on average the most vulnerable

As demonstrated by indicator 1.3.1, climate change is making environmental conditions increasingly favourable for the transmission of certain arboviruses. While interventions to reduce vulnerabilities can partly counteract these threats, environmental pressures make this increasingly challenging. This indicator combines the environmental suitability for the transmission of dengue (as described in indicator 1.3.1) with key indicators of social vulnerability to this disease: access to sanitation and water services, income level, and healthcare quality.^{109,110}

Due to improvements in sanitation, income and healthcare quality, vulnerability to mosquito-borne diseases is decreasing, even despite increases in their environmental suitability. However, improvements have been slower in the lower HDI country groups: while the vulnerability for transmission by *A. aegypti* has decreased by 34% in the low HDI country groups from 2000 to 2017, the reduction in the high HDI country groups has been of 61%. The vulnerability index remains inversely related to the level of HDI, with countries in the low HDI group having a vulnerability index over 360 times higher than countries in the very high HDI group in 2017 (appendix pp 45-46).

1.4 Food Security and Undernutrition

Indicator 1.4.1: Terrestrial Food Security and Undernutrition

Headline finding: crop yield potential continues to follow a downward trend, with 6.0% reduction in the crop yield potential of maize; 3.0% for winter wheat; 5.4% for soybean, and 1.8% for rice, relative to 1981-2010 levels

Food insecurity is on the rise and affected 2 billion people in 2019.¹¹¹ Climate change threatens to exacerbate this crisis, which will disproportionately affect the most vulnerable and those already facing undernutrition. Due to socially defined gender roles and lower empowerment, food insecurity disproportionately affects rural women, reinforcing their disadvantaged position through reduced educational attainment, income and socioeconomic status.¹¹²

This indicator tracks the change in crop yield potential resulting from rising temperatures using the same methods as for the 2020 report. Rising temperatures shorten the time taken for crops to reach maturity, thereby leading to reduced seed yield potential.¹¹³ A reduction in crop yield potential can be considered an indicator of future crop yield reductions due to higher growing season temperatures (and therefore a shortened growing season). Crop yield potential continues to follow a consistently downward trend, adding extra pressure to already strained food systems around the world. Reductions in time to maturity are observed in all staple crops tracked, amounting to 6.0% reduction for maize, 3.0% for winter wheat, 5.4% for soybean, and 1.8% for rice, relative to 1981-2010 levels (Figure 9).

Data from the Food Insecurity Experience Scale of the United Nations' Food and Agriculture Organization (FAO) was used to assess self-reported experience of 'severe food insecurity', defined as a situation in which an individual went at least one whole day without eating as a result of lack of resources in the prior 12 months, in 83 countries. A fixed-effects, time-varying regression showed that every 1°C of temperature increase was associated with 1.4% increase in the probability of 'severe food insecurity' (95% CI: 1.3 to 1.47; p-value: <0.001) in 2014 and 1.64% (95% CI: 1.6 to 1.65; p-value: <0.001) in 2019, globally.

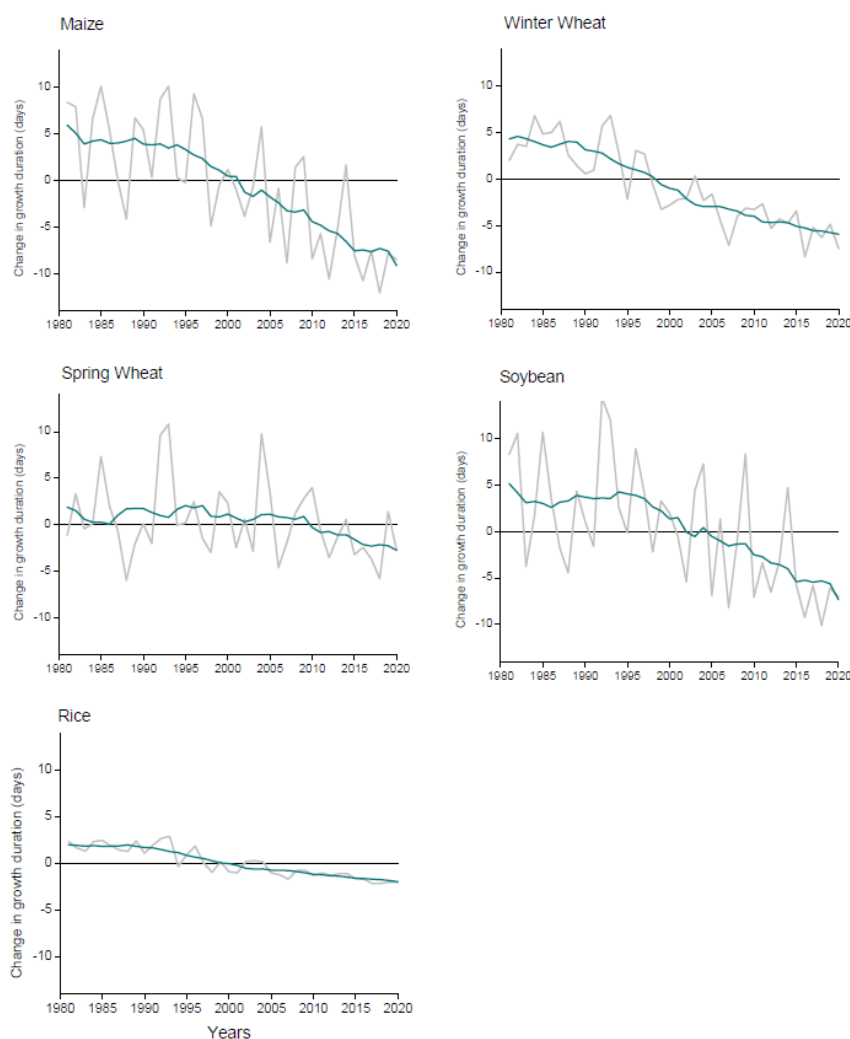


Figure 9. Change in crop growth duration relative to the 1981–2010 baseline. The grey line represents the annual global area-weighted change. The blue line represents the running mean over 11 years (5 years forward and 5 years backward).

Indicator 1.4.2: Marine Food Security

Headline finding: in 2018-2020, nearly 70% of countries showed increases in average sea surface temperature in their territorial waters compared to 2003-2005, reflecting an increasing threat to their marine food productivity and marine food security

Per-capita fish consumption has increased steadily since the 1960s.¹¹⁴ About 3.3 billion people depend on marine food, with coastal populations in low and medium HDI countries, SIDS, and indigenous people in particular, relying on it for their nutrition and livelihoods.^{114,115} Climate change is driving shifts in marine fish capacity and capture through increases in sea water

temperatures (and the associated reduced oxygenation), ocean acidification, and coral reef bleaching. As a result of this, coastal tropical countries are facing the biggest reductions in marine yield potential, while also being the most vulnerable to the associated socioeconomic impacts.¹¹⁵⁻¹¹⁷

This indicator expands its geographical scope for 2021, tracking sea surface temperature in territorial waters of 136 countries to reflect the changing threats of climate change on marine productivity, and therefore on marine food security. It is complemented by reporting the changes in marine capture based-per-capita fish consumption, using data collected by FAO (see appendix pp 50-70).

Average sea surface temperature increased in the territorial waters of 95 out of 136 studied countries (70%) in 2018-2020 compared to 2003-2005, posing threats to marine food productivity. Marine capture-based fish consumption was also reduced since the 1990s, coupled with an increase in the consumption of farm-based fish products of lower nutritional quality and omega-3 content.¹¹⁸ These trends expose the threats of climate change poses on marine food security around the world.

1.5 Migration, Displacement, and Rising Sea Levels

Headline finding: there are currently 569.6 million people settled below 5 metres above sea level, who could face risks from the direct and indirect hazards posed by the rising sea levels

Between 1902 and 2015, the global mean sea level increased by 0.12–0.21 metres.¹⁵ If unabated, sea level rise is projected to reach up to 2 metres above current levels within 80 years, or even more in certain locations if considering ice sheet collapse, waves, and tidal contributions and other factors.¹¹⁹⁻¹²² This indicator tracks the population settled in areas at risk of global mean sea level rise, based on coastal elevation and population distribution,^{123,124} and national policies connecting climate change, human mobility, and health.

There are currently 146.6 million people living in coastal areas less than 1 metre above current sea levels, 27.3% of which reside in areas with low HDI levels. Further, the 569.6 million people settled below 5 metres above current sea levels could face rising risks of increased flooding, more intense storms, soil and water salinification,¹²⁵ and local emergence of infectious diseases,¹²⁶ as sea levels continue to rise; 26.6% of these people live in areas with low HDI levels. Where erosion occurs, dwellings and other infrastructure can be damaged.

Migration and mobility could be a response, which might be exacerbated through other impacts of climate change, like those described in other indicators in this section. This would affect livelihoods, access to essential services, and psychosocial wellbeing.¹²⁷⁻¹²⁹ Up to December 31, 2020, 45 policies connecting climate change and migration were identified in 37 countries (see appendix pp 72-77), all of which mentioned health or wellbeing, but

typically related to climate change impacts rather than to the potential health impacts of forced migration. Although they commonly accepted that mobility could be domestic and international, immobility was rarely acknowledged. National policies that recognise and respond to the health risks and health benefits of different mobility patterns will, in part, shape the overall health outcomes.¹³⁰

Panel 2. Gender, Health and Climate Change

The health impacts of climate change are both underpinned and amplified by gender norms and gender inequities, with numerous examples cited throughout this report.¹³¹ Gender also influences who sets the agenda and drives responses to climate change. Evidence shows that greater representation of women in parliament is associated with stronger climate change policies.¹³²⁻¹³⁴ However, only 21% (41 out of 196) of the heads of delegation to the UNFCCC Conference of Parties in 2019 were women, and women headed just 29% of national delegations to the UNFCCC intersessional in June 2019. Moreover, of the 1,000 scholars listed by Reuters as the most influential on climate change, only 122 were women.¹³⁵

There is an urgent need for gender-sensitive responses to the health dimensions of climate change. This must be underpinned by the collection and reporting of data that is sufficiently disaggregated, granular and intersectional to reveal local inequities – for example data disaggregated not only by gender but also by geography, age, ethnicity, class, and other markers of marginalisation and vulnerability.¹³⁶⁻¹⁴⁰ However, in many cases a severe lack of standardised, gender-disaggregated data hampers these efforts,¹⁴¹⁻¹⁴⁵ and it is the very social structures that shape how gender is perceived and prioritised that undermine progress: cultural norms often translate into weak political and financial support, and limit the capacity of researchers to engage with gender inequities.^{143,146} Only 6% of all scientific articles covering climate change and health in 2020 also considered gender (indicator 5.3), and despite a workstream established for this purpose, only 6 of the 44 indicators in the 2021 report of the *Lancet* Countdown provide data by sex or gender.

Starting to reverse this, the United Nations Entity for Gender Equality and the Empowerment of Women (UN Women) is leading global efforts to increase the availability of information on gender through its “Making Every Woman and Girl Count” flagship programme. Through this programme, UN Women supports countries with the development of priority indicators to capture gender inequities – both through indicator selection and through data collection.¹⁴⁷ A model questionnaire has been developed for that purpose, and several countries, including Bangladesh, Mongolia and several Pacific Island countries, have either begun (or are currently preparing for) their rollout. With the purpose of helping countries understand the connections between the environment and gender equality, the programme also supports data reprocessing, and the integration of geospatial information with demographic and health surveys. The importance of this work is already materialising: preliminary analysis demonstrates the accentuation of gender inequities as a result of weather events, including drought episodes driving spikes in child marriage for girls in almost all Asian countries analysed.

Gender, as a social construction, affects everyone in society.⁹⁻¹³ A gender-sensitive response to climate change would generate benefits for the whole of society. Ensuring gender is represented in national statistical strategies and regular data collection processes will expose the true dimensions of the challenge. This, along with more diverse leadership, will inform and drive a commensurate response.

737 Conclusion

738 In this fifth iteration of the *Lancet* Countdown indicators, section 1 of the 2021 report
739 highlights a continuous increase in the impacts of climate change on all monitored aspects of
740 human health, providing further evidence that climate change is having quantifiably and
741 increasingly negative impacts on human health.

742 While its health impacts are felt across the world, climate change disproportionately affects
743 disadvantaged populations, exacerbating their vulnerabilities. The stratification of indicators
744 by HDI groups reveals the higher risks faced by low and medium HDI countries, particularly
745 with regards to labour capacity and livelihoods, food security, and vector-borne disease
746 transmission. Capturing the health impacts on disadvantaged groups, necessary for
747 adaptation responses (described in the following section), represents a major challenge,
748 exacerbated by the lack of disaggregated data.³⁸ With respect to gender, this is further
749 explored in panel 2. Moreover, although this section considers the impact of heat on
750 sentiment, the difficulties of capturing the mental health impacts of climate change still
751 remain. Work will continue to focus on addressing this gap.

Section 2: Adaptation, Planning, and Resilience for Health

The past year affirmed the centrality of health and wellbeing to socioeconomic development, illustrating how health risks can compound and cascade across other sectors and nations, and dramatically highlighting the potential consequences of chronic, limited investments into climate-resilient and environmentally sustainable health systems.^{148,149} The COVID-19 pandemic also exposed stark differences in the capacity of health systems and the resilience of populations to health emergencies,^{4,5} identifying the urgent need for health authorities to increase national and international coordination and preparedness. This should include integrated surveillance and monitoring of emerging health threats, developing and deploying early warning and response systems, and financially supporting low-resource nations and communities.¹⁵⁰ Importantly, for the public health response to be effective, it must address the needs of the most vulnerable – with the benefits of reduced inequities for the whole of society.

Building climate-resilient and environmentally sustainable health systems would not only help reduce the health impacts of climate change explored in the previous section, but also contribute to minimising the risk of future pandemics. This section reports eight indicators of adaptation, planning, and resilience, closely linked with the components of the WHO Operational Framework for Building Climate Resilient Health Systems: 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 funding and spending (indicator 2.4). Each of these indicators provide insights into inequities. Data on health adaptation funding from global financing mechanisms – necessary to help low and medium HDI countries adapt to the worsening health impacts of climate change – have been reintroduced into this year’s report (indicator 2.4).

A remaining challenge within section 2 is the scarcity of clear metrics to monitor adaptation progress. While efforts were made to validate the indicators, self-reported data for adaptation plans, assessments, and services may be subject to reporting bias, particularly where COVID-19 resulted in redeployment of public health resources, and where surveys experienced a decline in participation.

2.1: Adaptation Planning and Assessment

Indicator 2.1.1: National Adaptation Plans for Health

Headline finding: in 2021, 37 countries out of 70 reported having national health and climate change strategies or plans in place

Health systems are under pressure to respond to the acute and long-term threats from climate change, while simultaneously facing other critical public health risks. Comprehensive,

788 implemented health adaptation plans can not only improve health resilience to climate
789 change, but also contribute to broader health systems strengthening, and catalyse effective
790 collaboration with other health-determining sectors.

791 Data for indicators 2.1.1 and 2.1.2 are sourced from the 2021 WHO Health and Climate
792 Change Global Survey,¹⁵¹ that provides self-reported data on health sector response to
793 climate change from 70 governments (described in the appendix pp 78-79). This indicator
794 tracks the development of national health and climate change strategies and plans and
795 barriers to implementation.

796 In the 2021 survey just over half of countries (37 out of 70) reported to have a national health
797 and climate change strategy or plan in place, comparable to the proportion reported in 2018.
798 Implementation remains a challenge for countries from all HDI levels with less than a quarter
799 of these countries reaching high or very high levels of implementation. Insufficient financing
800 was identified as a main barrier to reaching full implementation by 73% of all responding
801 countries with one-fifth (8 out of 37) reporting to have no current sources of funding available
802 for taking action on priorities set out in their strategies/plans. Other key barriers to
803 implementation were insufficient human resource capacity (59%), COVID-19 related
804 constraints (54%), and a lack of research and evidence (49%).

805 A desktop review of National Adaptation Plans (NAPs) submitted to the UNFCCC found that
806 four of the 19 NAPs considered gender in health adaptation actions. However, although NAPs
807 may mention the principles of gender equality, they often fail to demonstrate mainstreaming
808 gender in a way that challenges gender norms, power, and structures. The recommendations
809 in the *WHO Guidance for Mainstreaming Gender in Health and Climate Change Programmes*
810 provide countries with guidance for achieving gender mainstreaming, including through
811 national health and climate change plans.^{152,153}

812

813 [Indicator 2.1.2: National Assessments of Climate Change Impacts, Vulnerability, and](#)
814 [Adaptation for Health](#)

815 *Headline finding: 36 out of 70 countries in 2021 reported having conducted a climate change*
816 *and health vulnerability and adaptation assessment*

817 Evidence-based policy development and planning require a comprehensive evaluation of the
818 climate change-associated health risks faced by populations and health systems. This
819 indicator monitors the number of countries who report having conducted a climate change
820 and health vulnerability and adaptation assessment. These assessments are critical, because
821 they not only allow countries to establish and re-evaluate health risks, but also consider the
822 vulnerabilities contributing to health outcomes.

While 36 out of 70 countries disclosed they had conducted a climate change and health vulnerability and adaptation assessment, only about one-third of these reported that the findings influenced the allocation of human and financial resources. However, 56% (20 out of 36) reported that the findings informed the development of their national health and climate change strategy/plan, suggesting evidence-based policy setting. Over two-thirds of countries specifically considered vulnerable population groups in their assessments, including children, women, the elderly, workers, rural/urban populations, those living in poverty and, to a lesser extent, indigenous groups, migrant or displaced populations. However, the comprehensiveness of these assessments varied widely.

As explored in section 1, health vulnerabilities to climate change are unevenly distributed and can exacerbate existing health inequities. As health vulnerability and adaptation assessments inform national health and climate change plans and programmes, it is essential that data gathered for these assessments are disaggregated according to social determinants of health. This will enable public health interventions to actively identify and support the most vulnerable communities, and proactively reduce sub-national health inequities relating to climate change.

Indicator 2.1.3: City-level Climate Change Risk Assessments

Headline finding: in 2020, 546 of 670 cities reported having completed or being in the process of undertaking climate change risk assessments. Heat-related illness was the most common climate-related health concern, identified by 169 out of 308 cities

The COVID-19 pandemic revealed the persistent health inequities and vulnerabilities of cities and urban sub-populations.^{154,155} Home to over half the world's population (a proportion projected to increase to 70% by 2050), cities play a crucial role in leading local health adaptation to climate change.¹⁵⁶ Using data from the CDP's 2020 survey of global cities, this indicator captures the number of cities that report having completed a climate change risk or vulnerability assessment; and the climate-related health impacts and vulnerabilities that cities identified.

In 2020, 546 of 670 cities (81%) reported they had completed or were currently undertaking climate change risk assessments. For those cities who responded in both 2019 and 2020, an additional 45 (9%) reported having completed a climate change risk assessment in 2020. Importantly, however, 94% of responding cities belonged to countries with high or very high HDI, meaning that cities and countries of low and medium levels of HDI were underrepresented in the data. 308 cities identified that climate change poses a threat to one or more health areas. The most prominent perceived health concern pertained to heat-related illness, with 169 (55%) cities reporting this concern. The most vulnerable groups identified were the elderly (reported by 213 [69%] cities), children and youth (180 [58%]), and

low-income households (170 [55%]), while 94 cities (31%) identified women as vulnerable to climate-related health impacts.

Indicator 2.2: Climate Information Services for Health

Headline finding: in 2020, national meteorological and hydrological services of 86 countries reported providing climate information to the health sector; only five out of the 86 indicated these climate services guide health sector policy and investment plans

Health adaptation to climate change relies on accurate meteorological data and forecasts for the integrated surveillance and monitoring of emerging health threats, the development and deployment of early warning and response systems, and the implementation of adaptation interventions. This indicator monitors the extent to which national health and meteorological services provide climate information services to the health sector, using data reported to the World Meteorological Organization (WMO).

In 2020, 86 national meteorological and hydrological services reported providing climate services to the health sector. In very high HDI countries, 50% of those providing services to the health sector reported that they were co-designing or providing tailored climate information services or products, in contrast with 36% of low HDI countries.

2.3: Adaptation Delivery and Implementation

Indicator 2.3.1: Detection, Preparedness and Response to Health Emergencies

Headline finding: 124 out of 166 countries reported medium-to-high implementation of a national health emergency framework in 2020; an increase of 14% compared to 2019

The International Health Regulations (IHR) are legally-binding instruments defining countries' rights and obligations in handling public health events and emergencies that could cross national borders.¹¹ Under the IHR, State Parties are required to provide self-evaluations of emergency response preparedness against 13 core capacities published in the State Party Annual Report (SPAR). Limitations of the IHR in ensuring an effective response to the COVID-19 pandemic were identified and continue to be evaluated, and reviews currently underway are discussed in the appendix (pp 89-90). Notwithstanding, countries with higher SPAR scores had lower incidence and mortality per 100,000 population within 30 days from first COVID-19 diagnosis, stressing the relevance of the IHR.¹⁵⁷

This indicator tracks the degree to which countries have implemented a national health emergency framework under IHR core capacity eight, which includes emergency

preparedness and response planning, emergency management structures, and mobilisation of resource. This assesses whether countries are prepared and operationally ready to respond to all public health events, including climate-related emergencies. In 2020, 166 (85%) of State Parties to the IHR completed the relevant section of the SPAR relating to capacity eight, and 75% of countries reported medium-to-high degrees of implementation of a national health emergency framework – a 14% increase compared to 2019. Importantly, however, only 37% of countries reported high implementation, indicated by a capacity score of 75% or greater. The level of implementation varied greatly by HDI, with 89% of very high HDI countries reporting medium-to-high implementation, compared to 55% of low HDI countries.

In preparing for future health crises, it is essential that global institutions improve emergency response preparedness, using lessons learned during the pandemic. The ongoing review of the IHR is an important step in this direction to ensure that the IHR is effective when faced with health emergencies associated with climate change.

Indicator 2.3.2: Air Conditioning: Benefits and Harms

Headline finding: use of air conditioning, a widespread technology for indoor cooling in some regions of the world, averted an estimated 195,000 heat-related deaths among people ≥65 years of age in 2019. However, it also contributed to greenhouse gas emissions, air pollution, peak electricity demand, and urban heat islands

Indoor cooling represents an effective strategy for preventing heat-related mortality.¹⁵⁸ In this year's report, this indicator combines the prevented fraction¹⁵⁹ and heat-related death estimates from indicator 1.1.6, to track the number of heat-related deaths averted by air conditioning in the 65-and-older population (methods described in appendix pp 91-101).

Applying country- and region-specific prevented fractions to the data from indicator 1.1.6 revealed that, in the absence of air conditioning, an estimated 195,400 heat-related deaths would have occurred globally in the 65-and-older population, in addition to the 345,000 heat-related deaths that are estimated to have occurred in 2019. In this age group, air conditioning averted an estimated 69,500 deaths in China (where 72,000 deaths attributable to heat exposure are estimated to have occurred; 65% of households had air conditioning), 47,800 in the USA (where 20,500 deaths are estimated to have occurred; 92% of households had air conditioning), 30,400 in Japan (where 12,400 deaths are estimated to have occurred; 93% of households had air conditioning), but only 2,400 in India (where 46,600 deaths are estimated to have occurred; 6% of households had air conditioning). These figures demonstrate the power of indoor cooling to prevent mortality, as well as the inequities in access to indoor cooling across countries.

Current air conditioning technology is unsustainable, and leads to adverse health outcomes from increased air pollution, urban heat, and greenhouse gas emissions (see panel 3).¹⁶⁰ In 2019, the number of premature deaths from PM_{2.5} exposure attributable to fossil-fuel powered electricity used for air conditioning is estimated (using the same approach as in indicator 3.3) to have been 21,000 globally. Between 2000 and 2019, the global proportion of households with air conditioning rose 57% and CO₂ emissions from air conditioning use rose 61% (Figure 10).

Sustainable indoor cooling approaches are urgently needed, including strong, enforced codes that mandate energy-efficient buildings,¹⁶⁰ a return to traditional tropical and sub-tropical building designs in these regions and elsewhere,¹⁶⁰ use of fans in climate zones where they provide effective cooling,¹⁶¹ stringent minimum energy performance standards for air conditioners,¹⁶⁰ cool roofs (see panel 3), and increased urban green space (Indicator 2.2.3).

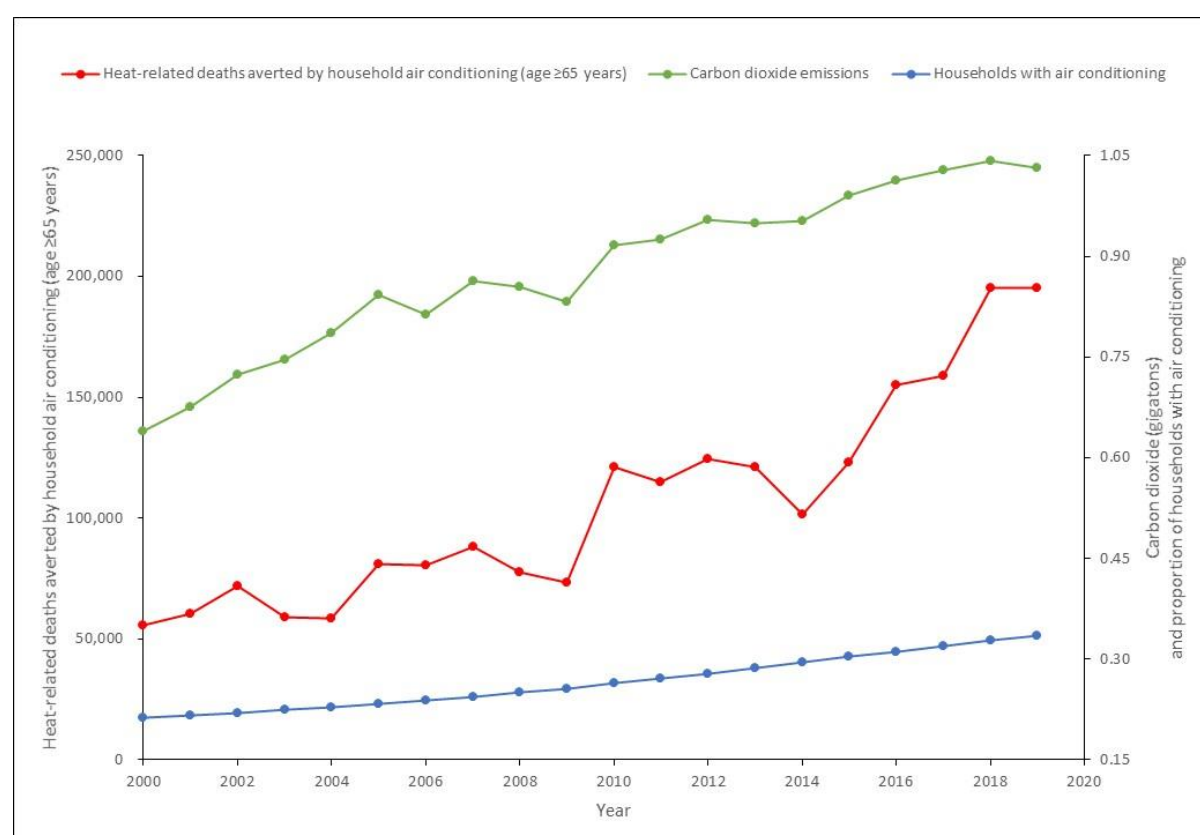


Figure 10. Global heat-related deaths averted by household air conditioning in the 65-and-older population (red line), proportion of households with air conditioning (blue line), and carbon dioxide emissions from air conditioning (green line), 2000-2019

Panel 3. The Urban Heat Island and the Impact of Cool Roofs

As a result of human activity and the urban fabric, cities tend to be hotter than surrounding rural or suburban areas, a phenomenon known as the urban heat island (UHI) effect.

With increasing temperatures and urbanisation, the demand for cooling mechanisms is on the rise. While offering protection from life-threatening extreme heat exposure, the use of air conditioning contributes to climate change through its energy consumption and its leakage of hydrofluorocarbons that act as powerful greenhouse gases; contributes to intensifying the urban heat island through its waste heat emissions; and contributes to increasing peak electricity demand and urban air pollution (see indicator 2.3.2).¹⁶²⁻¹⁶⁴ Furthermore, its high costs are amplifying the energy poverty gap.^{164,165} The development of sustainable and affordable cooling alternatives is therefore crucial to protect the health of urban populations, while keeping the world on track to meeting the Paris Agreement goals.

This case study explores the use of ‘cool’ (reflective) roofs as sustainable cooling mechanisms, ranging from specially designed roofing materials, to affordable alternatives such as light-coloured paint. Focusing on Birmingham and the West Midlands region of the UK, urban air temperatures were simulated at 1 km x 1 km horizontal resolution by combining detailed land use data with a building energy parameterisation scheme in a regional climate model (WRF).¹⁶⁶ To estimate the impact of the UHI, temperatures are compared with those from a simulated counterfactual scenario, with urban surfaces replaced by rural types.

The UHI intensity was found to be around 3°C during summer, and up to 9°C during heatwaves in this region. The resulting overheating was estimated to contribute to approximately 40% of mortality associated with UHI over a summer season, and up to 50% during heatwaves.¹⁶⁷⁻¹⁶⁹ Spatial analysis further revealed that the most underserved population groups were particularly exposed to urban heat.¹⁶⁹

Simulations introducing reflective surfaces found that cool roofs could reduce maximum daytime air temperatures by 0.5°C on average, and up to 3°C during heatwaves. This has the potential of reducing heat-related mortality due to the UHI by 18% over a summer season, and 23% during a heatwave.¹⁷⁰ Considering this assessment was done in a country with relatively cool climate, the impact of cool roofs might be even greater if applied in warmer parts of the world. Moreover, while the UHI can reduce cold-related mortality by around 15% in the winter, cool roofs were shown to have negligible effects in winter months, suggesting they would not contribute to increased mortality in the winter.^{171,172}

Because roofs may affect other factors such as precipitation, their use must be assessed on a case-by-case basis.¹⁷³ However, with a net annual benefit on temperature-related mortality, adoption of cool roofs in the face of a warming world could provide a low-carbon cooling alternative, with health benefits to the whole urban population.

977 Indicator 2.3.3: Urban Green Space

978 *Headline finding: globally in 2020, 27% of urban centres were classified as being moderately*
979 *green or above, an increase from 14% in 2010. This level of greenness varied between 17% of*
980 *urban centres in the low Human Development Index country group and 39% of urban centres*
981 *in the very high country group*

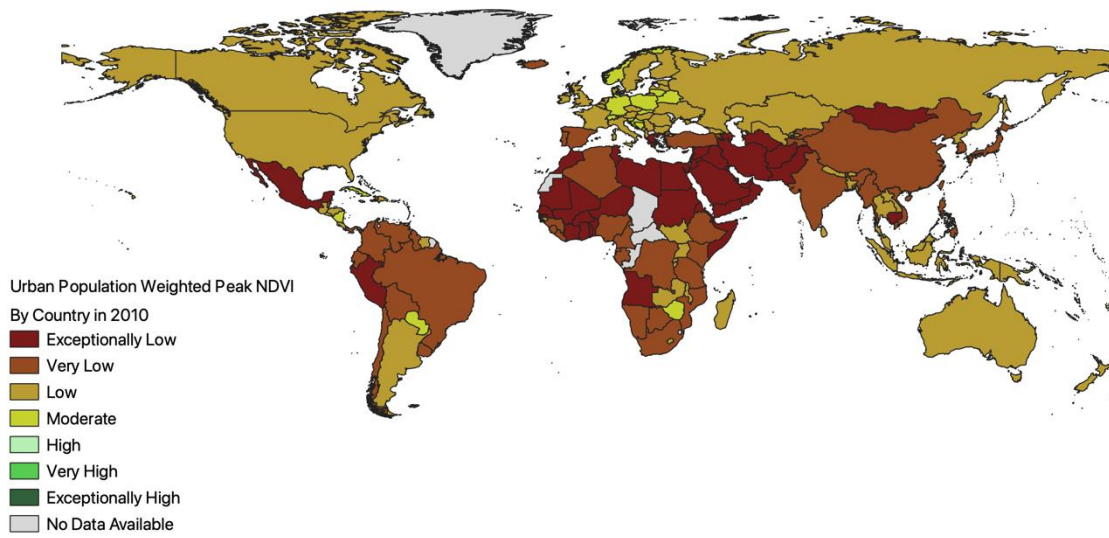
982 There is increasing evidence that access to urban green spaces provides benefits to human
983 physical and mental health. This includes reducing exposures to air pollution, relieving stress,
984 and increasing social interaction and physical activity, with overall improved general health
985 outcomes and lower mortality risk.^{174,175} Green space also helps climate change mitigation
986 and adaptation by sequestering carbon and delivering local cooling benefits. However, urban
987 green spaces must be carefully designed and managed to conserve biodiversity, and ensure
988 they do not provide habitats and breeding sites for vectors of human diseases, or contribute
989 to increased gender and other social inequities.¹⁷⁶⁻¹⁸²

990 Indicator 2.3.3 provides an estimate of the magnitude of green vegetation in urban centres,
991 using the satellite-based Normalized Difference Vegetation Index (NDVI), with higher values
992 indicating higher greenness levels. In the 2021 report, the sample size was increased to
993 include 1,029 urban centres across 139 countries. These encompass all urban centres of over
994 500,000 inhabitants, as well as the most populated one in those countries that had no urban
995 centre above this threshold. Full details are in the appendix (pp 102-106).

996 Averaged across all urban centres sampled, population-weighted peak NDVI increased 23%
997 from 2010 to 2020 (mean NDVI 0.26 to 0.32), with 27% of urban centres being classified as
998 moderately green or above (an NDVI ≥ 0.40) in 2020 (Figure 11). The level of greenness varies
999 greatly by HDI level. In the very high HDI country group, 39% of urban centres have at least
1000 moderate levels of greenness (mean NDVI 0.34) in 2020, compared to 17% (mean NDVI 0.27),
1001 36% (mean NDVI 0.33), and 15% (mean NDVI 0.30) in low, medium and high HDI country
1002 groups, respectively. This highlights the inequities in the availability of green spaces across
1003 urban centres.

1004 With their potential to simultaneously improve health outcomes, reduce health inequities,
1005 and facilitate climate mitigation and adaptation, urban green space design must involve
1006 interdisciplinary experts to ensure the health and environmental benefits are maximised.¹⁸³
1007 More broadly, with health at the centre of planning in areas such as housing, transport,
1008 energy, and water and sanitation, urban centres can be places that are safe, comfortable, and
1009 enjoyed by everyone.¹⁸⁴

A



B

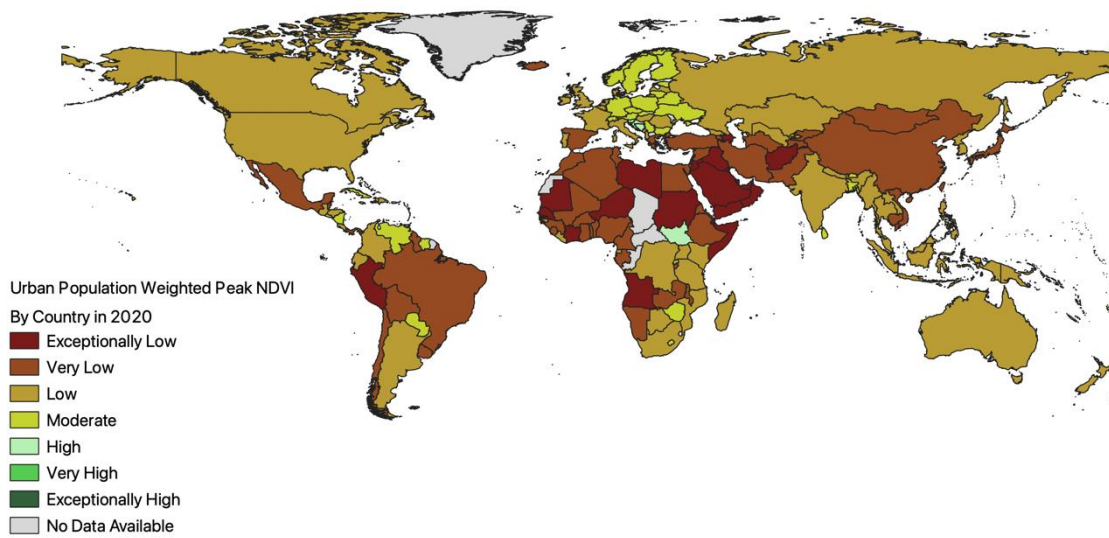


Figure 11. Average urban population-weighted peak Normalized Difference Vegetation Index (NDVI) in urban centres of >500,000 inhabitants by country, for 2010 (A) and 2020 (B). For countries without an urban centre of >500,000 inhabitants, the most populated urban centre was used in the analysis.

1014 Indicator 2.4: Health Adaptation-Related Global Funding and Financial Transactions

1015 *Headline finding: globally, adaptation funding directed at health systems represents a small*
1016 *portion of total climate change adaptation funding (0.3%), and only 5.6% of all transactions*
1017 *with adaptation potential were relevant to health in 2019/20*

1018 This indicator monitors two elements of spending that could provide adaptation for health:
1019 1) the global funding approved for health-related adaptation projects through multilateral
1020 funds, and 2) global financial transactions with the potential to deliver adaptation in the
1021 health and care sector, as well as in other sectors that are relevant to the determinants of
1022 health. The former draws on data from the Climate Funds Update Data Dashboard, while the
1023 latter uses the Adaptation and Resilience to Climate Change (A&RCC) dataset produced by
1024 kMatrix.^{185,186} These complementary elements provide an evaluation of proactive adaptation
1025 funding potentially related to health, and of the global size of all economic transaction that
1026 can offer climate change adaptation potential for health.

1027 Between 2018 and 2020, \$5.1 billion of multilateral climate change adaptation funding was
1028 approved globally. Only \$711 million (13.9%) was related to health. This consisted of \$14.0
1029 million (0.3%) of approved funding directed specifically at health systems, and \$697 million
1030 (13.6%) with potential secondary benefits for health identified.

1031 Meanwhile, the value of all financial transactions with the potential to deliver adaptation for
1032 health (adaptation-relevant transactions within the dataset-defined “health and healthcare”
1033 sectors) increased by 14.0% in 2019/20 compared with 2018/19, reaching 5.6% of total
1034 adaptation spending. Spending in other sectors that could be relevant to health (including in
1035 the waste and water management, built environment, or agricultural sectors, for example) is
1036 estimated to have increased by 7.6%, representing 28.6% of total transactions. Grouped by
1037 HDI, \$234 million (1%) of spending was within low HDI countries (Figure 12). This compares
1038 to \$1.8 billion (8%) in medium HDI countries, \$5.7 billion (27%) in high HDI countries, and
1039 \$13.3 billion (64%) in very high HDI countries. For spending in health-relevant economic
1040 sectors, a similar narrative emerges: \$1.2 billion (1%) of spending occurred in low HDI
1041 countries, compared with 62% in countries with very high HDI. As the data covers financial
1042 years, the data up to 31st of March 2020 presented in this indicator are unlikely to reflect the
1043 anticipated economic impact of the COVID-19 pandemic on adaptation spending.

1044 These findings highlight a growing global market for health-relevant adaptation transactions,
1045 but this has yet to translate into sufficient targeted health adaptation funding. As world
1046 economies recover from COVID-19, sufficient resources must be redirected towards health
1047 adaptation to build resilience to the increasing health threats of climate change.

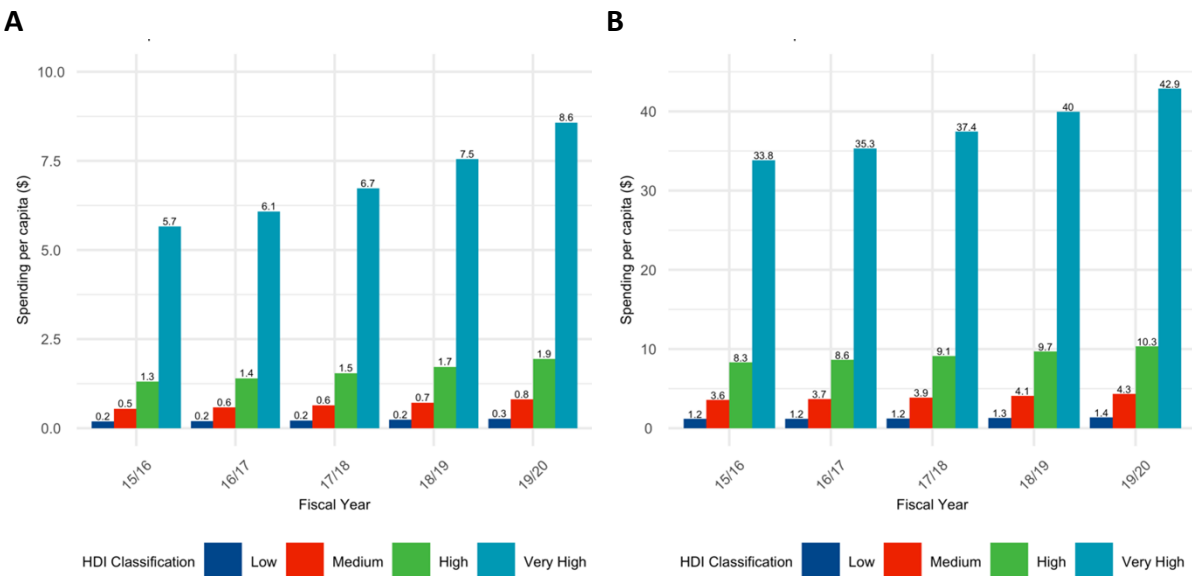


Figure 12. Per capita potential adaptation transactions in the health and health care sector (A) and health-relevant sectors (B) for financial years 2015/16 to 2019/20, by 2019 Human Development Index country group

Conclusion

The indicators in this section paint a complex landscape of adaptation, planning, and resilience for health in the past 12 months, where the small global improvements to adaptation planning and assessment (indicators 2.1.1, 2.1.2, and 2.1.3) and intersectoral collaboration (indicator 2.2) are overshadowed by slow progress in implementation (indicators 2.3.2, 2.3.3) and insufficient investment (indicator 2.4). A key theme across all the indicators is inequities, and while these indicators largely track inequities between countries, within-country inequities are significant for moving towards resilience and sustainability.

While the world economy and health systems are on the road to recovery from a significant acute global health crisis, climate change poses a much greater health threat in the coming decades. It is crucial that organisations and institutions capitalise on the insights generated from the pandemic to improve adaptability and resilience. Research is needed to identify current and future vulnerabilities; project risks from climate change at scales relevant for decision-making under different climate and development scenarios; and identify and evaluate adaptation options to prepare for and protect health in a changing climate. Adaptation plans should be reviewed and updated to consider medium and long-term risks of climate change for health, and to further build resilience. Greater collaboration and

1071 coordination are necessary across public and private sectors and global institutions, along
1072 with increasing investments in adaptation.
1073

1074 Section 3: Mitigation Actions and Health Co-Benefits

1075 Global atmospheric CO₂ levels passed 415 ppm in January 2021 – continuing an unbroken
1076 upward trend – and for the first time, the concentrations for much of 2020 are expected to
1077 be 50% higher than the 1750-1800 average.⁴² Total emissions of all greenhouse gases in 2019
1078 were 59.1 GtCO₂e (±5.9) including those generated by land-use changes. To limit warming to
1079 1.5°C, annual global emissions must be reduced to 25 GtCO₂e by 2030.¹⁶

1080 COVID-19 and associated lockdowns across the globe have had profound impacts on the
1081 global economy – most significantly in the surface and air transportation, and industrial
1082 sectors.¹⁸⁷ Emissions from very high HDI countries, which account for 48% of the global total,
1083 were around 10% lower than 2019 levels.¹⁸⁷ However, without targeted intervention,
1084 emissions will rebound as the world recovers from the pandemic. Indeed, the 5.8% drop in
1085 energy-related CO₂ emissions seen in 2020 is forecast to be matched with an unprecedented
1086 4.8% rise in 2021.²²

1087 The necessity of steering the economic recovery to a lower-emissions pathway has been well
1088 publicised but has yet to be well-integrated into recovery plans (see panel 4).¹⁸⁸ Nevertheless,
1089 the COVID-19 recovery presents the challenge and simultaneous opportunity to encourage
1090 action that yields benefits to health.

1091 Tracking this global challenge, section 3 covers the relationships between climate change
1092 mitigation actions and health. It provides an overview of the global energy system (indicator
1093 3.1) alongside associated global exposure to ambient PM_{2.5} air pollution and its health impacts
1094 (indicator 3.3). Energy use in the home is also reported, with new detail on fuels used and
1095 estimates of indoor air pollution concentrations (indicator 3.2). Following this, individual
1096 sectors are examined: transport (indicator 3.4); food and agriculture (indicators 3.5.1 and
1097 3.5.2); and the global healthcare sector (indicator 3.6). Where possible, the ways in which
1098 relationships between health and climate change mitigation both influence and are
1099 influenced by societal inequities are explored.

1100

1101 Indicator 3.1: Energy System and Health

1102 *Headline finding: from 2014 to 2018, despite strong growth in renewables in very high Human*
1103 *Development Index countries, the carbon intensity of the global energy system has seen an*
1104 *annual average decline of just 0.6% - a rate incompatible with meeting the ambitions of the*
1105 *Paris Agreement*

1106 Fossil fuel combustion within the energy system is the largest single source of greenhouse gas
1107 emissions, with a global share of 65%.¹⁶ The rapid shift from coal to renewable energy use is
1108 crucial, not only to mitigate these emissions, but also to prevent deaths due to ambient air

1109 pollution (indicator 3.3) and eliminate other harmful pollutants related to coal mining and
1110 combustion.¹⁸⁹ Drawing data from the IEA, this indicator tracks three components: the carbon
1111 intensity of the global energy system; coal phase-out; and zero-emission electricity. Full
1112 details are described in the appendix (pp 110-115).

1113 The carbon-intensity of the global energy system fell slightly for the fifth year in a row, to 56.0
1114 tCO₂e/TJ (excluding land use emissions) in 2018. However, progress remains very limited, with
1115 an annual rate of decline of just 0.6% from 2014 to 2018. At this rate it would take over 150
1116 years to fully decarbonise the energy system – far from the 2040 deadline required to keep
1117 temperature rise to 1.5°C.¹⁹⁰ Progress has been made in the very high HDI country group since
1118 1970 and carbon intensity in the high HDI country group could be at a possible peak. However,
1119 driven by the need to develop, the low and medium HDI country groups have shown sustained
1120 growth in emissions per unit of energy over the period (Figure 13).

1121 China continues to dominate global coal consumption – although it represents 18.1% of the
1122 world's population, it accounted for 53% of global coal use in 2019. While global coal use for
1123 all activities fell 1.2% in 2019, including a fall of 13.4% in the USA and 21% in Europe, China's
1124 usage grew by 1.1%.

1125 For the five years until 2018, electricity generation from renewable wind and solar increased
1126 by an annual average of 17%, with its global share of electricity generation reaching 7.2% in
1127 2018. While energy demand for coal, gas, oil and nuclear fell in 2020, renewables demand
1128 grew by a small amount (0.9%).¹⁹¹

1129 Concerningly, global coal demand is expected to rise by 4.5% in 2021, although at the same
1130 time demand for renewables is set to expand by over 8%.²² A redirection of efforts towards
1131 the decarbonisation of the energy system (see panel 4), could put the world on track to meet
1132 the 1.5°C temperature goal and prevent deaths associated with climate change and air
1133 pollution.

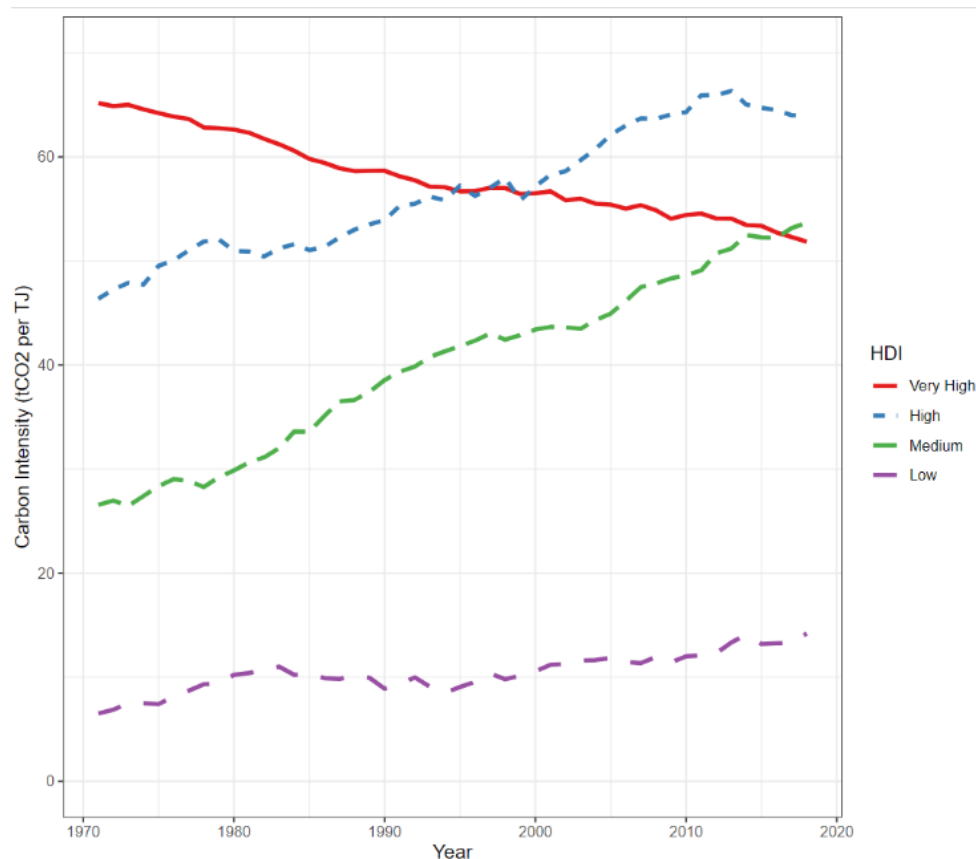


Figure 13. The carbon intensity of the energy system for 1970-2018, by 2019 Human Development Index country group

Indicator 3.2: Clean Household Energy

Headline finding: in 2019, only 5% of rural households in countries in the low Human Development Index country group relied primarily on clean fuels and technologies for cooking (up from just 2% in 2000) – putting them at risk of morbidity and mortality due to exposure to household air pollution

Around 10% of the world's population, three quarters of whom live in sub-Saharan Africa, lack access to electricity for any service provision, and 2.6 billion people continue to lack access to clean fuel for cooking.^{191,192} COVID-19 poses further impediment to achieving the energy access goal (SDG7), with 2020 seeing a 2% rise in lack of access to electricity in sub-Saharan Africa,¹⁹³ driving low-income communities in places such as Nairobi, Kenya to increase their usage of wood and kerosene.¹⁹⁴ Energy poverty remains a concern even in high and very high HDI countries – around 7% of people in the EU struggle to afford sufficient heat for their homes,¹⁹⁵ putting them at risk of cold-related adverse health outcomes.¹⁹⁶ Here, and

1152 around the world (as highlighted in panel 3), energy poverty related to excess heat is also an
1153 important issue.¹⁹⁷

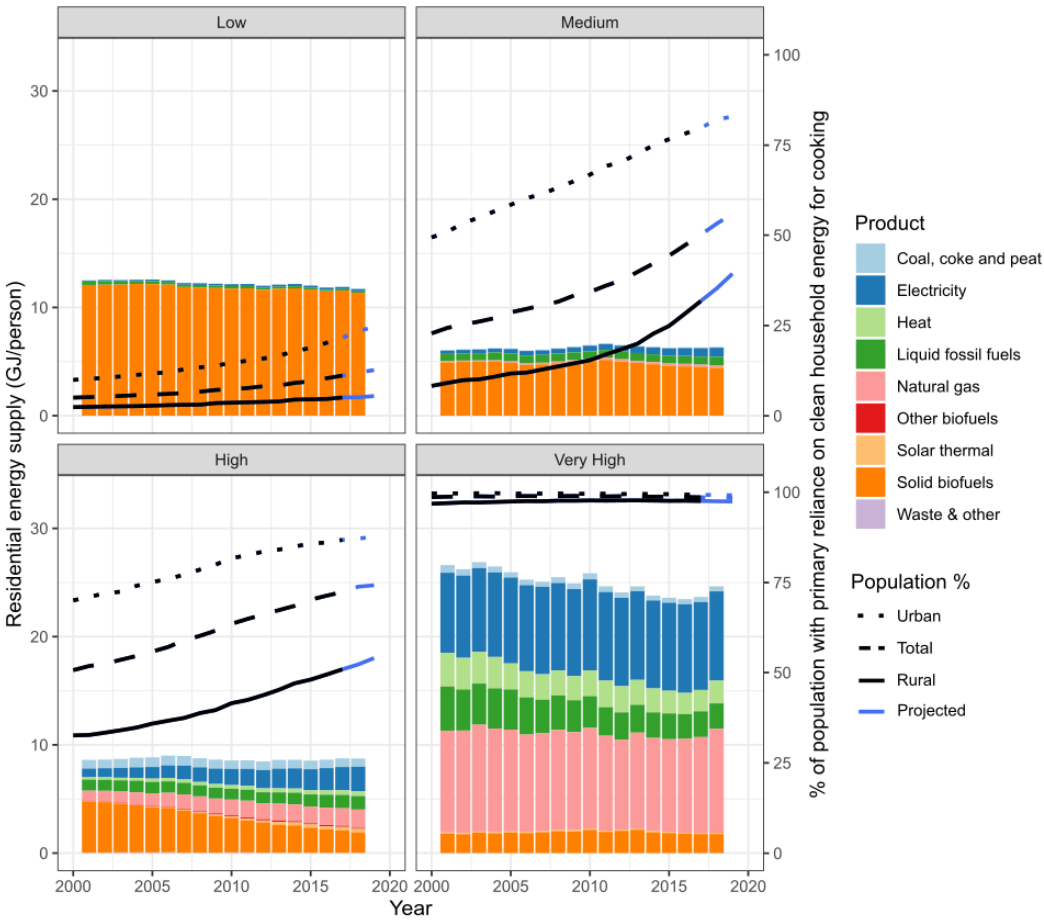
1154 This indicator tracks energy usage in the home, using data from both the IEA and the
1155 WHO.^{192,198-200} The WHO household energy database compiles data from national surveys,
1156 collected up to 2017 and projected to 2019, presenting information on fuels and technologies
1157 used for cooking, heating, and lighting. Using these data, this indicator also presents an
1158 estimation for household air pollution concentration for 29 countries. A full description of the
1159 methods, data, and caveats is given in the appendix (pp 116-119).

1160 In the low HDI country group, domestic energy use is dominated by bio-fuels. Primary reliance
1161 on clean fuels and technologies for cooking in households in the low HDI country group is
1162 estimated at only 12% in 2019. The share is even lower in rural households of this HDI group,
1163 with only 5% relying on clean fuels and technologies – a marginal increase from 2% in 2000
1164 (Figure 14). In homes in the medium and high HDI country groups, the share of solid biofuel
1165 use has fallen more rapidly, and clean cooking fuel and technology use has risen substantially
1166 – although in rural areas it remains at 54% for the high HDI group and 39% for the medium
1167 HDI group.

1168 These patterns of energy use, as well as the infiltration of air from outside, have implications
1169 on household air pollution concentrations. In rural households in several low and medium
1170 HDI countries the average PM_{2.5} concentration in the main indoor cooking area is estimated
1171 to be above 500µg m⁻³. In Ethiopia it is over 1200 µg m⁻³ – 120 times the WHO threshold of
1172 10 µg m⁻³.²⁰¹ Exposure to these harmful air pollutants in the home results in an estimated 2.31
1173 million deaths per year.²⁰²

1174 While gender-differentiated impacts might change across different geographies and
1175 cultures,²⁰³ exposure to household air pollution is estimated to be around 40% higher for
1176 women than for men.²⁰⁴ In many places women are also at higher risk of musculoskeletal
1177 injuries and violence that result from their domestic role in collecting and using fuels for
1178 cooking and heating, which further poses risks to their physical and mental wellbeing.²⁰⁵⁻²⁰⁸
1179 Thus, progress towards meeting the SDG7 would improve health and reduce gender
1180 inequities.

1181



1182

1183

1184

1185

1186

Figure 14. Residential energy supply by 2019 Human Development Index country group for 2000 to 2019. Primary axis: per capita fuel type (coloured bars). Secondary axis: percentage of population with primary reliance on clean fuels and technology for cooking. Data taken from the WHO and IEA. 198-200

1187

1188

Indicator 3.3: Mortality from Ambient Air Pollution by Sector

1189

1190

1191

Headline finding: 3.3 million deaths were attributable to ambient PM_{2.5} pollution from human sources in 2019 – a third of which were directly related to fossil fuel combustion. The medium and high Human Development Index country groups suffered the highest mortality rates

1192

1193

1194

1195

1196

Awareness of the health impacts of air pollution has increased over the past years, with legislation shifts such as the proposed revision of the EU Ambient Air Quality Directives²⁰⁹ and a landmark ruling on the death of nine-year-old Ella Adoo-Kissi-Debrah in 2020 in the UK thought to be the first time air pollution was listed as a cause of death in a death certificate.²¹⁰ This indicator estimates ambient PM_{2.5} exposure and the resulting attributable deaths from

different economic sectors. For the 2021 report, the methods have been updated to use the integrated exposure-response functions (MR-BRTs) used by the 2019 GBD study.²¹¹

In total, 4.0 million deaths were estimated to be attributable to exposure to ambient PM_{2.5} in 2019 – 3.3 million of which were from anthropogenic sources and 1.1 million were directly related to fossil fuel combustion. Deaths due to coal combustion have decreased from 620,000 in 2015 to 507,000 in 2019, largely due to strict air pollution control measures in China, including the reduction of coal for residential heating.

Ambient concentrations of PM_{2.5} differ strongly across world regions and between urban and rural areas. As a result of higher industrial activity, poorer emissions controls, and the continuing use of solid fuels in the domestic sector, countries in medium and high HDI groups face the highest rates of air pollution-related mortality (60 deaths per 100,000 inhabitants, and 65 deaths per 100,000 inhabitants, respectively) (Figure 15). Deaths are lower in both the low and very high HDI country groups (at 34 deaths per 100,000 inhabitants, and 40 deaths per 100,000 inhabitants, respectively). This is due to lower industrial activity and younger populations in low HDI countries; and cleaner electricity generation, industrial production, and end-of-pipe emission controls in very high HDI countries.

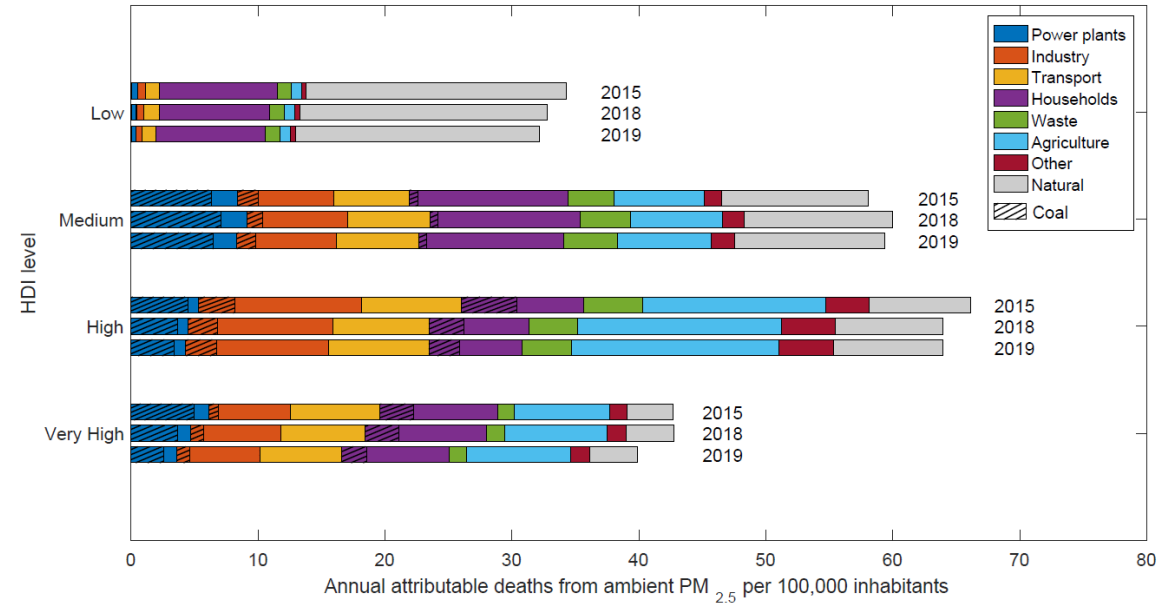


Figure 15. Mortality attributable to ambient PM_{2.5} in 2015, 2018 and 2019 by source and by 2019 Human Development Index country group.

1217 Indicator 3.4: Sustainable and Healthy Road Transport

1218 *Headline finding: electricity use in transport rose by 15% from 2017 to 2018 and the global*
1219 *electric vehicle fleet topped 7.2 million cars in 2019. However, emissions from road transport*
1220 *also continued to increase*

1221 With road transport accounting for nearly 18% of global CO₂ emissions in 2019, the shift to
1222 electric vehicles is an important mitigation measure.²¹² Beyond this, the promotion of walking
1223 and cycling (active travel) could not only cut emissions, but also provide enormous health
1224 dividends through the increase of physical activity.²⁸ The mode share of cycling varies greatly
1225 between and within countries of different levels of HDI – ranging from 0.3% and 0.6% of all
1226 trips in São Paulo and Cape Town, to 1.1-1.9% in USA and Australian cities, to 4.8% in Delhi,
1227 to 14.1-28.7% in cities in Germany, Japan and the Netherlands – with a higher mode share
1228 being associated with more equal gender representation in cycling.²¹³ Unless active travel
1229 infrastructure is rolled out with consideration of sociocultural inequities, the benefits may not
1230 be equally manifested across all groups.²¹⁴⁻²¹⁸

1231 This indicator uses data from the IEA to monitor fuels used for transport and electric vehicles,
1232 with full details provided in the appendix (pp 122-123).²¹⁹⁻²²¹ The global number of electric
1233 vehicles (EVs) rose from 5.1 million in 2018 to 7.2 million in 2019. However, EVs still only
1234 represent 1% of global car stock, and road transport emissions also increased in 2019, as
1235 demand for larger vehicles grew in the USA, Europe, and Asia, in tandem with increasing
1236 demand for transport in low and medium HDI countries. Overall, total direct use of fossil fuels
1237 for road transport increased by 0.7% whereas the use of electricity in transport rose by 15%
1238 from 2017 to 2018, although it remains just 0.27% of total road transport energy use.

1239 With respect to the same period in 2019, the COVID-19 pandemic led to a nearly 50%
1240 decrease in global road transport demand by the end of March 2020.^{222,223} However, while
1241 the use of fossil fuels for road travel has largely rebounded, many public transport networks
1242 now face critical decreases in ridership.²²⁴ City governments around the world implemented
1243 measures to promote active travel during their lockdowns, many of which are intended to be
1244 permanent.^{222,223} As cities emerge from the COVID-19 crisis, implementing policies to
1245 reinforce positive shifts in travel modality presents a triple opportunity to promote physical
1246 activity, reduce urban air pollution, and mitigate climate change.²²⁵

1247

1248 3.5: Food, Agriculture, and Health

1249 Indicator 3.5.1: Emissions from Agricultural Production and Consumption

1250 *Headline finding: mostly driven by high levels of red meat consumption, per capita emissions*
1251 *from food consumption are considerably greater in of the very high Human Development*

1252 *Index country group – 61% higher than in those in the low Human Development Index group*
1253 *in 2018*

1254 Food systems, including agricultural production, are responsible for 21-37% of all greenhouse
1255 gas emissions, while also holding high carbon sequestration potential.¹⁰ This makes them key
1256 to limiting global warming to 1.5°C. This indicator tracks emissions from agricultural
1257 production and consumption of food products, combining modelling and FAO data.²²⁶

1258 Despite moderate improvements in efficiency, total agricultural production emissions
1259 continued to grow, reaching 5.6 GtCO₂e in 2018 (1.5% higher than in 2017). Of this total, cattle
1260 products (mainly meat and milk) contributed 52% of global agricultural production emissions.

1261 Data reveal stark differences in per-capita consumption-based agricultural emissions across
1262 countries in different levels of HDI: per capita emissions in the very high HDI country group
1263 are 39% above those of the high HDI group, and 45% higher than those of the low HDI group
1264 (Figure 16). This is despite a high emission-intensity for beef products in the low HDI group
1265 (around three times higher than in the very high HDI group), which is mitigated by a much
1266 lower per capita consumption of beef. Importantly, 68% of the total consumption-based
1267 agricultural emissions in the very high HDI country group are attributable to cattle products,
1268 mainly beef production, which is slightly down from 71% in 2000.

1269 Progress towards zero hunger (SDG2) will likely be associated with increases in consumption-
1270 based agricultural emissions in low and medium HDI countries. In order to meet emission
1271 reduction goals, consumption of red meat should be safely reduced in relevant population
1272 groups, especially in very high HDI countries.²²⁷ This would also deliver substantial health co-
1273 benefits, as indicator 3.5.2 shows. Further scope to reduce emissions from the food
1274 production system comes from waste reduction, deforestation curtailment and yield
1275 improvement.²²⁸

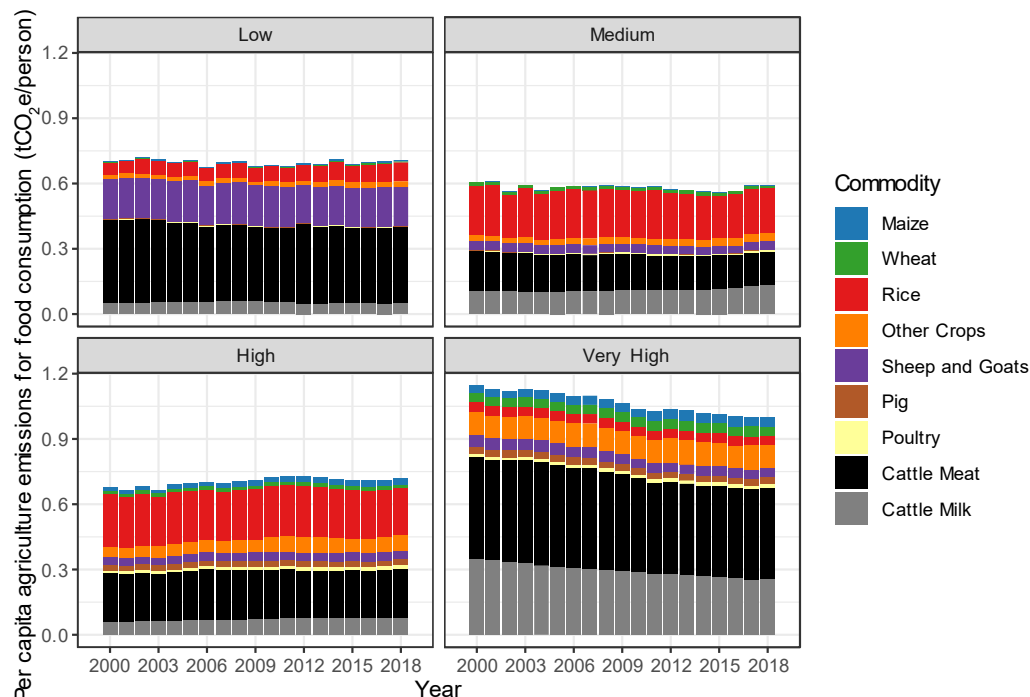


Figure 16. Per capita yearly greenhouse gas emissions associated with consumption of agri-food products, by 2019 Human Development Index country group and commodity, 2000-2018.

Indicator 3.5.2: Diet and Health Co-Benefits

Headline finding: between 2017 and 2018, estimated deaths due to excess red meat consumption rose by 1.8% to 842,000

With current production efficiency interventions failing to curb or reduce agricultural greenhouse gas emissions, dietary shifts – greatly reducing red meat and increasing plant-based foods – are necessary, particularly in the very high and high HDI countries.²⁸ For the low and medium HDI countries, sustainable farming and agricultural practices will help keep agricultural emissions low while efforts are made to meet the nutritional requirements of populations.²²⁹ Monitoring this dietary transition, this indicator models deaths attributable to dietary risk factors, using updated data on food consumption and mortality rates by sex, age and country.^{230,231}

In 2018, 9.6 million deaths were attributable to imbalanced diets (both dietary composition and caloric intake). Although dietary risks and baseline mortality rates declined, there was an overall increase compared with 2017 (see appendix, pp 130-138). Diets in the high and very

high HDI country groups contain 4 to 7 times more red meat than in the low and medium HDI groups. Together with greater non-communicable disease-related mortality rates, this translates to a rate of red meat-related mortality almost nine times greater in the very high HDI country group (19 deaths per 100,000) compared with the low HDI group (2 deaths per 100,000).

Diets and the associated health impacts differ across sexes. In general, male diets tend to be less healthy than those of females, containing fewer fruits (-6% on average globally), vegetables (-1%), and legumes (-10%), and more red meat (+4%).²³²⁻²³⁵ The differences in risks resulted in an estimated 455,000 (10%) more men dying from preventable, diet-related diseases than women – a pattern reflected across each of the HDI country groupings (Figure 17).

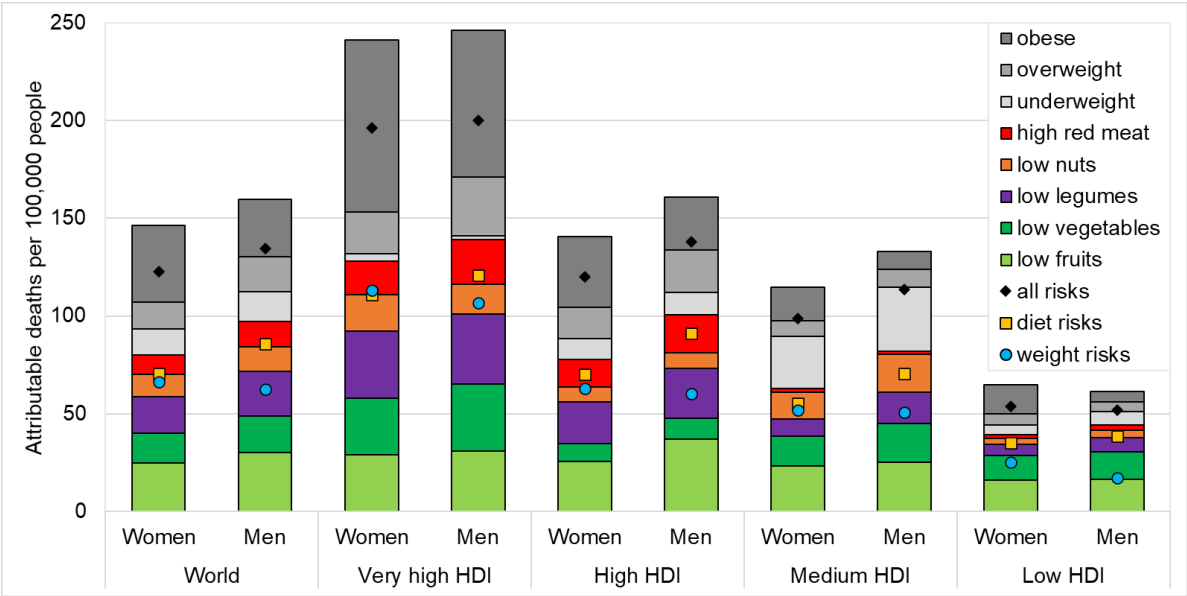


Figure 17. Deaths attributable to imbalanced diets and weight in 2018 by risk factor, sex, and 2019 Human Development Index country group. The size of each component in the stacked bar represents its individual contribution to attributable deaths. Since these contributions cannot be summed directly, the overall contribution by diet and weight components are represented by the dots as given in the key.

Indicator 3.6: Healthcare Sector Emissions

Headline finding: in 2018, emissions from the healthcare sector increased slightly to 4.9% of global greenhouse gas emissions. Healthcare emissions are positively associated with Human Development Index levels, largely through health spending, but minimal association is seen after 400 kg CO_{2e} per capita

1319 The healthcare sector is central to improving human development. In providing services,
1320 healthcare systems mobilise a vast array of products and use energy in various forms, all of
1321 which result in emissions of greenhouse gases and other pollutants that can be calculated
1322 throughout global supply chains. With this contribution to greenhouse gas emissions and
1323 their important leadership role in improving patient care in the face of climate change,²³⁶
1324 healthcare institutions are beginning to seriously commit to reducing emissions.²³⁷

1325 In this indicator, both direct and indirect emissions from the global healthcare sector are
1326 modelled using environmentally extended multi-region input-output (EE-MRIO) models,
1327 combined with annual WHO data on national healthcare expenditure, with a full description
1328 in the appendix (pp 139-140).

1329 In 2018, the global healthcare sector contributed approximately 4.9% of global GHG
1330 emissions, a rise of 5.2% from 2017. Expansion of healthcare services in China was responsible
1331 for more than half of this global increase. Although its national healthcare emissions are now
1332 35% greater than those of the USA, on a per-capita basis, China ranks 21st among all major
1333 economies assessed.

1334 Per-capita comparisons do not account for differences in healthcare access and quality,
1335 specifically measured through health outcomes, such as life expectancy, which is one of the
1336 components of the HDI. Plotting per capita healthcare emissions against HDI (Figure 18)
1337 reveals that emissions are positively associated with HDI, an association strongest for lower
1338 emissions levels. A wide range of HDI levels are associated with per capita healthcare
1339 emissions of 500-600 kgCO₂e, reflecting both differences in health system efficacy and other
1340 development indicators, but also in emissions intensities. Above these levels, additional
1341 emissions are not associated with improved HDI.

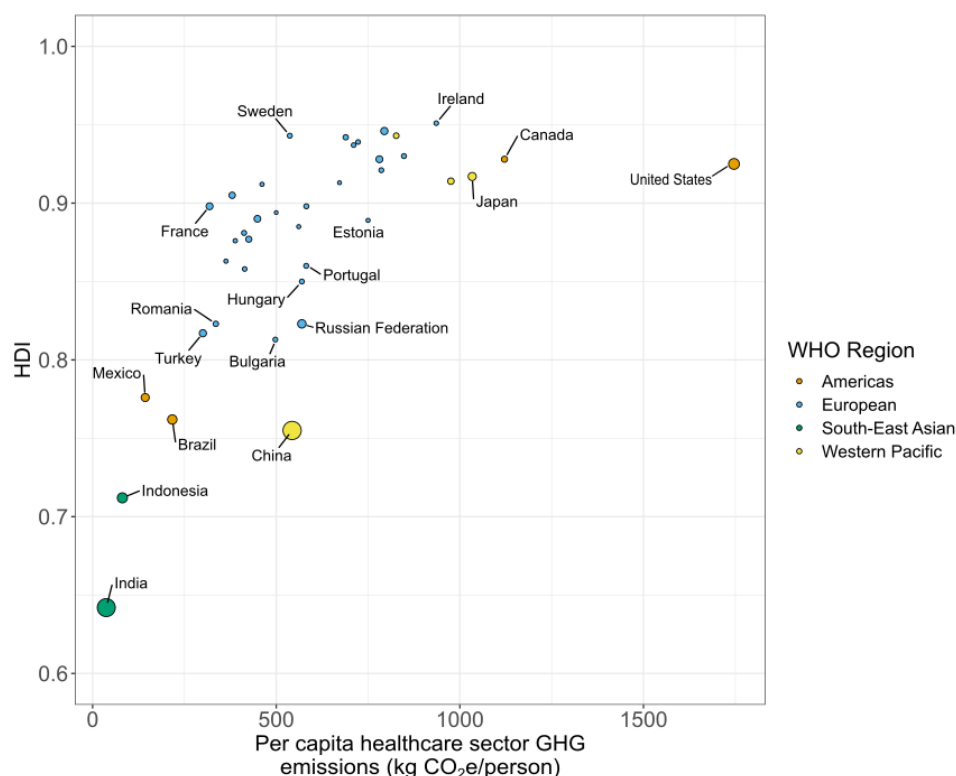


Figure 18. National per capita healthcare greenhouse gas emissions for 2018 against 2019 country Human Development Index level. Dot size is proportional to population

Conclusion

Prior to the pandemic, the rapid rate of growth in renewable electricity generation was insufficient to counteract the sluggish decline in coal use. The result of this was that the carbon intensity of the global energy system remained virtually unchanged. At the same time, there has been very little progress in increasing the use of clean household energy. These delays are costing millions of lives each year, from both household and ambient air pollution. Food-related agricultural emissions continue to rise and so too do deaths attributable to dietary risk factors.

Across this section, many inequities can be highlighted. Low HDI countries have the highest use of dirty fuels in the home, putting them at greater risk of morbidity and mortality from exposure to household air pollution. Countries of medium and high levels of HDI have the highest carbon intensity of energy and the greatest burden of deaths due to ambient air pollution, as a result of higher industrial activity and inadequate emissions controls. People in very high HDI countries have the most carbon intensive diets, and, with high levels of red meat consumption, they also have the most to gain from a shift towards more plant-based foods.

1362 Although the impacts of the COVID-19 pandemic are not yet fully captured, there was a
1363 temporary, but significant drop in emissions due to lockdowns, and the associated reductions
1364 in economic activities and international travel. However, emissions are already rebounding.
1365 The challenge moving forward will be to adopt measures that provide near-term economic
1366 relief, whilst building towards long-term emission reductions and protecting future health –
1367 a challenge further explored in the following section.

1368 Section 4: Economics and Finance

1369 Avoiding the worst of the climate change impacts described in section 1 will require both
1370 sustained adaptation efforts (section 2), as well as a rapid transformation of the world's
1371 economies to cut greenhouse gas emissions (section 3). Section 4 examines the economic and
1372 financial implications of this transition.

1373 First, this section explores the economic impact of climate change and its mitigation
1374 (indicators 4.1.1 to 4.1.4). The indicators use a range of methods to estimate some of the
1375 costs that climate change may already be imposing on society through its impacts on human
1376 health. Then, the economics of the transition to zero-carbon economies (indicators 4.2.1 to
1377 4.2.5), which are fundamental to the improvement of human health and wellbeing are
1378 investigated. The indicators consider whether investments and jobs are beginning to move
1379 away from fossil fuels, and if the appropriate economic signals are encouraging this. A new
1380 indicator for this year's report (indicator 4.2.5) explores the effect of global trade on
1381 greenhouse gas and PM_{2.5} emissions associated with economic activities, highlighting that
1382 harms may occur in countries different from the demands that drive them.

1383 Achieving the required investments in the low-carbon transition requires clear and
1384 committed action from both governments and private sector actors and could result in both
1385 health and economic benefits. Aiming for a green global recovery from COVID-19 over
1386 'business as usual' economic growth will ensure that the economy recovers through the
1387 generation of new jobs in low-carbon industries, as well as accelerate progress towards the
1388 Paris Agreement goals and the SDGs – yielding health gains through the prevention of further
1389 climate change and through the co-benefits of climate change mitigation.²³⁸ International
1390 economic cooperation will be essential to ensure global emission targets are met, and to
1391 prevent the widening of inequity gaps.²⁵ This section also therefore reflects on the extent to
1392 which post-COVID-19 recovery spending has prioritised green investment (panel 4), and the
1393 alignment of fossil fuel companies' strategies with the requirements of the transition (panel
1394 5).

1395

1396 4.1 The Economic Impact of Climate Change and its Mitigation

1397 Indicator 4.1.1: Economic Losses due to Climate-Related Extreme Events

1398 *Headline finding: when normalised by GDP, economic losses from climate-related extreme*
1399 *events in 2020 were collectively three times greater in with the medium Human Development*
1400 *Index country group compared with the very high Human Development Index group*

1401 The loss of physical infrastructure and resulting economic losses due to climate-related
1402 extreme events can further exacerbate the health impacts described in section 1. This
1403 indicator tracks the total annual economic losses (insured and uninsured) that result from
1404 climate-related extreme events, using data provided by Swiss Re, with methods described in
1405 the appendix (pp 141-143).^{239,240}

1406 In 2020 there were 242 recorded climate-related extreme events, with absolute economic
1407 losses totalling US\$178 billion. Although two-thirds of these losses occurred in very high HDI
1408 economies, when normalised by GDP, losses the medium HDI country groups are around
1409 three times greater. Importantly, while two-thirds of losses in the very high HDI country group
1410 are insured, almost 93% of losses were uninsured in the high HDI group. This number rises to
1411 97% and 100% of measurable losses in the medium and low HDI country groups, respectively
1412 – creating a bigger economic burden for these disadvantaged countries, as uninsured losses
1413 are either not replaced, or are replaced through out-of-pocket expenses, reinforcing
1414 inequities.

1415

1416 [Indicator 4.1.2: Costs of Heat-Related Mortality](#)

1417 *Headline finding: the monetised value of global heat-related mortality increased by 6.7% from*
1418 *0.27% of gross world product in 2018, to 0.28% in 2019. Europe continued to be the worst*
1419 *affected region, facing costs equivalent to the average income of 6.1 million of its citizens*

1420 The increase in morbidity and mortality due to extremes of heat represents a high cost to all
1421 of society. This indicator uses data on years of life lost due to extremes of heat from indicator
1422 1.1.6 to provide a measure of the costs of global deaths attributable to heat.⁹⁶ Improved in
1423 the 2021 report, it combines a value of statistical life-year (VSLY) with years of life lost (YLLs),
1424 to monetise the loss caused by premature mortality. The valuation of life across varying HDI
1425 levels presents a methodological and ethical challenge, which this indicator addresses by
1426 presenting costs as the proportion of GDP and the equivalent annual average income.

1427 The monetised value of global heat-related mortality in the 65-and-over population increased
1428 by 6.7%, from 0.27% of gross world product in 2018 to 0.28% in 2019 (Figure 19). Reflecting
1429 the distribution of impacts found in indicator 1.1.6, the costs of heat-related mortality for the
1430 low, medium, high, and very high HDI country groups, were found to be equivalent to the
1431 average income of 0.94, 4.80, 8.20, and 7.52 million of their citizens, respectively. As in
1432 indicator 1.1.6, the WHO's European region was the worst affected in 2019, with costs equal
1433 to the average income of 6.1 million of its citizens and 0.66% of regional GDP. However, the
1434 costs were lower than the year before, due to fewer estimated heat-related deaths in 2019
1435 compared to 2018 in this region (indicator 1.1.6). On the other hand, costs increased in other
1436 regions, especially the WHO's South-East Asia region.

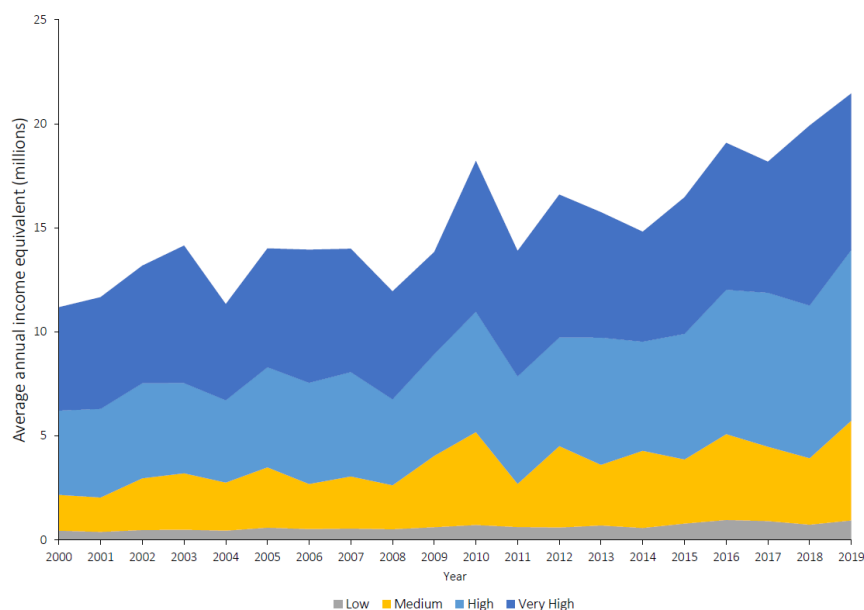


Figure 19. Monetised cost of heat-related (in terms of expressed as the number of people whose average income the loss is equivalent to) by 2019 Human Development Index country group for 2000-2019

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

Headline finding: working in conditions of extreme heat is a health risk. Such conditions could reduce the capacity for paid labour, with an impact on workers' earnings equivalent to 4-8% of GDP in the low Human Development Index country group in 2020

As reflected in indicator 1.1.4, higher temperatures, driven by climate change, are affecting people's ability to work. This indicator considers the loss of earnings that could result from such reduced capacity. Such earnings losses could further compound the health impacts through effects on the socioeconomic determinants of good health.²⁴¹ It combines the outputs of indicator 1.1.4 with data on average earnings by country and sector held in the International Labour Organization (ILO) databases, with methods and additional analysis described in the appendix (pp 146-151).²⁴² In this year's report, the number of countries covered in this indicator has been increased from 25 to 183.

Indicators 1.1.6 and 4.1.2 found Europe to be the region most affected by heat-related mortality in populations aged 65 and over. In contrast, this indicator focusses on working age populations and, in alignment with the outputs of indicator 1.1.4, finds that greater loss of earnings due to labour capacity loss occur in low and medium HDI countries. Countries with lower HDI levels tend to experience greater proportional losses of earnings, emphasising the impact of climate change on deepening inequities. In the low HDI country group, potential

income losses in 2020 were equivalent to 4-8% of GDP, depending on the degree of shade or sun exposure during agricultural and construction work (Figure 20). The ranges for the medium, high, and very high HDI country groups in 2020 were 2-4%, 1-2% and 0.3-0.5% of GDP, respectively. The impacts will mainly affect men in sectors such as construction, where they represent more than 90% of the workforce globally, and in manufacturing and agriculture where, where they represent more than 60% of the workforce.⁸⁴ However, the data does not account for informal or unpaid domestic and agricultural work, in which women are often overrepresented.²⁴³⁻²⁴⁵ The indirect economic impacts from reduced labour capacity extend well beyond the loss of earnings. For example, modelling both direct and indirect impacts, the heat-related economic cost of labour loss in 2020 was estimated at 1.36% of China's GDP and 6.75% of GDP in Hainan Province.⁵¹

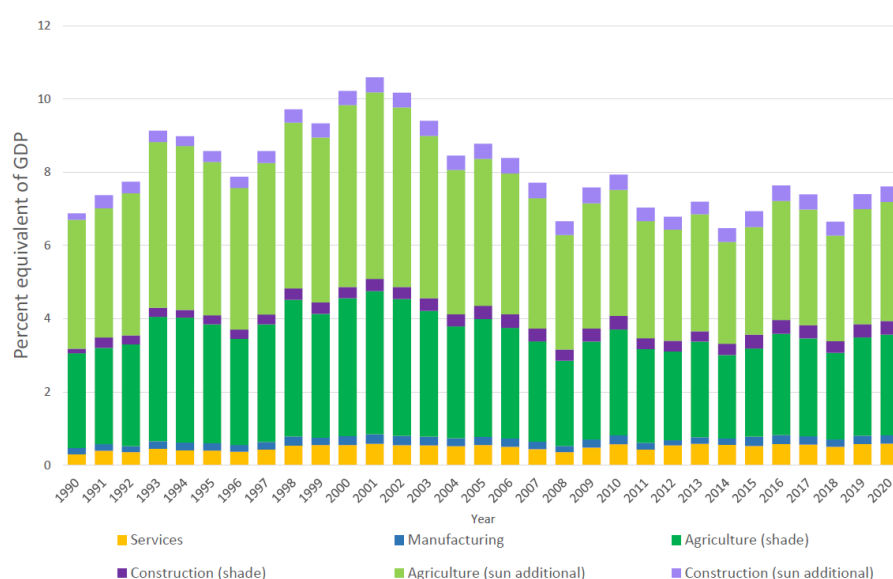


Figure 20 Average potential loss of earnings in the low Human Development Index country group as a result of potential labour loss due to heat exposure. Losses are presented as share of GDP, by sector of employment,. The agriculture and construction (sun additional) blocks represent the losses that would have been incurred in addition to those from agriculture and construction (shade) if all of the activities in these sectors had been carried out in direct sunlight.

Indicator 4.1.4: Costs of the Health Impacts of Air Pollution

Headline finding: equivalent to the annual income of 71.1 million and 99.1 million people, the greatest economic costs of mortality due to air pollution fall on countries in the medium and high Human Development Index country groups. Costs relative to GDP decreased between 2015 and 2019 globally, with the exception of costs in South-East Asia

As described in indicator 3.3, global mortality due to ambient PM_{2.5} pollution has increased. This indicator captures the cost of this mortality by placing an economic value on the YLLs that result from exposure to anthropogenic ambient PM_{2.5}. This indicator has been expanded for the 2021 report, from a European-only focus to global coverage, and with a revised definition of YLLs. The methods, data and further analysis are described in full in the appendix (pp 152-154).

Figure 21 presents the economic value of YLLs in 2015 and 2019 by country HDI groups, relative to both total GDP and the annual income of the average person in these categories. The greatest relative costs fall on the medium and high HDI country groups, equivalent to the annual income of 74.6 million and 99.1 million people, respectively. Costs relative to average income increased between 2015 and 2019 in the low and medium HDI country groups. However, with rates of growth of GDP outpacing those of population, costs relative to total GDP have decreased in all HDI groups.

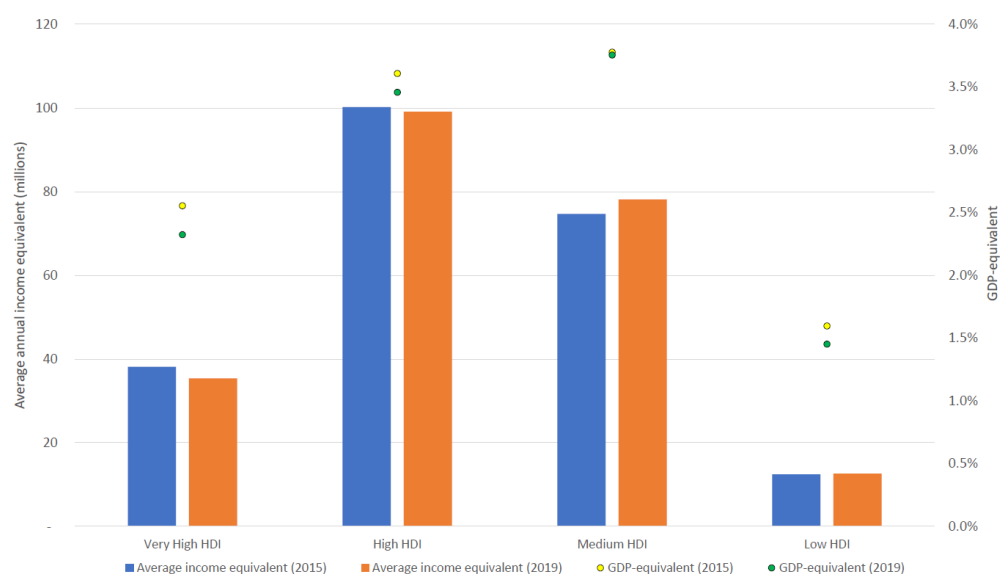


Figure 21. Economic cost of YLLs in 2015 and 2019, relative to the annual income of the average person and total GDP, by 2019 Human Development Index country group

4.2 The Economics of the Transition to Zero-Carbon Economies

Panel 4. Recovering from Covid-19: Stimulus Measures for a Sustainable Economy

The COVID-19 pandemic, and measures to tackle it, triggered a global recession of a depth only exceeded in the last 150 years by two World Wars and the Great Depression of the 1930s.²⁴⁶ Governments with the fiscal capacity have responded with massive spending packages; by the end of 2020, the world's 50 largest economies had committed USD 14.6 trillion in fiscal measures (many times higher than the value of global stimulus measures following the 2008-09 financial crisis). Although 87% of this was designed to prevent an even deeper health and economic crisis (USD 12.7 trillion), rather than encourage recovery (USD 1.9 trillion),²⁴⁷ as time goes by and further measures are announced, promoting recovery will come to the fore.

How these measures are designed and targeted will determine whether this spending entrenches existing technical, economic, and social structures and systems, or promotes those that are more sustainable, healthy, and equitable. Evidence from stimulus measures introduced following the 2008-09 financial crisis shows that 'green' stimulus measures often have advantages over 'brown' or 'colourless' measures.²³⁸

So far, the signs are not encouraging. Of the USD 1.9 trillion directed toward recovery by the end of 2020, just 18% is expected to reduce greenhouse gas emissions (or 2.5% of the value of all fiscal measures), while the overall impact on air pollution, and particularly on natural capital – through the expansion of road transport and defence services in particular – is likely to be negative. Positive measures are highly concentrated in just a few nations, particularly in Europe,²⁴⁷ although measures announced so far in 2021 indicate some movement towards greater consideration of sustainability in other countries.^{248,249} However, despite global CO₂ emissions dropping by a record 6% in 2020 overall, they have rebounded quickly, with global CO₂ emissions in December 2020 around 2% higher than in December 2019.²⁵⁰ The urgency with which the trillions of dollars for stimulus measures yet to be announced must be oriented toward a green and healthy recovery is therefore great.

In May 2020, the WHO published six prescriptions for a healthy and green recovery: (1) Protect and preserve the source of human health: Nature; (2) Invest in essential services, from water and sanitation to clean energy and healthcare facilities; (3) Ensure a quick, healthy energy transition; (4) Promote healthy, sustainable food systems; (5) Build healthy, liveable cities; and (6) Stop using taxpayers money to fund pollution (particularly through fossil fuel subsidies).²⁵¹ If governments are serious about their commitments under the Paris Agreement and SDGs, they must take note of these priorities, plan ahead, and learn from both their own previous experience and from that generated elsewhere, to implement them using well-designed and context-appropriate policy. Where necessary, multilateral institutions, processes and instruments should be galvanised in support of a global recovery that is both sustainable and equitable.²⁴⁷

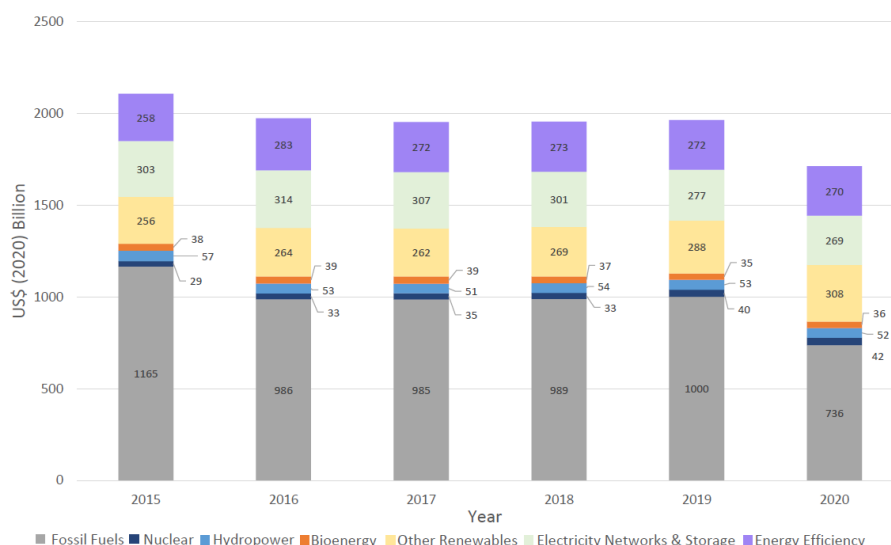
1533 Indicator 4.2.1: Coal and Clean Energy Investment

1534 *Headline finding: global investment in energy supply and energy efficiency reduced 13%*
1535 *between 2019 and 2020. Investment in renewable energy and energy efficiency increased by*
1536 *3%, but investment in new coal capacity reduced by 13%*

1537 Coal combustion has been responsible for over 30% of the global average temperature
1538 increase above pre-industrial levels and for 491,000 deaths from PM_{2.5} exposure in 2019
1539 (indicator 3.3).²⁵² Therefore, coal phase-out is essential for both mitigating climate change
1540 and for reducing premature mortality due to air pollution. At the same time, it is necessary to
1541 invest in renewables, energy efficiency, and the electricity grid in order to reduce the carbon
1542 intensity of energy supply, as described in indicator 3.1. Taking data from the IEA, this
1543 indicator tracks global investment in energy supply and energy efficiency, and highlights
1544 ongoing capital spending in new coal-fired power generation, globally and for key countries
1545 and regions. The data, presented as an index, represents ongoing capital spending.

1546 Between 2019 and 2020 investment in global energy supply and energy efficiency reduced
1547 from nearly \$2 trillion to around \$1.7 trillion, almost entirely due to declining investment in
1548 fossil fuels, following reduced demand as a result of the pandemic (investment in coal power
1549 capacity declined by 13%). In parallel, investment in renewables and energy efficiency
1550 increased by 3%, with their share of total investment in global energy supply increasing from
1551 33% to 39%. However, for a pathway consistent with 1.5°C of warming this century, annual
1552 investments in clean energy must at least triple over the 2020s.²⁵³

1553



1554

1555 *Figure 22. Economic value of annual investment in renewable and fossil fuel energy supply and*
 1556 *energy efficiency, 2014-2020*

1557

1558 Indicator 4.2.2: Employment in Low-Carbon and High-Carbon Industries

1559 *Headline finding: direct employment in fossil fuel extraction declined by 14% from 13.1 million*
 1560 *in 2019 to 12.7 million in 2020*

1561 Evidence suggests that employees in some fossil fuel extraction industries, particularly coal
 1562 mining, and their local communities, suffer a greater incidence of cardiovascular and
 1563 cerebrovascular disease, respiratory disease and cancers.²⁵⁴ Investments in renewable
 1564 energies and energy efficiency are estimated to create almost three times more jobs per unit
 1565 of spend than those in fossil fuel industries.²⁵⁵ Along with strong labour and environmental
 1566 standards, investment and employment in renewables present an opportunity to improve
 1567 health and livelihoods. This indicator tracks global direct employment in fossil fuel extraction
 1568 industries and direct and indirect (supply chain) employment in renewable energy, with a full
 1569 description available in the appendix (pp 158-159).

1570 Around 11.5 million people globally were employed directly or indirectly by the renewable
 1571 energy industry in 2019, representing an increase of 4.2% from 2018. At the time of writing
 1572 data for 2020 was unavailable, although due to the pandemic, the extent to which such data
 1573 will be indicative of a long-term trend is currently unclear. Fossil fuel extraction industries
 1574 continue to employ more people globally than all renewable energy industries combined,

1575 although the number of jobs in 2019 are slightly lower than in 2018, at 12.7 million compared
1576 with 13.1 million.

1577 While men are still overrepresented in the energy sector, the field of renewable energy
1578 employs a considerably higher share of women (32%) than the oil and gas industry (22%).²⁵⁶
1579 With adequate policies in place, the transition to a low carbon economy therefore represents
1580 an additional opportunity to reduce gender inequities and empower women.

1581 With trillions of dollars earmarked for COVID-19 recovery, investments in the renewable fuel
1582 industry could offer a triple gain in terms of better health through safer jobs and improved
1583 livelihoods, climate change mitigation, and more employment opportunities.

1584

1585 [Indicator 4.2.3: Funds Divested from Fossil Fuels](#)

1586 *Headline finding: the global value of funds committing to fossil fuel divestment between 2008*
1587 *and 2020 is US\$14.52 trillion, with health institutions accounting for US\$42 billion*

1588 By reducing financial interests in the fossil fuel industry, divestment both reduces the ‘social
1589 licence to operate’ of fossil fuel companies, and hedges against investors’ risk of losses due
1590 to ‘stranded assets’ in an increasingly decarbonising world (panel 5).^{257,258} Investors can also
1591 effect change through shareholder action, exemplified recently by activist hedge fund Engine
1592 No 1 taking seats on ExxonMobil’s board.²⁵⁹ Concerned with the immediate and long-term
1593 damages of continued fossil fuel use, health institutions have the imperative to lead the way
1594 in divesting, to ensure they ‘first, do no harm’. This indicator tracks the total global value of
1595 funds divested from fossil fuels, and the value of funds divested by health institutions, using
1596 data provided by 350.org.²⁶⁰

1597 From 2008 until the end of 2020, 1,398 organisations, with assets worth at least US\$14.52
1598 trillion, have committed to divestment. Of these, only 25 are health institutions, with assets
1599 totalling US\$42 billion. The value of new funds committed to divesting in 2020 was US\$2.5
1600 trillion, with health institutions accounting for US\$47 million of these.

1601

Panel 5. Compatibility of fossil fuel company strategies with well below 2°C-consistent emissions trajectories

Globally, carbon dioxide (CO₂) from the combustion of fossil fuels represents 65% of total greenhouse gas emissions.¹⁶ In the 2015 Paris Agreement, countries agreed to reduce their emissions to keep global warming to ‘well below 2°C’ with respect to pre-industrial levels. The carbon budget for a 66% probability of limiting global warming to 1.5°C has been estimated at 420 GtCO₂.³⁷ However, the potential CO₂ emissions from reserves held by the 200 largest public fossil fuel companies is at least 1,541 GtCO₂,²⁶¹ whilst the carbon contained in global resources of fossil fuels is estimated at about 11,000 GtCO₂,²⁶² well beyond the maximum that can be used if the world is to meet the Paris Agreement goals. A third of oil reserves, half of gas reserves and over 80 per cent of coal reserves worldwide should remain unused to keep global warming below 2°C,²⁶² representing stranded assets and unburnable carbon.^{249,263} Future energy system scenarios with strict carbon constraints, low fossil fuel demand, high capital costs projects and carbon-intensive reserves increase the risk of stranding assets,²⁶⁴ with considerable financial consequences for their owners and industry stakeholders.²⁶⁵

Although the fossil fuel industry has begun to acknowledge that the energy system is transitioning away from unabated oil, gas and coal, countries’ fossil fuel production plans to 2030 could exceed levels consistent with limiting warming to 2°C by 50%, and by 120% in relation to 1.5°C.²⁶⁶ Companies are following diverging business strategies,²⁶⁷ with most of them falling short of what is required to mitigate transition risks. While an increasing number of oil and gas companies are announcing net-zero commitments, for these to be consistent with climate ambitions they must be framed on the basis of their total emissions rather than on their emission intensities, cover scope 1, 2 and 3 emissions, and account for activities based on a company’s full equity share.^{83,268} Those companies who better understand systemic risks, stress-test potential scenarios, and develop business strategies with interim targets and investments that align adequately with well below 2°C targets (and preferably 1.5°C) are likely to become more resilient over the coming years, as climate-risk scrutiny from investors and financial regulators increases.

Indicator 4.2.4: Net Value of Fossil Fuel Subsidies and Carbon Prices

Headline finding: 77% of the 84 countries reviewed had a net-negative carbon price in 2018. The resulting net loss of revenue was in many cases equivalent to substantial proportions of the national health budget

Placing a carbon price on fossil fuel use helps to reflect more accurately its negative externalities, including its impact on health, and to encourage the transition away from fossil fuels. However, not all countries set carbon prices, and where they are imposed, they can be undermined by subsidies provided for fossil fuels.

This indicator compares carbon prices and fossil fuel subsidies to calculate ‘net’ economy-wide average carbon prices and revenues. It covers 84 countries, which are responsible for around 92% of global CO₂ emissions. The indicator is based on data from the IEA,²⁶⁹ OECD,²⁷⁰

the World Bank,²⁷¹ and the WHO, with methods and further analysis in the appendix (pp 162-165).²⁷²

In 2018, 65 out of the 84 countries analysed (77%) had net-negative carbon prices, reflecting an overall subsidising of fossil fuels. The median value of the subsidy in these countries was US\$1 billion, with some countries providing net subsidies to fossil fuels in the tens of billions of dollars each year. 42 countries had a carbon pricing mechanism in place, but only 19 succeeded in discouraging fossil fuels with net-positive carbon prices – all of which were very high HDI countries. Nonetheless, most very high HDI countries still had net-negative carbon prices (Figure 23). These net subsidies are equivalent to substantial proportions of national health spending in many countries.

With low-income populations vulnerable to energy costs, removing subsidies can be a challenge, but redirecting spending from fossil subsidy to healthcare and health-related services would most likely deliver net benefits to their wellbeing.²⁷³ Furthermore, international financing mechanisms to support low-income countries in their transition to sustainable energy sources are essential to safeguard all dimensions of human health.²⁷⁴

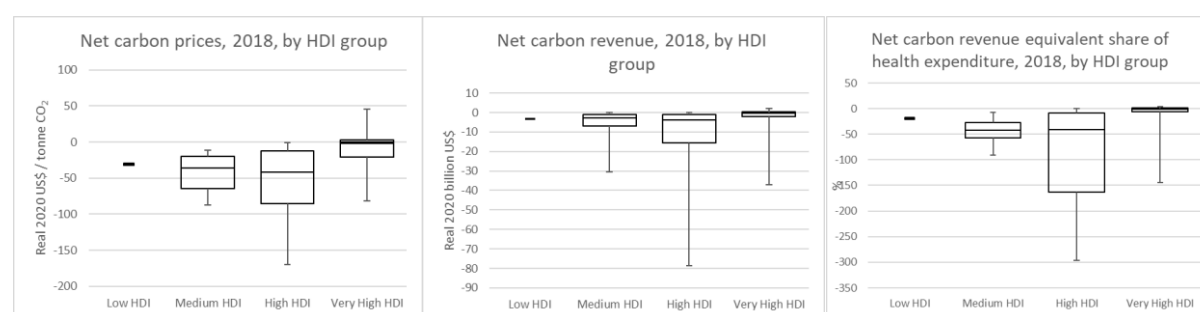


Figure 23. Net carbon prices (left), net carbon revenues (centre), and net carbon revenue as a share of current national health expenditure (right), across 84 countries in 2018, arranged by 2019 Human Development Index country group: low (n=1), medium (n=7), high (n=23) and very high (n=53). Boxes show the interquartile range (IQR), horizontal lines inside the boxes show the medians, and the brackets represent the full range from minimum to maximum.

Indicator 4.2.5: Production- and Consumption-Based Attribution of CO₂ and PM_{2.5} Emissions

Headline finding: in 2019, 18% of CO₂ and 17% of PM_{2.5} global emissions were embodied in trades between countries of different Human Development Index levels

The production of goods and services often drives both greenhouse gas and PM_{2.5} emissions, thus contributing to impacts on health and wellbeing. Emissions from local production ('production-based emissions') occur within the geographical territories of nations through the local production of goods and services. An alternative way of accounting for the burden

1667 of pollution is to assign the emissions to the country which is the final consumer of the
1668 products that are made – known as ‘consumption-based emissions’. A comparison of
1669 production- and consumption-based emissions gives a better understanding of how
1670 emissions are embodied in global trade, which is essential to enable better international
1671 policy formulation that protects human health in all geographies.

1672 This indicator captures the pollution burden from a country’s local production, as well as that
1673 driven by a nation’s domestic final consumption, including the burden embedded in its
1674 imports. It uses an EE-MRIO model and the EXIOBASE database, to estimate CO₂
1675 emissions,^{275,276} and the GAINS model to produce a PM_{2.5} emission inventory.²⁷⁷ More details
1676 on the methodology, and further analysis, can be found in the appendix (pp 166-172).

1677 In 2019, 18% of CO₂ (of 35.6 Gt world total) and 17% of PM_{2.5} (of 37.4 Mt world total) global
1678 emissions were embodied in trades among countries of different HDI levels. The largest
1679 contributors to global consumption-based CO₂ and PM_{2.5} emissions were China (28 % and
1680 18%), the USA (17% and 5%), the EU (10% and 6%), and India (7 % and 16%). The USA did the
1681 most ‘outsourcing’ of emissions, with 21% CO₂ (of 5.9 Gt total) and 49% PM_{2.5} (of 1.7 Mt total)
1682 emissions resulting from the production of goods it consumed, actually occurring in other
1683 countries. In contrast, 16% of CO₂ (of 10.8 Gt total) and 13% of PM_{2.5} (of 6.8 Mt total)
1684 emissions that occurred in China resulted from the local production of goods that were
1685 ultimately exported to consumers in other countries.

1686 The very high HDI country group contributed the most production-based (45%) and
1687 consumption-based (49%) CO₂ emissions in 2019. However, the high HDI country group was
1688 the biggest contributor to both production-based (38%) and consumption-based (35%) PM_{2.5}
1689 emissions (Figure 24), with the very high HDI country group the lowest emitter of PM_{2.5}, partly
1690 as a result of stricter local air pollution regulations. Importantly, the very high HDI country
1691 group was the only group with higher consumption-based emissions than production-based
1692 emissions, i.e. a net ‘outsourcing’ in terms of their consumption-related emissions.

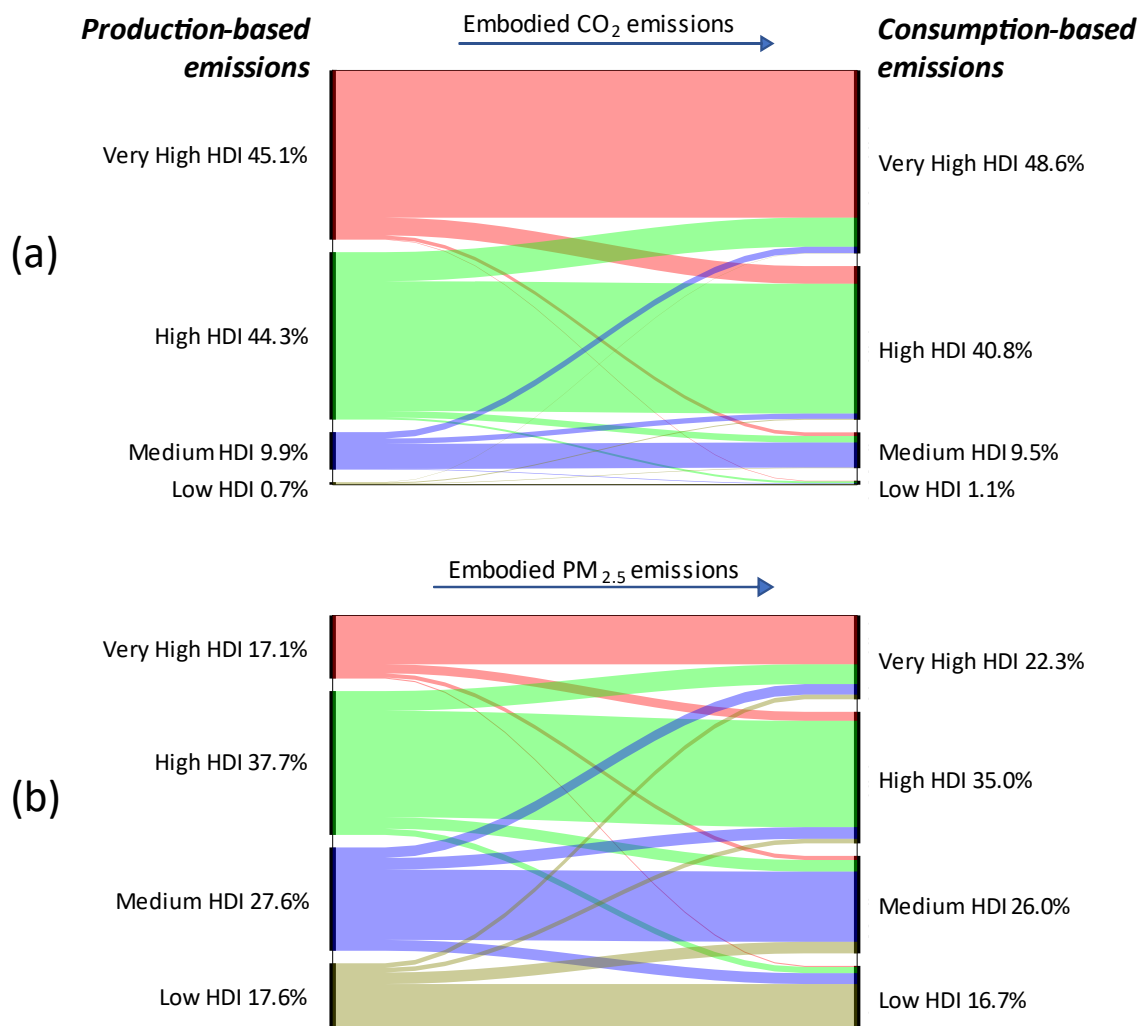


Figure 24. The flows of embodied CO₂ and PM_{2.5} emissions among different Human Development Index country groups in 2019

Conclusion

The impacts of climate change on health are already having significant economic consequences and fall in different ways across countries of all levels of HDI. The economic losses of climate-related extreme events are three times higher in medium HDI countries than in very high HDI countries. However, the monetised value of global heat-related deaths is highest in Europe, and the greatest costs of premature mortality due to air pollution fall in countries with medium and high HDI levels. South-East Asia was the only region with increasing air pollution mortality costs between 2015 and 2019, relative to GDP. Extreme heat can create economic impacts by reducing labour capacity. In this case, those employed in low-wage, outdoor work in low HDI countries are likely to be most affected.

1707 Because of the potentially large and unequally distributed impacts of climate change on
1708 human health, incomes and wellbeing, substantial and sustained investment in the low
1709 carbon transition is required. Overall, global investments in coal power continue to decline,
1710 although with worrying counter-trends in certain countries. Investments in renewables and
1711 energy efficiency continue to grow, as do divestments from fossil fuel assets, however a
1712 considerable increase in the pace of change is required.

1713 Both governments and the private sector have crucial roles to play in bringing about the
1714 required transition. Governments across all HDI groups must address fossil fuels subsidies in
1715 countries. Although withdrawing energy subsidies is challenging when it affects people on
1716 low incomes, other forms of government spending, including on health services, can provide
1717 better and more targeted support to decrease inequities and maximise wellbeing. The global
1718 trade system means that almost a fifth of CO₂ and PM_{2.5} emissions occur in the production of
1719 goods that are subsequently traded between countries of different HDI levels. This underlines
1720 the importance of inclusive global agreements that facilitate cooperation on policies for the
1721 reduction of both production and consumption emissions.

1722 As governments begin to invest in recovery from COVID-19, there is a crucial window of
1723 opportunity to reduce fossil fuel subsidies, invest more in clean energy, and support a green
1724 recovery. Policies and regulations must be developed that subject fossil fuel companies to
1725 greater scrutiny and ensure their alignment with a world well below 2°C.

1726 Section 5: Public and Political Engagement

1727 As the preceding sections make clear, climate change is damaging people's health and
1728 widening the fault lines of inequality, with the human costs amplified by COVID-19.^{9,278,279}
1729 Those least responsible for climate change are most exposed to impacts that are 'hitting
1730 harder and sooner' than climate assessments indicated even a decade ago.²⁸⁰ Action at the
1731 speed and scale needed to meet the ambitions of the Paris Agreement requires public and
1732 political engagement, particularly in industrialised countries where 'the major part of
1733 emissions originate'.²⁸¹ This section tracks engagement in health and climate change in the
1734 media as well as by individuals, scientists, governments and the corporate sector.

1735 The mainstream media is a major platform for public engagement. It remains the most widely-
1736 used source of information,²⁸² shaping public perceptions²⁸³⁻²⁸⁵ and influencing the social
1737 media agenda.²⁸⁶ Indicator 5.1 tracks coverage of health and climate change in 67 newspapers
1738 from 37 countries, including the *People's Daily (Renmin Ribao)*, China's longest-running
1739 national newspaper and the official outlet of government.^{287,288} The indicator also includes a
1740 content analysis of coverage in India and the USA, focusing on 'prestige' newspapers with
1741 influence on the countries' political and economic elites.²⁸⁹⁻²⁹¹

1742 Individual engagement (indicator 5.2) is tracked through individuals' searches on Wikipedia,
1743 the online information source with wider reach and coverage than traditional
1744 encyclopaedias.²⁹²⁻²⁹⁴ The third indicator (Indicator 5.3) tracks engagement in peer-reviewed
1745 journals, the primary source of scientific evidence for the media, government, and the
1746 public.²⁹⁵

1747 Government engagement (indicator 5.4) is tracked by statements made by national leaders
1748 at the UN General Assembly, the policy-making body of the UN. The annual meeting opens
1749 with the General Debate where heads of government, or their high-ranking representatives,
1750 address the global community on issues they consider important.^{296,297} Indicator 5.4 also
1751 considers engagement with health in the enhanced NDCs, submitted in compliance with the
1752 2015 Paris Agreement.²⁹⁸⁻³⁰⁰ Panel 6 compares health engagement in the initial and enhanced
1753 set of NDCs held on the UNFCCC NDC registry on 1 April 2021.

1754 Action by the corporate sector will be decisive in moving societies away from dependence on
1755 fossil fuels.³⁰¹⁻³⁰³ Indicator 5.5 tracks engagement in health and climate change by companies
1756 within the UN Global Compact, the world's biggest corporate sustainability initiative.^{304,305}
1757 Companies commit to shared principles of sustainable behaviour and submit annual reports
1758 on progress.

1759 With increasing acknowledgement of the need to recognise and investigate gender inequities
1760 in the representation, communication, and governance of climate change,³⁰⁶⁻³⁰⁹ engagement
1761 with gender is incorporated where appropriate. Engagement with health, climate change and

1762 COVID-19, and analyses by WHO region and HDI country group are also included. Details of
1763 data sources and methods for all indicators are provided in the appendix, along with
1764 additional analyses.

1765

1766 [Indicator 5.1 Media Coverage of Health and Climate Change](#)

1767 *Headline finding: in 2020, the upward trend in coverage of health and climate change*
1768 *continued, but failed to match the increase seen in 2019. In 2020, most of the coverage of*
1769 *health and climate change referred to COVID-19*

1770 Newspapers provide an important forum for public engagement. They shape public
1771 understanding of climate change, both through their influence on their readers and on the
1772 wider political agenda.^{284,310} This indicator tracks coverage of health and climate change from
1773 2007, the year before the WHO World Health Assembly made a multilateral commitment to
1774 protect people's health from climate change.³¹¹ The indicator includes 66 newspapers
1775 spanning 36 countries and four languages, together with an additional analysis of China's
1776 People's Daily. The indicator also examines the content of 2020 coverage in newspapers in
1777 India and the USA. Methods and further analysis are provided in the appendix (pp 172-195)

1778 Across the 36 countries, the upward trend in newspaper coverage of health and climate
1779 change continued, reaching 11,371 articles in 2020. However, the rate of increase was lower
1780 than that of 2019 – 6% from 2019 to 2020, compared with 96% from 2018 to 2019. As in 2019,
1781 coverage was greatest in the WHO America and Europe regions and lowest in the African
1782 region.

1783 Engagement with gender and with COVID-19 was examined in English language newspapers
1784 across 23 countries. While the proportion of articles referring to gender increased between
1785 2007 and 2020 (from 97 (2%) of 6,044 articles to 573 (6%) of 10,092), gender remains marginal
1786 to the representation of health and climate change in the mainstream press. In 2020, over
1787 60% (6,238) of the 11,371 articles referring to health and climate change also referred to
1788 COVID-19; in April and May 2020, it was over 80%.

1789 In China's *People's Daily*, the limited coverage of health and climate change noted in earlier
1790 *Lancet* Countdown reports was again evident in 2020. Of the 1,106 articles discussing climate
1791 change, 2% were related to human health. Across the 2008-2020 period, no articles related
1792 to health and climate change engaged with gender issues. In 2020, no articles discussed the
1793 relationships between climate change and COVID-19, or how they together influenced health.

1794 Analysis of the content of coverage of health and climate change focuses on India (medium
1795 HDI) and the USA (very high HDI). The selected newspapers, the *Times of India* and *Hindustan*
1796 *Times* along with the *New York Times* and *Washington Post*, form part of the 'prestige' press,

1797 seen to exercise influence on political and economic elites and on the wider policy
1798 agenda.^{291,312}

1799 One set of themes related to the health impacts of climate-related hazards, including
1800 heatwaves and wildfires. For example, the *New York Times* (18 June), noted that “people with
1801 health issues, older people and young children are especially susceptible to the effects of
1802 extreme heat [and...] it’s a threat that grows as climate change continues”.³¹³ Another set of
1803 themes related to the spread of infectious disease, including COVID-19. For example, the
1804 *Hindustan Times* (25 February) reported that “climate change may revert back successes of
1805 controlling infectious diseases” with “consensus among scientists that there has been a rise
1806 in zoonotic diseases - Nipah, Ebola, Zika, Corona viruses - in recent decades ... driven by
1807 biodiversity loss and climate change”.³¹⁴ As this last comment indicates, climate change and
1808 environmental change are often linked together; scientific reports (including the *Lancet*
1809 Countdown reports) are cited as evidence that “we are close to running out of time —
1810 approaching a point of no return for human health, which depends on planetary health” (*New*
1811 *York Times*, 28 April).³¹⁵

1812

1813 [Indicator 5.2: Individual Engagement in Health and Climate Change](#)

1814 *Headline finding: individual information-seeking about health and climate change decreased*
1815 *overall by 15% from 2019 to 2020; spikes in engagement in mid-2020 were almost exclusively*
1816 *due to interest in pandemic-related content*

1817 Individual engagement in climate change and health is tracked through the digital footprint
1818 of users of the online encyclopaedia, Wikipedia. Wikipedia has outpaced traditional
1819 encyclopaedias in terms of reach, coverage, and comprehensiveness and is one of the most-
1820 visited websites worldwide.^{292,316,317} The analysis is based on the English-language Wikipedia
1821 which represents around 50% of global traffic to all Wikipedia language editions.^{318,319}

1822 The indicator focuses on ‘clickstream’ activity, where an individual clicks between an article
1823 on health and climate change (or vice versa). Because clickstream activity captures only pairs
1824 of sequential visits, for the 2021 report, the set of articles was extended to include a wider
1825 range of health and climate change articles. In 2020, as in previous years, individuals seldom
1826 moved between health and climate change; instead, co-click activity was predominantly
1827 within the set of articles on health or climate change.

1828 Figure 25 tracks co-click activity from 2018 to 2020, looking separately at the volume
1829 generated by clicks on a climate-related link in a health-related page, vice versa, and the sum
1830 of both. Overall numbers are very low, confirming that engagement in either climate change
1831 or health rarely triggers engagement in the other topic. Further, the volume of health-climate
1832 co-views fell in 2020 by 15%, reversing the upward trend evident in 2019. When co-clicks to

an article relating to COVID-19 are excluded, the downward trend in 2020 becomes even more pronounced. The spike in co-clicks in mid-2020 was almost exclusively due to interest in pandemic-related content, which then sparked interest in climate change, whereas the rise over September/October was generated by an initial interest in climate change.

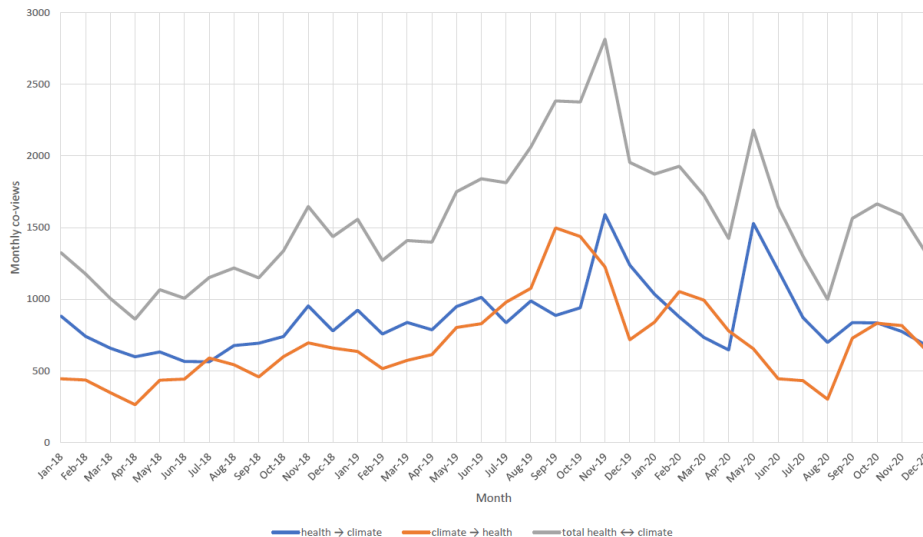


Figure 25. Aggregate monthly co-clicks on Wikipedia articles related to human health and climate change, 2018–2020. Blue: co-click from health-related page to climate-related page. Orange: co-click from climate-related page to health-related page. Grey: sum of all health and climate co-click activity.

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

Headline finding: original research on health and climate change increased eleven-fold between 2007 and 2020, driven primarily by scientists in countries of the highest Human Development Index levels. Gender remained marginal to research on health and climate change across the period. In 2020, 7% of health and climate change articles referred to COVID-19

Scientific evidence is a key resource for the media, individuals and governments, and is playing a critical role shaping public and political engagement in health and climate change.^{294,320} The indicator is based on searches in OVID Medline and OVID Embase, using references to health and climate change in article titles and abstracts, with methods and further analyses provided in the appendix (pp 218-231).

The upward trend in scientific engagement in health and climate change noted in previous *Lancet* Countdown reports has been maintained, with the number of articles on health and climate change increasing by 28% between 2019 and 2020, to reach its highest recorded level

of 858 articles. The trend is driven by the rapid increase in original research (primary studies and systematic reviews), which increased by 32% between 2019 and 2020. Research-related articles (e.g. evidence reviews, editorials, letters) also increased, but at a lower rate.

Increasing scientific engagement in health and climate change is driven by very high HDI countries (Figure 26); 76% of the total output in 2020 was led by researchers in this group. In contrast, scientists in low HDI countries were lead authors of just 1% of journal articles.

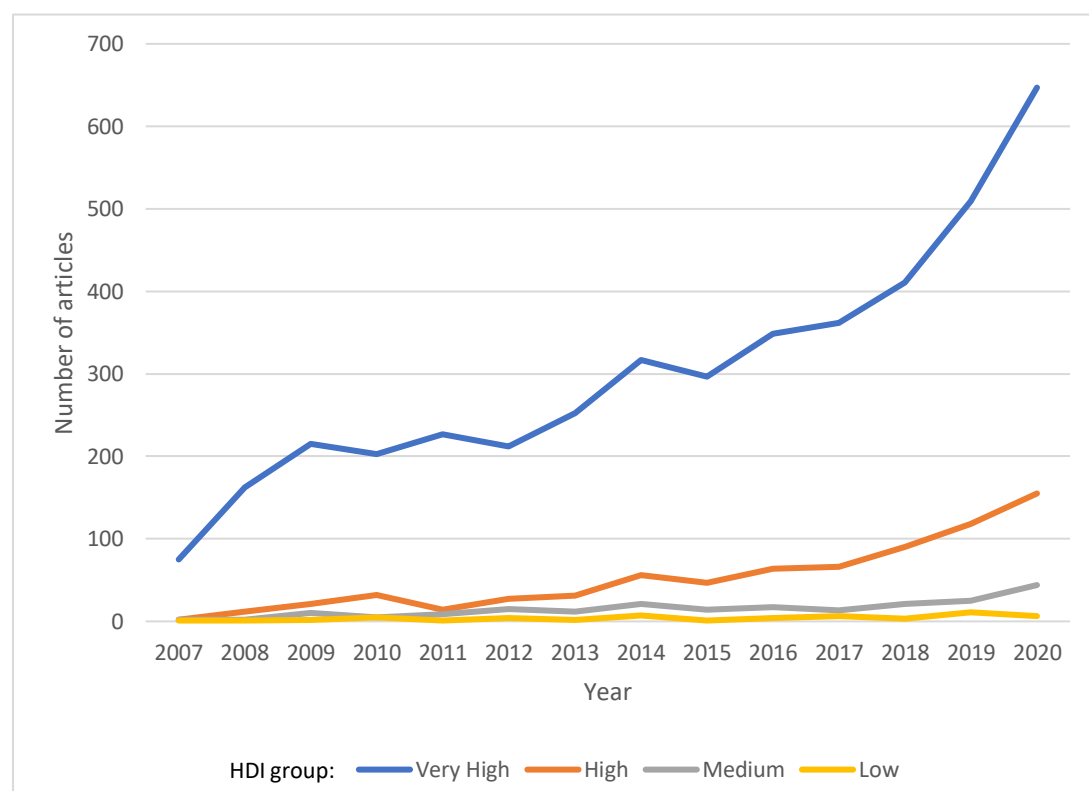


Figure 26. Scientific journal articles relating to health and climate change, 2007-2020, by 2019 country Human Development Index country group

In 2007/08, under 2% of health and climate change articles engaged with gender in some way; in 2020, the proportion was 6%. Similarly, 2020, only 7% of the articles on health and climate change addressed COVID-19, suggesting this rise in scientific research in health and climate change is independent of the concurrent global health crisis. Articles engaging with gender and with COVID-19 were predominantly led by scientists in the very high HDI countries.

1874 Indicator 5.4: Government Engagement in Health and Climate Change

1875 *Headline finding: in 2020, 47% of government leaders engaged with the health dimensions of*
1876 *climate change in their statements at the UN General Debate, more than double the*
1877 *proportion in 2019. The increase was linked to engagement with the COVID-19 pandemic*

1878 Government leadership, backed by strong near-term policies, is required if the increase in
1879 global temperature is to be halted.¹⁶ This indicator examines government engagement with
1880 health and climate change in the UN General Debate (UNGD). Engagement with health in
1881 commitments to emissions reduction made by governments under the 2015 Paris Agreement
1882 is also considered in panel 6.

1883 The UNGD opens each new session of the UN General Assembly. It provides all UN member
1884 states with an opportunity to address the global community on priorities for action. Among
1885 many global challenges, including economic recession and social conflict, the indicator
1886 captures whether government leaders draw attention to health and climate change. Analysis
1887 is based on the application of a key word search in the United Nations General Debate corpus
1888 using natural language processing,^{321,322} with 8,288 statements analysed across 1970-2020.

1889 Figure 27 tracks the proportion of countries referring to health and climate change in their
1890 UNGD statements between 1970 and 2020. In 2020, the proportion of countries engaging
1891 with the health dimensions of climate change reached the highest recorded level, increasing
1892 from 22% (43 countries) in 2019 to 47% (91 countries) in 2020. Additionally, and for the first
1893 time in the UNGD, every member state referred to health in their 2020 address – a reflection
1894 of the ongoing global pandemic.

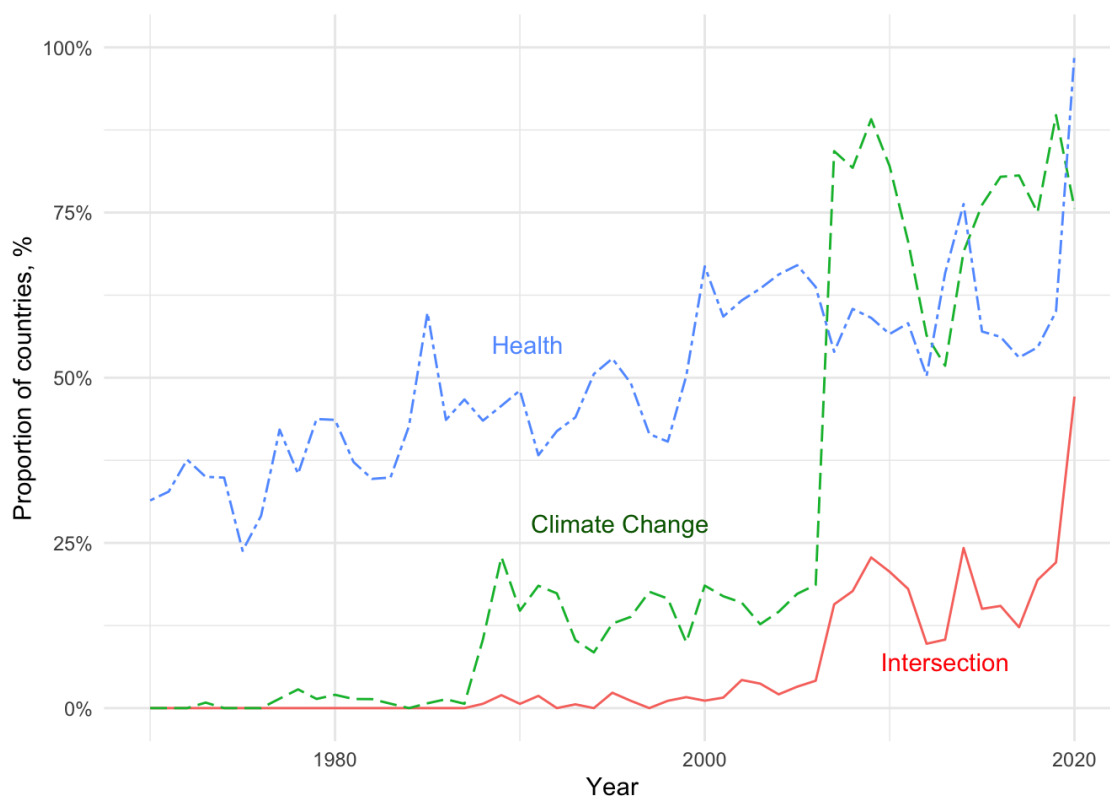


Figure 27. Proportion of countries referring to climate change, health, and the intersection between the two in their UNGD statements, 1970-2020

Increased engagement in health and climate change is linked to discussion of the COVID-19 pandemic, represented by government leaders as both a threat and an opportunity. The pandemic highlights “the vulnerabilities of our societies [to]...global disasters...lurking just around the corner... [like] climate change” (Austria). It also presents an opportunity to tackle the climate crisis: “our recovery from this pandemic must mark a transition to a decarbonized, climate-resilient economic system” (Fiji).

Engagement in health and climate change continues to be led by countries in the low HDI group and, in particular, by the SIDS.^{299,300} For the SIDS, COVID-19 has amplified the risks of climate change: “our unique circumstances and consequent vulnerabilities have left us exposed to the ravages of the twin crises of the pandemic and climate change” (St Lucia). In 2020, 75% of the SIDS discussed health and climate change in the 2020 UNGD. However, 2020 also saw greater engagement among higher-income countries. A key issue is whether this pandemic-related increase in engagement among richer countries will be maintained in future years.

=====

Panel 6: The place of health in the enhanced NDCs

1915 The 2015 Paris Agreement is the only global framework for reducing greenhouse gas emissions to protect
 1916 people's health.¹ Countries committed to emissions reductions via Nationally Determined Contributions (NDCs),
 1917 to be enhanced every five years. In 2015/16, 185 countries, including an EU submission for 27 countries,
 1918 submitted initial NDCs. By July 2021, 87 countries, including an EU submission for 26 countries, had submitted
 1919 enhanced or new NDCs.³²³

1920 Compared with their initial NDCs, the proportion of countries referring to health increased, from 56% (49) to
 1921 91% (79). However, health engagement remained low. Overall, in both initial and enhanced NDCs, under 3% of
 1922 the text related to health; in the enhanced NDCs, this represented an average of 240 of 10466 words. Of the
 1923 references to health, 30% (249 references) noted health impacts, challenges or risks; for example, "the Kenyan
 1924 economy is dependent on climate-sensitive sectors, such as rain-fed agriculture, water, energy, tourism, wildlife,
 1925 and health, whose vulnerability is increased by climate change" (Kenya, updated submission). A further 25%
 1926 (210) related to health sector adaptation; for example, climate change "threatens the ability of health
 1927 institutions and organizations to maintain and improve health services into the future" (Marshall Islands, second
 1928 submission).

1929 The enhanced NDCs demonstrate an increased engagement with gender, health, and climate change with 9
 1930 (10%) NDCs making a meaningful connection compared with just 2 (2%) in their initial contributions. The
 1931 majority of these are references to the specific impact of climate change on women; for example, "further strain
 1932 on the workload of women and climate change related stress during pregnancy could contribute to low birth
 1933 weight, leading to increases in risks of undernutrition and non-communicable diseases" (Cambodia, updated
 1934 submission).

1935 In summary, while health engagement remains low, there is greater recognition that climate change takes a
 1936 disproportionate toll on women.

1937 Indicator 5.5: Corporate Sector Engagement in Health and Climate change

1938 *Headline finding: in 2020, engagement in health and climate change increased to its highest*
1939 *level among companies in the UN Global Compact. Over a third (38%) of companies referred*
1940 *to the health dimensions of climate change in their 2020 progress reports*

1941 The indicator tracks engagement in health and climate change among companies signed up
1942 to the UN Global Compact, established to promote corporate social and environmental
1943 responsibility,³⁰⁴ although its effectiveness has been critiqued, with the suggestion that
1944 membership could be a form of ‘greenwashing’ and ‘bluewashing’ for some companies.³²⁴
1945 The Compact represents over 12,000 companies from 160 countries, with each submitting an
1946 annual Communication on Progress (GCCOP) against a set of social and environmental
1947 principles.

1948 The indicator is based on the application of a key word search in the text corpus of 17,984
1949 GCCOP reports submitted in English between 2011 and 2020.³⁰⁴ In the 2019 and 2020 *Lancet*
1950 Countdown reports, the focus was on the healthcare sector. This report considers corporate
1951 engagement across all sectors.

1952 Figure 28 tracks engagement in health and climate change in annual GCCOP reports from
1953 2011 to 2020. As it indicates, the large majority of reports refer to health (84% of 2020 reports
1954 in 2020) and climate change (75%) as separate topics. In contrast, only a minority made
1955 reference to the health dimensions of climate change (38% in 2020). However, it represents
1956 a large increase from 2014, the low point of engagement, when only 21% of corporations
1957 made reference to the intersection between climate change and health. Three sectors stand
1958 out for their high levels of engagement in health and climate change: food and drug retailers,
1959 oil and gas producers, and alternative energy. In 2020, over 70% of corporations in these
1960 sectors made reference to health and climate change; in the healthcare sector, the proportion
1961 was only 37%.

1962 Additional analyses examined references to gender in the GCCOP reports engaging with
1963 health and climate change. Only a minority additionally referred to gender. However, the
1964 proportion increased from 2014 to 2019, with a particularly sharp rise (to 19%) in the 2019
1965 report. In 2020, gender engagement fell to 13% (see appendix pp 249-264).

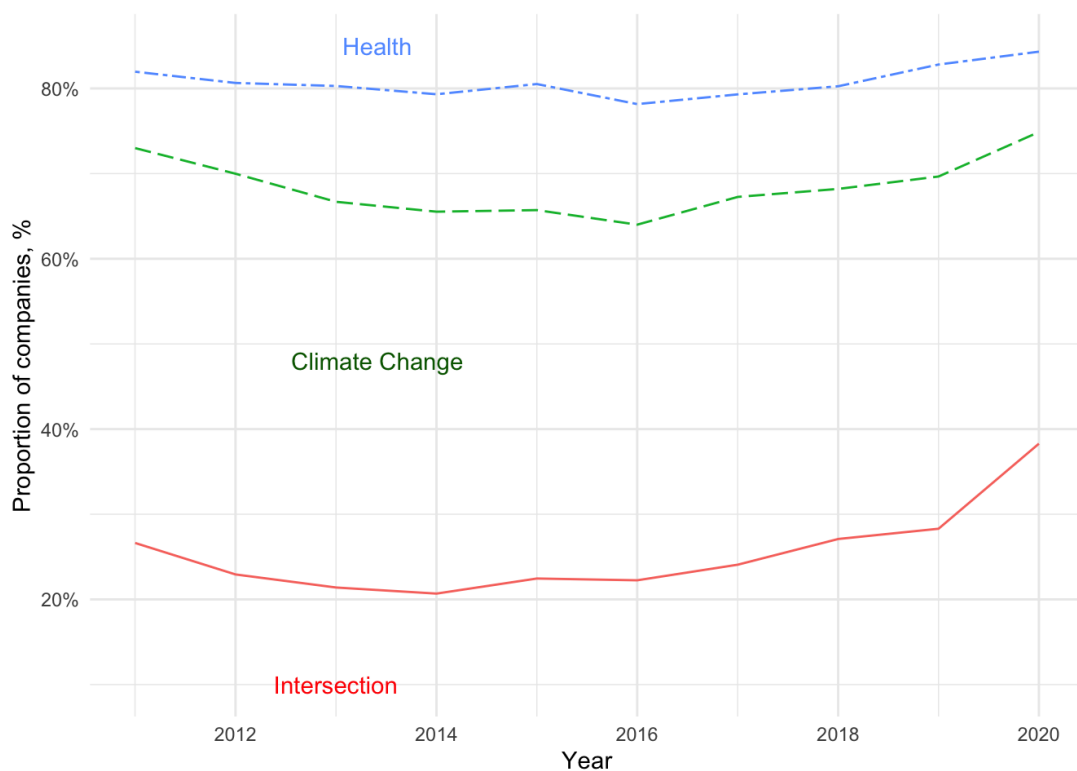


Figure 28. Proportion of companies referring to climate change, health, and the intersection of health and climate change in their UN Global Compact Communication on Progress (GCCOP) reports, 2011-2020.

Conclusion

Public and political engagement is essential if the ambitions of the Paris Agreement are to be realised.¹⁶ Section 5 has focused on five areas of engagement: the media, the public, the scientific community, national government and the corporate sector. Three conclusions can be drawn.

Firstly, health and climate change are increasingly addressed together. The trend is particularly pronounced for indicators relating to the media, science, government and the corporate sector. In all these areas, engagement with health and climate change reached its highest recorded level in 2020. Gender is rarely integrated into engagement within the health-climate change nexus, although there is increased recognition in countries' enhanced NDCs.

Secondly, the COVID-19 pandemic appears to be a major driver of engagement in 2020. For example, over half of newspaper coverage of health and climate change was linked to COVID-19 and individual engagement in health and climate change was largely sustained by searches for articles related to COVID-19. Government engagement in the health dimensions of climate

1986 change was similarly underpinned by engagement in the pandemic. It remains to be seen if
1987 the heightened engagement in health and climate change will be maintained if and when the
1988 pandemic-related crises are contained.

1989 Thirdly, social inequities remain deeply etched into public and political engagement. In the
1990 media and in science, coverage of health and climate change engagement is greatest in the
1991 very high HDI countries, the group exerting the greatest pressure on the planet but relatively
1992 protected from the health impacts of climate change. Meanwhile, medium and low HDI
1993 countries have much smaller carbon and environmental footprints – yet, are shouldering the
1994 immediate burden of climate change, and are far less represented in the scientific literature.
1995 As in previous years, the SIDS are leading global engagement with the health impacts of
1996 climate change at the UN General Debate. What is required is for their leadership to be
1997 matched by a decisive break with ‘business as usual’ by countries and communities
1998 contributing most to climate change.

1999 Conclusion: the 2021 Report of the *Lancet* Countdown

2000 The 2021 report of the *Lancet* Countdown finds a world overwhelmed by an ongoing global
2001 health crisis, while it has made little progress to protect its population from the
2002 simultaneously aggravated health impacts of climate change. The inequities of these impacts
2003 and the response, including those of gender, are brought into sharp focus within each of the
2004 indicators presented. This exposes the urgent need for collection of standardised data to
2005 capture inequities and vulnerabilities (panel 2).

2006 Climate-sensitive infectious diseases are of increasing global concern and the environmental
2007 suitability for the transmission of all infectious diseases tracked is rising (indicator 1.3.1). For
2008 non-cholerae *Vibrio* bacteria, the environmental suitability for transmission in northern
2009 latitudes increased by 56% since the 1980s. The number of months suitable for malaria
2010 transmission has increased by 39% in highland areas of the low HDI country group and, over
2011 the past 5 years, the environmental suitability for the transmission of emerging arboviruses
2012 – dengue, chikungunya and Zika – was between 7% and 13% higher than in the 1950s.

2013 The high temperatures in 2020, a year that tied with 2016 as the hottest year on record,
2014 resulted in extreme heat-related health impacts, affecting the emotional and physical
2015 wellbeing of populations around the world (indicators 1.1.1-1.1.6). These higher
2016 temperatures and altered weather patterns are also leading to more frequent extreme
2017 weather events and increased wildfire exposure (indicators 1.2.1, 1.2.2 and 1.2.3), and are
2018 putting years of progress on food and water security at risk in many parts of the world. The
2019 five years with the greatest area of the world's surface affected by droughts have all occurred
2020 since 2015 (indicator 1.2.2), the yield potential of all major staple crops continues to fall as a
2021 result of the rising temperatures (indicator 1.4.1), and 79% of all potential work hours lost to
2022 extreme heat in low HDI countries occurred in the agricultural sector in 2020 (indicator 1.1.4).

2023 However, measures to curb emissions have been grossly inadequate. Emissions are declining
2024 too slowly or heading in the wrong direction in the highest emitting sectors (indicators 3.1,
2025 3.4 and 3.5.1). This delay in progress is contributing to millions of deaths each year due to
2026 exposure to indoor and ambient PM_{2.5} pollution, and due to high-carbon, unhealthy diets
2027 (indicators 3.2, 3.3 and 3.5.2). Importantly, these impacts manifest differently between HDI
2028 country groups and genders, underscoring profound inequities.

2029 Despite years of scientific reporting on climate change impacts, efforts to build resilience have
2030 been slow and unequal, with countries of low levels of Human Development Index the least
2031 prepared to respond to the changing health profile of climate change, and funding remaining
2032 a consistent challenge (indicators 2.1.1, 2.3.1, and 2.4). At the same time, 65 out of 84
2033 countries reviewed continue to provide subsidies for fossil fuels that outweigh any revenue

2034 received from carbon pricing instruments. The resulting ‘net carbon subsidy’ is in many cases
2035 equivalent to substantial proportions of countries’ national health budgets (indicator 4.2.4).

2036 Governments with the fiscal capacity have responded to the COVID-19 pandemic with
2037 massive spending packages, to cushion the impacts of the crisis and start to bring about
2038 economic recovery. But as the world approaches COP26, the response to climate change, and
2039 commensurate investment, remains inadequate. The opportunity for the green recovery is in
2040 danger of being missed. A fossil-fuel driven recovery, whilst potentially meeting narrow and
2041 near-term economic targets, could push the world irrevocably off course for the ambitions of
2042 the Paris Agreement, with enormous costs to human health.

2043 With government leaders more engaged with the health dimensions of climate change than
2044 ever before (indicator 5.4), countries across the globe must pursue low carbon economic
2045 recovery pathways, implementing policies that reduce inequities and improve human health.
2046 The *Lancet* Countdown indicators show the evidence to support the urgency and opportunity
2047 of this transition, and that none of us is safe until everyone is safe.

2048

2049 Contributors

2050 The Lancet Countdown and the work for this paper was conducted by five working groups,
2051 which were responsible for the design, drafting, and review of their individual indicators and
2052 sections. All authors contributed to the overall paper structure and concepts, and provided
2053 input and expertise to the relevant sections.

2054 ER, CDN, NA, SA-K, JC, LC, SD, LEE, SHG, IK, TK, DK, BL, JKWL, YL, ZL, RL, JM-U, CM, KMi, MM-
2055 L, KAM, NO, MO, FO, MRa, JCS, LS, MT, JTr, BV, and MY contributed to Working Group 1. KLE,
2056 MN, LJ, DC-L, RD, LG, DG, CH, JH, MPJ, PLK, MM, KMo, TN, MOS, JR, and JS-G contributed to
2057 Working Group 2. TO, IH, HK, KB, CD, MD, PD-S, ME, SH, S-CH, GK, ML, NM, JM, DP, JS, MS,
2058 JTa, PW, and MW contributed to Working Group 3. PE, PD, NH, BSR, WC, KH, ZM, FW, and SZ
2059 contributed to Working Group 4. HG, PL, WC, SC, ND, SJ, LM, SM, and OP contributed to
2060 Working Group 5. AC, HM, PG, IH, MRo, AM and RS provided coordination, strategic direction,
2061 and editorial support.

2062 Declaration of interest

2063 We declare no competing interests.

2064 Acknowledgements

2065 We thank the Wellcome Trust, in particular Madeleine Thomson and Lukasz Aleksandrowicz,
2066 for financial and strategic support, without which this research collaboration would not be
2067 possible.

2068 The Lancet Countdown's work is supported by an unrestricted grant from the Wellcome Trust
2069 (grant number 209734/Z/17/Z). 10 of the authors (IH, MRo, AM, CDN, LJ, HK, PD, NH, BSR, PL)
2070 were compensated for their time while working on the drafting and development of the
2071 Lancet Countdown's report.

2072 The work of CH is supported by a NERC fellowship (grant number NE/R01440X/1) and funding
2073 from the Wellcome Trust HEROIC project (grant number 216035/Z/19/Z). The work of CD was
2074 supported by the UK Natural Environment Research Council Independent Research
2075 Fellowship (grant number NE/N01524X/1) and contributes to the Sustainable and Healthy
2076 Food Systems (SHEFS) project supported by the Wellcome Trust (grant number
2077 205200/Z/16/Z). The work of MD was supported by the Wellcome Trust's Complex Urban
2078 Systems for Sustainability and Health (CUSSH) project (grant number 209387/Z/17/Z). The
2079 work of TO was supported by the Engineering and Physical Sciences Research Council Centre
2080 for Research in Energy Demand Solutions (grant number EP/R035288/1). The work of YL, LS,
2081 and BV was supported by the NASA Applied Sciences Program, managed by J. Haynes (grant
2082 number 80NSSC21K0507). RL was supported by a Royal Society Dorothy Hodgkin Fellowship.
2083 The work of JR and MOS was supported by the Swedish Research Council Formas (grant
2084 number 2018–01754 and 2017–01300). The work of MW was supported by the UK Energy
2085 Research Centre research programme which is funded by the UK Research and Innovation
2086 Energy Programme (grant number EP/S029575/1). The work of SHG and JKWL was supported
2087 by the National Research Foundation, Prime Minister's Office, Singapore under its Campus
2088 for Research Excellence and Technological Enterprise (CREATE) programme, and a research
2089 grant from the NUS Initiative to Improve Health in Asia (NIHA) coordinated by the Global Asia
2090 Institute of the National University of Singapore and supported by the Glaxo Smith Kline-
2091 Economic Development Board (Singapore) Trust Fund. Any opinions, findings and conclusions
2092 or recommendations expressed in this material are those of the authors and do not reflect
2093 the views of the National University of Singapore, Singapore or the National Research
2094 Foundation, Singapore.

2095 While carrying out its work, The Lancet Countdown received invaluable technical advice and
2096 input from several individuals, including Heather Adair-Rohani, Miguel Gomez-Escolar Viejo
2097 and Jessica Lewis (World Health Organization, Geneva, Switzerland), Ginette Azcona, Antra
2098 Bhatt, and Sara Duerto Valero (UN Women), Simon Bennett, Chiara Delmastro, Ryszard
2099 Pospiech, and Michael Waldron (International Energy Agency, Paris, France), Peter James and
2100 Catherine Ngo (Harvard University, Boston, MA, USA), Sebastian Ramirez Ruiz (Hertie School,
2101 Berlin, Germany), Nicholas Goh (National University of Singapore, Singapore), Kaixin Huang
2102 (Northeastern University, Boston, MA, USA), Kai Chen and Amy Darefsky (Yale University, New

2103 Haven, CT, USA). Policy and communications advice was given by Emma-Louise Frost, Frances
2104 MacGuire, and Kim van Daalen (the Lancet Countdown).
2105

References

1. UNFCCC. Paris Agreement. 2015.
2. Johns Hopkins Center for Systems Science and Engineering. COVID-19 Dashboard. 2021. <https://www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6> (accessed 7 April 2021).
3. Office for National Statistics. Comparisons of all-cause mortality between European countries and regions: 2020. 2021. <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/article/s/comparisonsofallcausemortalitybetweeneuropeancountriesandregions/2020> (accessed 9 April 2021).
4. Independent Panel for Pandemic Preparedness and Response. Second report on progress, 2021.
5. British Columbia Government News. Chief coroner's updated statement on public safety during heat wave. Friday, July 2, 2021. <https://news.gov.bc.ca/releases/2021PSSG0062-001295#:~:text=Lisa%20Lapointe%2C%20chief%20coroner%2C%20has,heat%20wave%20in%20British%20Columbia%3A&text=%E2%80%9CWe%20are%20releasing%20this%20information,the%20increased%20number%20of%20deaths.>
6. Philip SY, Kew SF, van Oldenborgh GJ, et al. Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021, 2021.
7. Weichel A. Number of deaths recorded during B.C.'s heat wave up to 808, coroners say. 2021. <https://bc.ctvnews.ca/number-of-deaths-recorded-during-b-c-s-heat-wave-up-to-808-coroners-say-1.5512723> (accessed 19 July 2021).
8. Bekiempis V. Record-breaking US Pacific north-west heatwave killed almost 200 people. 2021. <https://www.theguardian.com/us-news/2021/jul/08/pacific-northwest-heatwave-deaths> (accessed 19 July 2021).
9. UNDP. Human Development Report 2020 - The Next Frontier: Human Development and the Anthropocene. 2020. <https://report.hdr.undp.org/> (accessed March 21 2021).
10. Mbow CR, L. Barioni, T. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M. Rivera-, Ferre TS, F. Tubiello, and Y. Xu, . Food security. In: Change IPoC, ed. Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. London: Working Group III Technical Support Unit; 2019.
11. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. *Ann N Y Acad Sci* 2019; **1436**(1): 157-73.
12. Semenza JC, Herbst S, Rechenburg A, et al. Climate Change Impact Assessment of Food- and Waterborne Diseases. *Crit Rev Environ Sci Technol* 2012; **42**(8): 857-90.
13. Ali M, Nelson AR, Lopez AL, Sack DA. Updated global burden of cholera in endemic countries. *PLoS neglected tropical diseases* 2015; **9**(6): e0003832.
14. Adhanom Ghebreyesus T. Director-General's opening remarks at the World Health Assembly - 24 May 2021. 2021. <https://www.who.int/director-general/speeches/detail/director-general-s-opening-remarks-at-the-world-health-assembly---24-may-2021> (accessed 1 July 2021).
15. Pörtner H, Roberts D, Masson-Delmotte V, et al. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. *IPCC Intergovernmental Panel on Climate Change: Geneva, Switzerland* 2019.
16. UNEP, UNEP DTU Partnership. Emissions Gap Report 2020. 2020. <https://www.unep.org/emissions-gap-report-2020>.
17. Hajat A, Hsia C, O'Neill MS. Socioeconomic Disparities and Air Pollution Exposure: a Global Review. *Current environmental health reports* 2015; **2**(4): 440-50.

18. Fairburn J, Schüle SA, Dreger S, Karla Hilz L, Bolte G. Social Inequalities in Exposure to Ambient Air Pollution: A Systematic Review in the WHO European Region. *International journal of environmental research and public health* 2019; **16**(17): 3127.
19. Climate Action Tracker. Temperature. 2021. <https://climateactiontracker.org/global/temperatures/> (accessed July 6, 2021).
20. OECD. Building back better: A sustainable, resilient recovery after COVID-19. 2020.
21. Shan Y, Ou J, Wang D, et al. Impacts of COVID-19 and fiscal stimuli on global emissions and the Paris Agreement. *Nature Climate Change* 2021; **11**(3): 200-6.
22. IEA. Global Energy Review 2021. Paris, France: IEA, 2021.
23. Independent Expert Group On Climate Finance. Delivering On The \$100 Billion Climate Finance Commitment And Transforming Climate Finance 2020.
24. OECD. The impact of the coronavirus (COVID-19) crisis on development finance. 2020.
25. Dibley A, Wetzer T, Hepburn C. National COVID debts: climate change imperils countries' ability to repay. *Nature* 2021; **592**(7853): 184-7.
26. Stiglitz J, Rashid H. Averting Catastrophic Debt Crises in Developing Countries. Extraordinary challenges call for extraordinary measures: Centre for Economic Policy and Research, 2020.
27. World Health Organization. WHO Manifesto for a healthy recovery from COVID-19. 2020. <https://www.who.int/news-room/feature-stories/detail/who-manifesto-for-a-healthy-recovery-from-covid-19> (accessed May 19, 2021).
28. Hamilton I, Kennard H, McGushin A, et al. The public health implications of the Paris Agreement: a modelling study. *The Lancet Planetary Health* 2021; **5**(2): e74-e83.
29. WHO. Pulse survey on continuity of essential health services during the COVID-19 pandemic: interim report. Geneva, Switzerland: World Health Organization, 2020.
30. International Monetary Fund. World Economic Outlook Update January 2021. Washington, DC, USA: International Monetary Fund, 2021.
31. World Bank. Poverty and Shared Prosperity 2020: Reversals of Fortune. Washington, DC, USA: World Bank, 2020.
32. McCarthy M, Christidis N, Stott P, Kaye N. Met Office: A review of the UK's climate in 2020. 2021. <https://www.carbonbrief.org/met-office-a-review-of-the-uks-climate-in-2020> (accessed 8 April 2021).
33. Stuart-Smith RF, Roe GH, Li S, Allen MR. Increased outburst flood hazard from Lake Palcacocha due to human-induced glacier retreat. *Nature Geoscience* 2021; **14**(2): 85-90.
34. van Oldenborgh GJ, Kriken 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.
35. Ciavarella A, Cotterill D, Stott P, et al. Siberian heatwave of 2020 almost impossible without climate change. 2020. <https://www.worldweatherattribution.org/siberian-heatwave-of-2020-almost-impossible-without-climate-change/> (accessed 8 April 2021).
36. Walton D, van Aalst M. Climate-related extreme weather events and COVID-19. A first look at the number of people affected by intersecting disasters. Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies, 2020.
37. IPCC. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change. Geneva, Switzerland: World Meteorological Organization, 2018.
38. Levy BS, Patz JA. Climate Change, Human Rights, and Social Justice. *Ann Glob Health* 2015; **81**(3): 310-22.
39. GISTEMP Team. GISS Surface Temperature Analysis (GISTEMP), version 4. 2021. <https://data.giss.nasa.gov/gistemp/> (accessed 7 April 2021).

2202 40. Lenssen NJL, Schmidt GA, Hansen JE, et al. Improvements in the GISTEMP Uncertainty Model.
2203 *Journal of Geophysical Research: Atmospheres* 2019; **124**(12): 6307-26.

2204 41. NOAA. More Near-Record Warm Years Are Likely On Horizon. 2021.
2205 <https://www.ncei.noaa.gov/news/projected-ranks> (accessed May 11, 2021).

2206 42. Met Office. Mauna Loa carbon dioxide forecast for 2021. 2021.
2207 [https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/forecasts/co2-](https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/forecasts/co2-forecast-for-2021)
2208 [forecast-for-2021](https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/forecasts/co2-forecast-for-2021) (accessed 7 April 2021).

2209 43. Green JK, Seneviratne SI, Berg AM, et al. Large influence of soil moisture on long-term
2210 terrestrial carbon uptake. *Nature* 2019; **565**(7740): 476-9.

2211 44. Lenton TM, Rockström J, Gaffney O, et al. Climate tipping points—too risky to bet against.
2212 Nature Publishing Group; 2019.

2213 45. Wunderling N, Donges JF, Kurths J, Winkelmann R. Interacting tipping elements increase risk
2214 of climate domino effects under global warming. *Earth Syst Dynam* 2021; **12**(2): 601-19.

2215 46. Le Quéré C, Jackson RB, Jones MW, et al. Temporary reduction in daily global CO2 emissions
2216 during the COVID-19 forced confinement. *Nature Climate Change* 2020.

2217 47. Friedlingstein P, O'Sullivan M, Jones MW, et al. Global carbon budget 2020. *Earth System*
2218 *Science Data* 2020; **12**(4): 3269-340.

2219 48. Climate Action Tracker. Global Update: Climate Summit Momentum. 2021.
2220 <https://climateactiontracker.org/publications/global-update-climate-summit-momentum/> (accessed
2221 7 May 2021).

2222 49. Watts N, Adger WN, Ayeb-Karlsson S, et al. The Lancet Countdown: tracking progress on
2223 health and climate change. *The Lancet* 2017; **389**(10074): 1151-64.

2224 50. Beggs PJ, Zhang Y, McGushin A. The 2021 report of the MJA-Lancet Countdown on health and
2225 climate change: Australia increasingly out on a limb. *Medical Journal of Australia* 2021 **In Press**.

2226 51. Cai W, Zhang C, Zhang S. The 2021 China Report of the Lancet Countdown on Health and
2227 Climate Change: Seizing the window of opportunity. *The Lancet Public Health* 2021; **In Press**.

2228 52. Allen C, West R, Beagley J, McGushin A. Climate Change and Health in Small Island Developing
2229 States. London, UK The Lancet Countdown: Tracking Progress on Health and Climate Change,
2230 2021.

2231 53. IPCC. Climate Change 2014. Impacts, Adaptation, and Vulnerability. Working Group II
2232 Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
2233 Cambridge and New York, 2014.

2234 54. Watts N, Amann M, Arnell N, et al. The 2020 report of The *Lancet* Countdown on health and
2235 climate change: responding to converging crises. *The Lancet* 2021; **397**(10269): 129-70.

2236 55. Hayward G, Ayeb-Karlsson S. 'Seeing with Empty Eyes': a systems approach to understand
2237 climate change and mental health in Bangladesh. *Climatic Change* 2021; **165**(1): 29.

2238 56. Kelman I, Ayeb-Karlsson S, Rose-Clarke K, et al. A review of mental health and wellbeing under
2239 climate change in small island developing states (SIDS). *Environmental Research Letters* 2021; **16**(3):
2240 033007.

2241 57. Position Statement PS03/21: Our planet's climate and ecological emergency: Royal College of
2242 Psychiatrists, 2021.

2243 58. Gopalkrishnan N. Cultural diversity and mental health: Considerations for policy and practice.
2244 *Frontiers in public health* 2018; **6**: 179.

2245 59. Li M, Gu S, Bi P, Yang J, Liu Q. Heat Waves and Morbidity: Current Knowledge and Further
2246 Direction-A Comprehensive Literature Review. *International Journal of Environmental Research and*
2247 *Public Health* 2015; **12**(5): 5256-83.

2248 60. Kovats RS, Hajat S. Heat Stress and Public Health: A Critical Review. *Annu Rev Public Health*
2249 2008; **29**(1): 41-55.

- 2250 61. Basu R. Relation between Elevated Ambient Temperature and Mortality: A Review of the
2251 Epidemiologic Evidence. *Epidemiologic Reviews* 2002; **24**(2): 190-202.
- 2252 62. Schmeltz M, Petkova E, Gamble J. Economic Burden of Hospitalizations for Heat-Related
2253 Illnesses in the United States, 2001–2010. *International Journal of Environmental Research and Public
2254 Health* 2016; **13**(9): 894.
- 2255 63. Hansen A, Bi L, Saniotis A, Nitschke M. Vulnerability to extreme heat and climate change: is
2256 ethnicity a factor? *Global Health Action* 2013; **6**(1): 21364.
- 2257 64. Chambers J. Global and cross-country analysis of exposure of vulnerable populations to
2258 heatwaves from 1980 to 2018. *Climatic Change* 2020; **163**(1): 539-58.
- 2259 65. Bassil KL, Cole DC. Effectiveness of public health interventions in reducing morbidity and
2260 mortality during heat episodes: a structured review. *International Journal of Environmental Research
2261 and Public Health* 2010; **7**(3): 991-1001.
- 2262 66. WHO. Heat and Health. 2018. [https://www.who.int/news-room/fact-sheets/detail/climate-
2263 change-heat-and-health](https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health) (accessed 17 April 2021).
- 2264 67. WMO Catalogue of Major Meteorological Hazards. Available at
2265 <http://puslitbang.bmkg.go.id/litbang/wmo-catalogue-of-major-meteorological-hazards/>. 2021.
- 2266 68. de Perez EC, van Aalst M, Bischiniotis K, et al. Global predictability of temperature extremes.
2267 *Environmental Research Letters* 2018; **13**(5).
- 2268 69. Di Napoli C, Pappenberger F, Cloke HL. Verification of Heat Stress Thresholds for a Health-
2269 Based Heat-Wave Definition. *Journal of Applied Meteorology and Climatology* 2019; **58**(6): 1177-94.
- 2270 70. Arem H, Moore SC, Patel A, et al. Leisure Time Physical Activity and Mortality: A Detailed
2271 Pooled Analysis of the Dose-Response Relationship. *JAMA Internal Medicine* 2015; **175**(6): 959-67.
- 2272 71. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence.
2273 *Canadian Medical Association Journal* 2006; **174**(6): 801-9.
- 2274 72. Nuzum H, Stickel A, Corona M, Zeller M, Melrose RJ, Wilkins SS. Potential Benefits of Physical
2275 Activity in MCI and Dementia. *Behavioural Neurology* 2020; **2020**: 7807856.
- 2276 73. Peluso MAM, Andrade LHSGd. Physical activity and mental health: the association between
2277 exercise and mood. *Clinics* 2005; **60**: 61-70.
- 2278 74. Zhang X, Li X, Sun Z, et al. Physical activity and COVID-19: an observational and Mendelian
2279 randomisation study. *Journal of Global Health* 2020; **10**(2).
- 2280 75. An R, Shen J, Li Y, Bandaru S. Projecting the Influence of Global Warming on Physical Activity
2281 Patterns: a Systematic Review. *Current Obesity Reports* 2020; **9**(4): 550-61.
- 2282 76. Heaney AK, Carrión D, Burkart K, Lesk C, Jack D. Climate Change and Physical Activity:
2283 Estimated Impacts of Ambient Temperatures on Bikeshare Usage in New York City. *Environmental
2284 Health Perspectives* 2019; **127**(3): 037002.
- 2285 77. Nazarian N, Liu S, Kohler M, et al. Project Coolbit: can your watch predict heat stress and
2286 thermal comfort sensation? *Environmental Research Letters* 2021; **16**(3): 034031.
- 2287 78. Andrews O, Le Quéré C, Kjellstrom T, Lemke B, Haines A. Implications for workability and
2288 survivability in populations exposed to extreme heat under climate change: a modelling study. *The
2289 Lancet Planetary Health* 2018; **2**(12): e540-e7.
- 2290 79. Armstrong LE, Casa DJ, Millard-Stafford M, Moran DS, Pyne SW, Roberts WO. Exertional Heat
2291 Illness during Training and Competition. *Medicine & Science in Sports & Exercise* 2007; **39**(3): 556-72.
- 2292 80. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers' Association Position
2293 Statement: Exertional Heat Illnesses. *Journal of Athletic Training* 2015; **50**(9): 986-1000.
- 2294 81. Flouris AD, Dinas PC, Ioannou LG, et al. Workers' health and productivity under occupational
2295 heat strain: a systematic review and meta-analysis. *The Lancet Planetary Health* 2018; **2**(12): e521-
2296 e31.

2297 82. International Labour Organization. ILO Monitor: COVID-19 and the world of work. Seventh
2298 edition. Geneva, Switzerland: International Labour Organization, 2021.

2299 83. ILO. Working on a warmer planet: The impact of heat stress on labour productivity and decent
2300 work. Geneva, Switzerland: International Labour Organization, 2019.

2301 84. International Labour Organization. Employment by sex and economic activity — ILO modelled
2302 estimates. 2020.

2303 85. International Labour Organization. Indigenous peoples and climate change: from victims to
2304 change agents through decent work Geneva: ILO, 2017.

2305 86. Obradovich N, Migliorini R, Paulus MP, Rahwan I. Empirical evidence of mental health risks
2306 posed by climate change. *Proc Natl Acad Sci U S A* 2018; **115**(43): 10953-8.

2307 87. Mullins JT, White C. Temperature and mental health: Evidence from the spectrum of mental
2308 health outcomes. *J Health Econ* 2019; **68**: 102240.

2309 88. Burke M, González F, Baylis P, et al. Higher temperatures increase suicide rates in the United
2310 States and Mexico. *Nature Climate Change* 2018; **8**(8): 723-9.

2311 89. Carleton TA. Crop-damaging temperatures increase suicide rates in India. *Proceedings of the
2312 National Academy of Sciences* 2017; **114**(33): 8746-51.

2313 90. Baylis P. Temperature and temperament: Evidence from Twitter. *Journal of Public Economics*
2314 2020; **184**: 104161.

2315 91. Baylis P, Obradovich N, Kryvasheyeu Y, et al. Weather impacts expressed sentiment. *PLoS One*
2316 2018; **13**(4): e0195750.

2317 92. Carleton TA, Hsiang SM. Social and economic impacts of climate. *Science* 2016; **353**(6304):
2318 aad9837.

2319 93. Hersbach H, Bell B, Berrisford P, et al. The ERA5 global reanalysis. *Q J Roy Meteor Soc* 2020;
2320 **146**(730): 1999-2049.

2321 94. Pennebaker JW, Boyd RL, Jordan K, Blackburn K. The development and psychometric
2322 properties of LIWC2015, 2015.

2323 95. Song X, Wang S, Hu Y, et al. Impact of ambient temperature on morbidity and mortality: An
2324 overview of reviews. *Science of The Total Environment* 2017; **586**: 241-54.

2325 96. Honda Y, Kondo M, McGregor G, et al. Heat-related mortality risk model for climate change
2326 impact projection. *Environ Health Prev Med* 2014; **19**(1): 56-63.

2327 97. Guo Y, Gasparrini A, Armstrong BG, et al. Temperature Variability and Mortality: A Multi-
2328 Country Study. *Environ Health Perspect* 2016; **124**(10): 1554-9.

2329 98. Vos T, Lim SS, Abbafati C, et al. Global burden of 369 diseases and injuries in 204 countries
2330 and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The
2331 Lancet* 2020; **396**(10258): 1204-22.

2332 99. Abatzoglou JT, Williams AP, Barbero R. Global Emergence of Anthropogenic Climate Change
2333 in Fire Weather Indices. *Geophysical Research Letters* 2019; **46**(1): 326-36.

2334 100. NASA EarthData. Active Fire Data. Available at [https://earthdata.nasa.gov/earth-observation-
2335 data/near-real-time/firms/active-fire-data](https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data). 2021.

2336 101. NASA Socioeconomic Data and Applications Center (SEDAC) Gridded Population of the World
2337 (GPWv4). Available at <https://beta.sedac.ciesin.columbia.edu/data/collection/gpw-v4>. 2021.

2338 102. Vitolo C, Di Giuseppe F, Barnard C, et al. ERA5-based global meteorological wildfire danger
2339 maps. *Sci Data* 2020; **7**(1): 216.

2340 103. Royal Commission into National Natural Disaster Arrangements. Royal Commission into
2341 National Natural Disaster Arrangements - Report, 2020.

2342 104. Stanke C, Kerac M, Prudhomme C, Medlock J, Murray V. Health effects of drought: a
2343 systematic review of the evidence. *PLoS currents* 2013; **5**.

2344 105. Thomas MA, Lin T. Illustrative Analysis of Probabilistic Sea Level Rise Hazard. *Journal of*
2345 *Climate* 2020; **33**(4): 1523-34.

2346 106. Centre for Research on the Epidemiology of Disasters. EM-DAT The International Disaster
2347 Database. Available at <https://emdat.be/>. 2021.

2348 107. Iwamura T, Guzman-Holst A, Murray KA. Accelerating invasion potential of disease vector
2349 *Aedes aegypti* under climate change. *Nature Communications* 2020; **11**(1): 2130.

2350 108. Ryan SJ, Carlson CJ, Mordecai EA, Johnson LR. Global expansion and redistribution of *Aedes*-
2351 borne virus transmission risk with climate change. *PLOS Neglected Tropical Diseases* 2019; **13**(3):
2352 e0007213.

2353 109. Hagenlocher M, Delmelle E, Casas I, Kienberger S. Assessing socioeconomic vulnerability to
2354 dengue fever in Cali, Colombia: statistical vs expert-based modeling. *International Journal of Health*
2355 *Geographics* 2013; **12**(1): 36.

2356 110. Vincenti-Gonzalez MF, Grillet M-E, Velasco-Salas ZI, et al. Spatial Analysis of Dengue
2357 Seroprevalence and Modeling of Transmission Risk Factors in a Dengue Hyperendemic City of
2358 Venezuela. *PLOS Neglected Tropical Diseases* 2017; **11**(1): e0005317.

2359 111. FAO. The state of food security and nutrition in the world. Rome, Italy: Food and Agriculture
2360 Organization of the United Nations, 2020.

2361 112. Botreau H, Cohen MJ. Gender inequality and food insecurity: A dozen years after the food
2362 price crisis, rural women still bear the brunt of poverty and hunger. *Advances in Food Security and*
2363 *Sustainability* 2020; **5**: 53-117.

2364 113. Craufurd PQ, Wheeler TR. Climate change and the flowering time of annual crops. *Journal of*
2365 *Experimental Botany* 2009; **60**(9): 2529-39.

2366 114. FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome: Food
2367 and Agriculture Organization, 2020.

2368 115. Lynn K, Daigle J, Hoffman J, et al. The impacts of climate change on tribal traditional foods.
2369 *Climatic Change* 2013; **120**(3): 545-56.

2370 116. Allison EH, Perry AL, Badjeck MC, et al. Vulnerability of national economies to the impacts of
2371 climate change on fisheries. *Fish Fish* 2009; **10**(2): 173-96.

2372 117. Barange M, Bahri T, Beveridge MC, Cochrane KL, Funge-Smith S, Poulain F. Impacts of climate
2373 change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation
2374 options: FAO; 2018.

2375 118. FAO. New Food Balance Sheets. Available at <http://www.fao.org/faostat/en/#data/FBS>. 2021.

2376 119. Melet A, Meyssignac B, Almar R, Le Cozannet G. Under-estimated wave contribution to coastal
2377 sea-level rise. *Nature Climate Change* 2018; **8**(3): 234-9.

2378 120. Kirezci E, Young IR, Ranasinghe R, et al. Projections of global-scale extreme sea levels and
2379 resulting episodic coastal flooding over the 21st Century. *Sci Rep* 2020; **10**(1): 11629.

2380 121. Le Bars D, Drijfhout S, de Vries H. A high-end sea level rise probabilistic projection including
2381 rapid Antarctic ice sheet mass loss. *Environmental Research Letters* 2017; **12**(4): 044013.

2382 122. Bakker AMR, Wong TE, Ruckert KL, Keller K. Sea-level projections representing the deeply
2383 uncertain contribution of the West Antarctic ice sheet. *Sci Rep* 2017; **7**(1): 3880.

2384 123. Rose AN, McKee JJ, Sims KM, Bright EA, Reith AE, Urban ML. LandScan 2019. 2019 ed. Oak
2385 Ridge, TN: Oak Ridge National Laboratory; 2020.

2386 124. Kulp SA, Strauss BH. CoastalDEM: a global coastal digital elevation model improved from SRTM
2387 using a neural network. *Remote sensing of environment* 2018; **206**: 231-9.

2388 125. Vineis P, Chan Q, Khan A. Climate change impacts on water salinity and health. *Journal of*
2389 *Epidemiology and Global Health* 2011; **1**(1): 5-10.

- 2390 126. Dvorak AC, Solo-Gabriele HM, Galletti A, et al. Possible impacts of sea level rise on disease
2391 transmission and potential adaptation strategies, a review. *Journal of Environmental Management*
2392 2018; **217**: 951-68.
- 2393 127. Schütte S, Gemenne F, Zaman M, Flahault A, Depoux A. Connecting planetary health, climate
2394 change, and migration. *The Lancet Planetary Health* 2018; **2**(2): e58-e9.
- 2395 128. Dannenberg AL, Frumkin H, Hess JJ, Ebi KL. Managed retreat as a strategy for climate change
2396 adaptation in small communities: public health implications. *Climatic change* 2019; **153**(1-2): 1-14.
- 2397 129. Ayeb-Karlsson S, Kniveton D, Cannon T. Trapped in the prison of the mind: Notions of climate-
2398 induced (im)mobility decision-making and wellbeing from an urban informal settlement in
2399 Bangladesh. *Palgr Commun* 2020; **6**(1).
- 2400 130. Schwerdtle PN, McMichael C, Mank I, Sauerborn R, Danquah I, Bowen KJ. Health and migration
2401 in the context of a changing climate: A systematic literature assessment. *Environmental Research*
2402 *Letters* 2020; **15**(10): 103006.
- 2403 131. Glazebrook T, Noll S, Opoku E. Gender Matters: Climate Change, Gender Bias, and Women's
2404 Farming in the Global South and North. *Agriculture (Switzerland)* 2020; **10**(267): 1-25.
- 2405 132. Chingarande D, Huyer S, Lanzarini S, et al. Background paper on mainstreaming gender into
2406 National Adaptation Planning and implementation in Sub-Saharan Africa. Wageningen, the
2407 Netherlands, 2020.
- 2408 133. Delaney P, Shrader E. Gender and Post-Disaster Reconstruction: The Case of Hurricane Mitch
2409 in Honduras and Nicaragua, 2000.
- 2410 134. Roehr U. Gender, climate change and adaptation. Introduction to the gender dimensions.
2411 August, 2007.
- 2412 135. Schipper ELF, Ensor J, Mukherji A, et al. Equity in climate scholarship: a manifesto for action.
2413 *Climate and Development* 2021: 1-4.
- 2414 136. Ampaire EL, Acosta M, Huyer S, et al. Gender in climate change, agriculture, and natural
2415 resource policies: insights from East Africa. *Climatic Change* 2020; **158**: 43-60.
- 2416 137. Butler J. Gender Trouble: Feminism and the Subversion of Identity. New York; 1990.
- 2417 138. Colebrook C. Gender. Hampshire, UK; 2004.
- 2418 139. Cornwall A, Harrison E, Whitehead A. Gender Myths and Feminist Fables: The Struggle for
2419 Interpretive Power in Gender and Development. *Development and Change* 2007; **38**(1): 1-20.
- 2420 140. Kabeer N. Gender equality and women's empowerment: A critical analysis of the Third
2421 Millennium Development Goal. *Gender and Development* 2005; **13**(1): 13- 24.
- 2422 141. Azcona G, Valero SD. Making women and girls visible: Data for gender equality, 2018.
- 2423 142. Equal M. SDG Gender Index. 2021.
- 2424 143. Sanga D. Addressing Gender Issues through the Production and Use of Gender-Sensitive
2425 Information. *The African Statistical Journal* 2008; **7**: 116-39.
- 2426 144. World Economic F. Global Gender Gap Report; 2020.
- 2427 145. Center on Gender Equity and Health U, Data2X, Foundation BMG, et al. Strengthening gender
2428 measures and data in the COVID-19 era: an urgent need for change, 2021.
- 2429 146. U. N. Women. Making every women and girl count: Supporting the monitoring and
2430 implementation of the SDGs through better production and use of gender statistics. May, 2016.
- 2431 147. ESCAP. Work of the secretariat and partners on mainstreaming gender in environment
2432 statistics. Bangkok: Economic and Social Commission for Asia and the Pacific 2020.
- 2433 148. Ibn-Mohammed T, Mustapha KB, Godsell J, et al. A critical analysis of the impacts of COVID-
2434 19 on the global economy and ecosystems and opportunities for circular economy strategies.
2435 *Resources, Conservation and Recycling* 2021; **164**: 105169.
- 2436 149. Nicola M, Alsafi Z, Sohrabi C, et al. The socio-economic implications of the coronavirus
2437 pandemic (COVID-19): A review. *Int J Surg* 2020; **78**: 185-93.

2438 150. Ebi K, Boyer C, Bowen K, Frumkin H, Hess J. Monitoring and Evaluation Indicators for Climate
2439 Change-Related Health Impacts, Risks, Adaptation, and Resilience. *International Journal of*
2440 *Environmental Research and Public Health* 2018; **15**(9): 1943.

2441 151. WHO. WHO Health and Climate Change Survey Report: Tracking Global Progress. Geneva,
2442 Switzerland: World Health Organization, 2019.

2443 152. WHO. Gender, Climate Change and Health, 2014.

2444 153. WHO. Mainstreaming gender in health adaptation to climate change programmes. Geneva,
2445 Switzerland, 2012.

2446 154. Moloney A. How COVID-19 is exposing 'hidden poverty' across unequal cities. World Economic
2447 Forum. 2020 2020/11.

2448 155. Sharifi A, Khavarian-Garmsir AR. The COVID-19 pandemic: Impacts on cities and major lessons
2449 for urban planning, design, and management. *Science of The Total Environment* 2020; **749**: 142391.

2450 156. WBG. Urban Development. 2020.
2451 <https://www.worldbank.org/en/topic/urbandevelopment/overview> (accessed 28 April 2020).

2452 157. Wong MCS, Huang J, Wong SH, Yuen-Chun Teoh J. The potential effectiveness of the WHO
2453 International Health Regulations capacity requirements on control of the COVID-19 pandemic: a cross-
2454 sectional study of 114 countries. *J R Soc Med* 2021; **114**(3): 121-31.

2455 158. Bouchama A, Dehbi M, Mohamed G, Matthies F, Shoukri M, Menne B. Prognostic factors in
2456 heat wave related deaths: a meta-analysis. *Archives of internal medicine* 2007; **167**(20): 2170-6.

2457 159. Miettinen OS. Proportion of disease caused or prevented by a given exposure, trait or
2458 intervention. *American journal of epidemiology* 1974; **99**(5): 325-32.

2459 160. Birol F. The future of cooling: opportunities for energy-efficient air conditioning. Paris, France:
2460 International Energy Agency, 2018.

2461 161. Hospers L, Smallcombe JW, Morris NB, Capon A, Jay O. Electric fans: A potential stay-at-home
2462 cooling strategy during the COVID-19 pandemic this summer? *Science of the Total Environment* 2020;
2463 **747**: 141180.

2464 162. Salamanca F, Georgescu M, Mahalov A, Moustauoui M, Wang M. Anthropogenic heating of the
2465 urban environment due to air conditioning. *Journal of Geophysical Research: Atmospheres* 2014;
2466 **119**(10): 5949-65.

2467 163. Waite M, Cohen E, Torbey H, Piccirilli M, Tian Y, Modi V. Global trends in urban electricity
2468 demands for cooling and heating. *Energy* 2017; (127): 786-802.

2469 164. Randazzo T, De Cian E, Mistry MN. Air conditioning and electricity expenditure: The role of
2470 climate in temperate countries. *Economic Modelling* 2020; **90**: 273-87.

2471 165. Mastrucci A, Byers E, Pachauri S, Rao ND. Improving the SDG energy poverty targets:
2472 Residential cooling needs in the Global South. *Energy and Buildings* 2019; **186**: 405-15.

2473 166. Chen F, Kusaka H, Bornstein R, et al. The integrated WRF/urban modelling system:
2474 development, evaluation, and applications to urban environmental problems. *International Journal of*
2475 *Climatology* 2011; **31**(2): 273-88.

2476 167. Heaviside C, Cai XM, Vardoulakis S. The effects of horizontal advection on the urban heat
2477 island in Birmingham and the West Midlands, United Kingdom during a heatwave. *Q J Roy Meteor Soc*
2478 2015; **141**(689): 1429-41.

2479 168. Heaviside C, Vardoulakis S, Cai XM. Attribution of mortality to the urban heat island during
2480 heatwaves in the West Midlands, UK. *Environmental Health: A Global Access Science Source* 2016; **15**.

2481 169. Macintyre HL, Heaviside C, Taylor J, et al. Assessing urban population vulnerability and
2482 environmental risks across an urban area during heatwaves – Implications for health protection.
2483 *Science of the Total Environment* 2018; **610-611**: 678-90.

2484 170. Macintyre H, Heaviside C. Potential benefits of cool roofs in reducing heat-related mortality
2485 during heatwaves in a European city. *Environment international* 2019; **127**: 430-41.

2486 171. Macintyre HL, Heaviside C, Cai X, Phalkey R. The winter urban heat island: Impacts on cold-
2487 related mortality in a highly urbanized European region for present and future climate. *Environment*
2488 *International* 2021; **154**: 106530.

2489 172. Macintyre HL, Heaviside C, Cai X, Phalkey R. Comparing temperature-related mortality
2490 impacts of cool roofs in winter and summer in a highly urbanized European region for present and
2491 future climate. *Environment International* 2021; **154**: 106606.

2492 173. He C, Zhao J, Zhang Y, et al. Cool Roof and Green Roof Adoption in a Metropolitan Area:
2493 Climate Impacts during Summer and Winter. *Environmental Science & Technology* 2020; **54**(17):
2494 10831-9.

2495 174. Kardan O, Gozdyra P, Misic B, et al. Neighborhood greenspace and health in a large urban
2496 center. *Sci Rep* 2015; **5**(1): 11610.

2497 175. Gascon M, Triguero-Mas M, Martínez D, et al. Residential green spaces and mortality: A
2498 systematic review. *Environment International* 2016; **86**: 60-7.

2499 176. Abelt K, McLafferty S. Green Streets : Urban Green and Birth Outcomes. *Int J Environ Res Public*
2500 *Health* 2017; **14**(771).

2501 177. Aronson MF, Lepczyk CA, Evans KL, et al. Biodiversity in the city: key challenges for urban
2502 green space management. *Frontiers in Ecology and the Environment* 2017; **15**(4): 189-96.

2503 178. Ode Sang Å, Knez I, Gunnarsson B, Hedblom M. Urban Forestry & Urban Greening The effects
2504 of naturalness, gender, and age on how urban green space is perceived and used. *Urban Forestry &*
2505 *Urban Greening* 2016; **18**: 268-76.

2506 179. Rahman KMA, Zhang D. Analyzing the Level of Accessibility of Public Urban Green Spaces to
2507 Different Socially Vulnerable Groups of People. *Sustainability* 2018; **10**(3917).

2508 180. Richardson EA, Mitchell R. Gender differences in relationships between urban green space
2509 and health in the United Kingdom. *Soc Sci Med* 2010; **71**(3): 568-75.

2510 181. Schipperijn J, Ekholm O, Stigsdotter UK, et al. Landscape and Urban Planning Factors
2511 influencing the use of green space : Results from a Danish national representative survey. *Landscape*
2512 *and Urban Planning* 2010; **95**: 130-7.

2513 182. Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an
2514 observational population study. *Lancet* 2008; **372**(9650): 1655-60.

2515 183. Geary RS, Wheeler B, Lovell R, Jepson R, Hunter R, Rodgers S. A call to action: Improving urban
2516 green spaces to reduce health inequalities exacerbated by COVID-19. *Preventive Medicine* 2021; **145**:
2517 106425.

2518 184. UN-Habitat, World Health Organization. Integrating health in urban and territorial planning.
2519 Geneva, Switzerland: UN-Habitat and World Health Organization, 2020.

2520 185. International Monetary F. World Economic Outlook Database. 2018.

2521 186. kMatrix Ltd. Adaptation and Resilience to Climate Change dataset. Rutland, UK; 2021.

2522 187. Le Quéré C, Peters GP, Friedlingstein P, et al. Fossil CO2 emissions in the post-COVID-19 era.
2523 *Nature Climate Change* 2021; **11**(3): 197-9.

2524 188. UNEP. Are We Building Back Better? Evidence from 2020 and Pathways for Inclusive Green
2525 Recovery Spending. Nairobi, Kenya: UN Environment Programme, 2021.

2526 189. Hendryx M, Zullig KJ, Luo J. Impacts of Coal Use on Health. *Annu Rev Public Health* 2020; **41**(1):
2527 397-415.

2528 190. Matthews HD, Tokarska KB, Nicholls ZRJ, et al. Opportunities and challenges in using
2529 remaining carbon budgets to guide climate policy. *Nature Geoscience* 2020; **13**(12): 769-79.

2530 191. IEA. World Energy Outlook 2020 Paris, France: International Energy Agency, 2021.

2531 192. WHO. World health statistics 2021: monitoring health for the SDGs, sustainable development
2532 goals. Geneva, Switzerland: World Health Organization, 2021.

193. Cozzi L, Contejean A, Samantar J, Dasgupta A, Rouget A, Arboleya L. The Covid-19 crisis is reversing progress on energy access in Africa. Paris: IEA, 2020.

194. Shupler M, Mwitari J, Gohole A, et al. COVID-19 Lockdown in a Kenyan Informal Settlement: Impacts on Household Energy and Food Security. *medRxiv* 2020: 2020.05.27.20115113.

195. EUROSTAT. People unable to keep their home adequately warm, 2019. 2020 2020. <https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20210106-1?redirect=/eurostat/en/news/whats-new> (accessed 14 April 2021).

196. Kolokotsa D, Santamouris M. Review of the indoor environmental quality and energy consumption studies for low income households in Europe. *Science of The Total Environment* 2015; **536**: 316-30.

197. Thomson H, Simcock N, Bouzarovski S, Petrova S. Energy poverty and indoor cooling: An overlooked issue in Europe. *Energy and Buildings* 2019; **196**: 21-9.

198. IEA. World Extended Energy Balances (2020 edition). Paris: IEA, 2021.

199. Stoner O, Shaddick G, Economou T, et al. Global household energy model: a multivariate hierarchical approach to estimating trends in the use of polluting and clean fuels for cooking. *Journal of the Royal Statistical Society: Series C (Applied Statistics)* 2020; **69**(4): 815-39.

200. WHO. Household Energy Database. Geneva: World Health Organization; 2021.

201. WHO. Air quality guidelines – global update 2005. 2005. [https://www.who.int/airpollution/publications/aqg2005/en/#:~:text=WHO%20Air%20Quality%20Guidelines%20\(AQG,they%20were%20revised%20in%201997](https://www.who.int/airpollution/publications/aqg2005/en/#:~:text=WHO%20Air%20Quality%20Guidelines%20(AQG,they%20were%20revised%20in%201997) (accessed 8 May 2021).

202. Bennitt FB, Wozniak SS, Causey K, Burkart K, Brauer M. Estimating disease burden attributable to household air pollution: new methods within the Global Burden of Disease Study. *The Lancet Global Health* 2021; **9**: S18.

203. Shupler M, Hystad P, Birch A, et al. Household and personal air pollution exposure measurements from 120 communities in eight countries: results from the PURE-AIR study. *The Lancet Planetary Health* 2020; **4**(10): e451-e62.

204. Shupler M, Godwin W, Frostad J, Gustafson P, Arku RE, Brauer M. Global estimation of exposure to fine particulate matter (PM_{2.5}) from household air pollution. *Environment international* 2018; **120**: 354-63.

205. Clougherty JE. Review A Growing Role for Gender Analysis in Air Pollution Epidemiology. *Environmental Health Perspectives* 2010; **118**(2): 167-76.

206. Oparaocha S, Dutta S. Gender and energy for sustainable development. *Current Opinion in Environmental Sustainability* 2011; **3**: 265-71.

207. Gordon SB, Bruce NG, Grigg J, et al. Respiratory risks from household air pollution in low and middle income countries. *The Lancet Respiratory Medicine* 2014; **2**(10): 823-60.

208. Kurata M, Takahashi K, Hibiki A. Gender differences in associations of household and ambient air pollution with child health: Evidence from household and satellite-based data in Bangladesh. *World Dev* 2020; **128**: 104779.

209. European Commission. Revision of the Ambient Air Quality Directives. 2021. https://ec.europa.eu/environment/air/quality/revision_of_the_aaq_directives.htm (accessed 18 May 2021).

210. Dyer C. Air pollution from road traffic contributed to girl's death from asthma, coroner concludes. British Medical Journal Publishing Group; 2020.

211. Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet* 2020; **396**(10258): 1223-49.

212. IEA. Transport. 2021. <https://www.iea.org/topics/transport> (accessed 14 April 2021).

2580 213. Goel R, Goodman A, Aldred R, et al. Cycling behaviour in 17 countries across 6 continents:
 2581 levels of cycling, who cycles, for what purpose, and how far? *Transport Reviews* 2021: 1-24.

2582 214. Ferla M, Graham A. Women slowly taking off: An investigation into female
 2583 underrepresentation in commercial aviation. *Research in Transportation Business and Management*
 2584 2019; **31**(September): 100378.

2585 215. Adlakha D, Parra DC. Mind the gap: Gender differences in walkability , transportation and
 2586 physical activity in urban India. *Journal of Transport & Health* 2020; **18**(100875): 1-17.

2587 216. Mackett RL. The health implications of inequalities in travel. *Journal of Transport & Health*
 2588 2014; **1**(3): 202-9.

2589 217. Fraszczyk A, Piip J. A review of transport organisations for female professionals and their
 2590 impacts on the transport sector workforce. *Research in Transportation Business and Management*
 2591 2019; **31**(November): 100379.

2592 218. Olsen JR, Mitchell R, Mutrie N, Foley L, Ogilvie D, study M. Population levels of, and
 2593 inequalities in, active travel: A national, cross-sectional study of adults in Scotland. *Prev Med Rep* 2017;
 2594 **8**: 129-34.

2595 219. IEA. Global EV Outlook 2020. 2020. <https://www.iea.org/reports/global-ev-outlook-2020>
 2596 (accessed 15 April 2021).

2597 220. IEA. Tracking Transport 2020. 2020. <https://www.iea.org/reports/tracking-transport-2020>
 2598 (accessed 15 April 2020).

2599 221. IEA. Extended world energy balances. IEA World Energy Statistics and Balances. Paris, France:
 2600 IEA; 2021.

2601 222. IEA. Changes in transport behaviour during the Covid-19 crisis. 2021.
 2602 <https://www.iea.org/articles/changes-in-transport-behaviour-during-the-covid-19-crisis> (accessed 15
 2603 April 2021).

2604 223. IEA. The Covid-19 Crisis and Clean Energy Progress. 2021. [https://www.iea.org/reports/the-](https://www.iea.org/reports/the-covid-19-crisis-and-clean-energy-progress)
 2605 [covid-19-crisis-and-clean-energy-progress](https://www.iea.org/reports/the-covid-19-crisis-and-clean-energy-progress) (accessed 15 April 2021).

2606 224. Füzéki E, Schröder J, Carraro N, et al. Physical Activity during the First COVID-19-Related
 2607 Lockdown in Italy. *International Journal of Environmental Research and Public Health* 2021; **18**(5):
 2608 2511.

2609 225. Bechauf R. Cycling and COVID-19: why investments to boost cycling are important for a
 2610 sustainable recovery. 2020. [https://www.iisd.org/sustainable-recovery/cycling-and-covid-19-why-](https://www.iisd.org/sustainable-recovery/cycling-and-covid-19-why-investments-to-boost-cycling-are-important-for-a-sustainable-recovery/)
 2611 [investments-to-boost-cycling-are-important-for-a-sustainable-recovery/](https://www.iisd.org/sustainable-recovery/cycling-and-covid-19-why-investments-to-boost-cycling-are-important-for-a-sustainable-recovery/) (accessed 14 April 2021).

2612 226. FAO. FAOSTAT. 2020. <http://www.fao.org/faostat/> (accessed 15 April 2021).

2613 227. Iannotti L, Tarawali S, Baltenweck I, et al. Livestock-derived foods and sustainable healthy
 2614 diets. Rome, Italy: UN Nutrition Secretariat, 2021.

2615 228. Gerber PJ, Steinfeld H, Henderson B, et al. Tackling climate change through livestock – A global
 2616 assessment of emissions and mitigation opportunities.
 2617 . Rome: FAO, 2013.

2618 229. Global Alliance for Improved Nutrition. GAIN Briefing Paper Series 2 - Animal-source foods for
 2619 human and planetary health. Geneva, Switzerland: Global Alliance for Improved Nutrition (GAIN),
 2620 2020.

2621 230. Food and Agriculture Organization of the United Nations. Food balance sheets. 2020.

2622 231. Wang H, Abbas KM, Abbasifard M, et al. Global age-sex-specific fertility, mortality, healthy life
 2623 expectancy (HALE), and population estimates in 204 countries and territories, 1950–2019: a
 2624 comprehensive demographic analysis for the Global Burden of Disease Study 2019. *The Lancet* 2020;
 2625 **396**(10258): 1160-203.

2626 232. Chai BC, Voort VDJR, Grofelnik K, Eliasdottir HG, Klöss I, Perez-cueto FJA. Which Diet Has the
2627 Least Environmental Impact on Our Planet ? A Systematic Review of Vegan , Vegetarian and
2628 Omnivorous Diets. *Sustainability* 2019; **11**(4110).

2629 233. Modlinska K, Adamczyk D, Maison D, Pisula W. Gender Differences in Attitudes to Vegans/
2630 Vegetarians and Their Food Preferences, and Their Implications for Promoting Sustainable Dietary
2631 Patterns – A Systematic Review. *Sustainability* 2020; **12**(6292): 1-17.

2632 234. Rosenfeld DL, Rothgerber H, Tomiyama AJ. Mostly Vegetarian , But Flexible About It :
2633 Investigating How Meat-Reducers Express Social Identity Around Their Diets. *Social Psychological and*
2634 *Personality Science* 2020; **11**(3): 406-15.

2635 235. Song S, Kim J, Kim J. Gender Differences in the Association between Dietary Pattern and the
2636 Incidence of Hypertension in Middle-Aged and Older Adults. *Nutrients* 2018; **10**(252).

2637 236. European Academies Science Advisory Council, Federation of European Academies of
2638 Medicine. Decarbonisation of the Health Sector: A Commentary by EASAC and FEAM. Brussels,
2639 Belgium: European Academies Science Advisory Council, 2021.

2640 237. Health Care Without Harm. Race to Zero. 2021.
2641 <https://healthcareclimateaction.org/racetozero> (accessed 24 June 2021).

2642 238. Hepburn C, O'Callaghan B, Stern N, Stiglitz J, Zenghelis D. Will COVID-19 fiscal recovery
2643 packages accelerate or retard progress on climate change? *Oxford Review of Economic Policy* 2020;
2644 **36**: S359-S81.

2645 239. International Monetary Fund. World Economic Outlook Update April 2021. Washington, DC,
2646 USA: International Monetary Fund, 2021.

2647 240. Swiss Re. Sigma explorer. Zurich, Switzerland: Swiss Re; 2021.

2648 241. Stringhini S, Carmeli C, Jokela M. Socioeconomic status and the 25 x 25 risk factors as
2649 determinants of premature mortality: a multicohort study and meta-analysis of 1.7 million men and
2650 women (vol 389, pg 1229, 2017). *Lancet* 2017; **389**(10075): 1194-.

2651 242. ILO. ILOSTAT Statistics on wages. 2021. <https://ilostat.ilo.org/topics/wages/> (accessed 1st
2652 April 2021).

2653 243. Muriithi MK, Mutegi RG, Mwabu G. Counting unpaid work in Kenya: Gender and age profiles
2654 of hours worked and imputed wage incomes. *The Journal of the Economics of Ageing* 2020; **17**:
2655 100120.

2656 244. Reddy AA, Mittal S, Roy NS, Kanjilal-Bhaduri S. Time Allocation between Paid and Unpaid Work
2657 among Men and Women: An Empirical Study of Indian Villages. *Sustainability* 2021; **13**(5): 17.

2658 245. Sarker MR. Labor market and unpaid works implications of COVID-19 for Bangladeshi women.
2659 *Gend Work Organ*: 8.

2660 246. World Bank. Global Economic Prospects. Washington DC; 2021.

2661 247. O'Callaghan B, Murdock E. Are We Building Back Better? Evidence from 2020 and Pathways
2662 to Inclusive Green Recovery Spending. 2021.

2663 248. Vivid Economics. Greenness of Stimulus Index - February 2021. 2021.

2664 249. Leaton J. Unburnable Carbon – Are the world's financial markets carrying a carbon bubble?
2665 *Carbon Tracker* 2011.

2666 250. IEA. After steep drop in early 2020, global carbon dioxide emissions have rebounded strongly
2667 - News - IEA.

2668 251. WHO Manifesto for a healthy recovery from COVID-19.

2669 252. IEA. Global Energy & CO2 Status Report 2019. 2019 (accessed April 15, 2021).

2670 253. IEA. World Energy Investment. Paris, France: International Energy Agency, 2021.

2671 254. Hendryx M, Zullig KJ, Luo J. Impacts of Coal Use on Health. *Annual Review of Public Health*
2672 2020; **41**: 397-415.

2673 255. Garrett-Peltier H. Green versus brown: Comparing the employment impacts of energy
2674 efficiency, renewable energy, and fossil fuels using an input-output model. *Economic Modelling* 2017;
2675 **61**: 439-47.

2676 256. IRENA. Renewable Energy: A Gender Perspective. Abu Dhabi, 2019.

2677 257. Plantinga A, Scholtens B. The financial impact of fossil fuel divestment. *Climate Policy* 2021;
2678 **21**: 107-19.

2679 258. Hunt C, Weber O. Fossil Fuel Divestment Strategies: Financial and Carbon-Related
2680 Consequences. *Organization & Environment* 2019; **32**: 41-61.

2681 259. Phillips M. Exxon Mobil Defeated by Activist Investor Engine No. 1. 2021.
2682 <https://www.nytimes.com/2021/06/09/business/exxon-mobil-engine-no1-activist.html> (accessed 29
2683 June 2021).

2684 260. 350.org. Divestment Commitments. 2020.
2685 <https://gofossilfree.org/divestment/commitments/> (accessed 30 March 2021).

2686 261. Ranger L. Unburnable Carbon 2013 : Wasted capital and stranded assets About the Grantham
2687 Research Institute on. *Management of Environmental Quality: An International Journal* 2013; **24**: 1-
2688 40.

2689 262. McGlade C, Ekins P. The geographical distribution of fossil fuels unused when limiting global
2690 warming to 2°C. *Nature* 2015; **517**: 187-90.

2691 263. Caldecott B, Tilbury, J., Carey, C. Stranded Assets and Scenarios. 2014.

2692 264. Curtin J, McNerney C, Ó Gallachóir B, Hickey C, Deane P, Deeney P. Quantifying stranding risk
2693 for fossil fuel assets and implications for renewable energy investment: A review of the literature.
2694 *Renewable and Sustainable Energy Reviews* 2019; **116**: 109402.

2695 265. Leaton J, Fulton M, Spedding P, et al. The \$2 trillion stranded assets danger zone: How fossil
2696 fuel firms risk destroying investor returns. *Carbon Tracker Initiative* 2015: 1-32.

2697 266. SEI I, ODI, E3G, UNEP. The Production Gap Report: 2020 Special Report. , 2020.

2698 267. Leaton J, Grant A. 2 degrees of separation: Transition risk for oil & gas in a low carbon world.
2699 *Carbon Tracker* 2017.

2700 268. Coffin M. Absolute Impact: Why oil majors' climate ambitions fall short of Paris limits. *Carbon*
2701 *Tracker* 2020: xi.

2702 269. IEA. Energy subsidies - tracking the impact of fossil fuel subsidies. 2021.
2703 <https://www.iea.org/topics/energy-subsidies> (accessed 16th February 2021).

2704 270. OECD. OECD Inventory of support measures for fossil fuels. 2021.
2705 https://stats.oecd.org/Index.aspx?DataSetCode=FFS_AUS (accessed 6th April 2021).

2706 271. World Bank. World Bank Carbon Pricing Dashboard. 2021.
2707 <https://carbonpricingdashboard.worldbank.org/> (accessed 3rd April 2021).

2708 272. WHO. World Health Organization Global Health Expenditure Database. 2021.
2709 <https://apps.who.int/nha/database/Select/Indicators/en> (accessed 7th April 2021).

2710 273. Younger SD, Osei-Assibey E, Oppong F. Fiscal Incidence in Ghana. *Rev Dev Econ* 2017; **21**(4):
2711 E47-E66.

2712 274. Inter-agency Task Force on Financing for Development. Financing for Sustainable
2713 Development Report 2020. New York, NY, USA: UN Department of Economic and Social Affairs, 2020.

2714 275. Mi Z, Zheng J, Meng J, et al. Economic development and converging household carbon
2715 footprints in China. *Nature Sustainability* 2020; **3**(7): 529-37.

2716 276. Stadler K, Wood R, Bulavskaya T, et al. EXIOBASE 3: Developing a time series of detailed
2717 environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology* 2018;
2718 **22**(3): 502-15.

2719 277. Amann M, Kiesewetter G, Schöpp W, et al. Reducing global air pollution: the scope for further
2720 policy interventions. *Philosophical Transactions of the Royal Society A* 2020; **378**(2183): 20190331.

2721 278. McCann G, Matenga C. COVID-19 and Global Inequality. *COVID-19 IN THE GLOBAL SOUTH*
2722 2020: 161.

2723 279. UNDP. COVID-19 and Human Development: Assessing the Crisis, Envisioning the Recovery.
2724 2020. http://hdr.undp.org/sites/default/files/covid-19_and_human_development_0.pdf (accessed
2725 March-21).

2726 280. UN_News. Ahead of UN summit, leading scientists warn climate change ‘hitting harder and
2727 sooner’ than forecast2019. <https://news.un.org/en/story/2019/09/1046972> (accessed March-21).

2728 281. Intergovernmental_Panel_on_Climate_Change. Policymakers Summary. In:
2729 Intergovernmental_Panel_on_Climate_Change, ed. Climate Change: the IPCC Response Strategies
2730 Report of the working group III; 1990.

2731 282. Newman N, Fletcher R, Schulz A, Andi S, Nielsen RK. Digital News Report 2020.
2732 <https://www.digitalnewsreport.org/> (accessed March-21).

2733 283. Barkemeyer R, Figge F, Hoepner A, Holt D, Kraak JM, Yu P-S. Media coverage of climate
2734 change: An international comparison. 2017; **35**(6): 1029-54.

2735 284. Gavin NT. Addressing climate change: a media perspective. *Environmental Politics* 2009; **18**(5):
2736 765-80.

2737 285. Boykoff M. Who Speaks for the Climate? Making Sense of Media Reporting on Climate Change:
2738 Cambridge University Press; 2011.

2739 286. Rogstad I. Is Twitter just rehashing? Intermedia agenda setting between Twitter and
2740 mainstream media. *Journal of Information Technology & Politics* 2016; **13**(2): 142-58.

2741 287. Duan R, Miller S. Climate change in China: A study of news diversity in party-sponsored and
2742 market-oriented newspapers. *Journalism* 2019: 1464884919873173.

2743 288. Wang H, Sparks C, Huang Y. Measuring differences in the Chinese press: A study of People’s
2744 Daily and Southern Metropolitan Daily. *Global Media and China* 2018; **3**(3): 125-40.

2745 289. Auerbach Y, Bloch-Elkon Y. Media Framing and Foreign Policy: The Elite Press vis-à-vis US
2746 Policy in Bosnia, 1992–95. *Journal of Peace Research* 2005; **42**(1): 83-99.

2747 290. Billett S. Dividing climate change: global warming in the Indian mass media. *Climatic change*
2748 2010; **99**(1-2): 1-16.

2749 291. Boykoff MT, Boykoff JM. Balance as bias: global warming and the US prestige press. *Global*
2750 *Environmental Change* 2004; **14**(2): 125-36.

2751 292. Amazon_Alexa. The top 500 sites on the Web. 2020. <https://www.alexa.com/topsites>.
2752 (accessed March-21).

2753 293. Schroeder R, Taylor L. Big data and Wikipedia research: social science knowledge across
2754 disciplinary divides. *Information, Communication & Society* 2015; **18**(9): 1039-56.

2755 294. Mesgari M, Okoli C, Mehdi M, Nielsen FÅ, Lanamäki A. “The sum of all human knowledge”: A
2756 systematic review of scholarly research on the content of Wikipedia. *Journal of the Association for*
2757 *Information Science and Technology* 2015; **66**(2): 219-45.

2758 295. Bornmann L. Scientific peer review. *Annual review of information science and technology*
2759 2011; **45**(1): 197-245.

2760 296. United Nations General Debate of the 75th session of the General Assembly. 2021.

2761 297. Peterson M. General Assembly. In: Daws S, Weiss T, eds. The Oxford Handbook on the United
2762 Nations (2nd edition); 2018.

2763 298. Change UNFCCC. The Paris Agreement. [https://unfccc.int/process-and-meetings/the-paris-](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement)
2764 [agreement/the-paris-agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement) (accessed March-21).

2765 299. Dasandi N, Graham H, Lampard P, Jankin Mikhaylov S. Engagement with health in national
2766 climate change commitments under the Paris Agreement: a global mixed-methods analysis of the
2767 nationally determined contributions. *The Lancet Planetary Health* 2021; **5**(2): e93-e101.

2768 300. Dasandi N, Graham H, Lampard P, Jankin Mikhaylov S. Intergovernmental engagement on
2769 health impacts of climate change. *Bull World Health Organ* 2021; **99**(2): 102-11B.

2770 301. Wright C, Nyberg D. Climate Change, Capitalism, and Corporations: Processes of Creative Self-
2771 Destruction. Cambridge: Cambridge University Press; 2015.

2772 302. Covington H, Thornton J, Hepburn C. Global warming: Shareholders must vote for climate-
2773 change mitigation. *Nature News* 2016; **530**(7589): 156.

2774 303. Ekwurzel B, Boneham J, Dalton M, et al. The rise in global atmospheric CO₂, surface
2775 temperature, and sea level from emissions traced to major carbon producers. *Climatic Change* 2017;
2776 **144**(4): 579-90.

2777 304. United_Nations. The United Nations Global Compact. <https://www.unglobalcompact.org/>
2778 (accessed March-21.

2779 305. Margaretha Jastram S, Klingenberg J. Assessing the Outcome Effectiveness of Multi-
2780 Stakeholder Initiatives in the Field of Corporate Social Responsibility – The Example of the United
2781 Nations Global Compact. *Journal of Cleaner Production* 2018; **189**: 775-84.

2782 306. Preet R, Nilsson M, Schumann B, Evengård B. The gender perspective in climate change and
2783 global health. *Global Health Action* 2010; **3**(1): 5720.

2784 307. Holmberg K, Hellsten I. Gender differences in the climate change communication on Twitter.
2785 *Internet Research* 2015.

2786 308. Mavisakalyan A, Tarverdi Y. Gender and climate change: Do female parliamentarians make
2787 difference? *European Journal of Political Economy* 2019; **56**: 151-64.

2788 309. Pearse R. Gender and climate change. *WIREs Climate Change* 2017; **8**(2): e451.

2789 310. Koch-Baumgarten S, Voltmer K. Introduction: Mass Media and Public Policy – Is There a Link?
2790 In: Koch-Baumgarten S, Voltmer K, eds. Public Policy and the Mass Media The Interplay of Mass
2791 Communication and Political Decision Making.

2792 311. World_Health_Organization. Sixty-first World Health Assembly.
2793 <https://www.who.int/mediacentre/events/2008/wha61/en/> (accessed March-21.

2794 312. Nagarathinam S, Bhatta A. Coverage of climate change issues in Indian newspapers and policy
2795 implications. *Current Science* 2015; **108**(11): 1972-3.

2796 313. Pierre-Louis K. Heat Waves in the Age of Climate Change: Longer, More Frequent and More
2797 Dangerous. The New York Times. 2020 June 18.

2798 314. HTCorrespondent. Need multi-sectoral coordination to tackle health impacts of climate
2799 change. Hindustan Times. 2020 February 25.

2800 315. Guterres A. A Time to Save the Sick and Rescue the Planet. The New York Times. 2020 April
2801 28.

2802 316. Giles J. Internet encyclopaedias go head to head. *Nature* 2005; **438**(7070): 900-1.

2803 317. Yoshida M, Arase Y, Tsunoda T, Yamamoto M. Wikipedia Page View Reflects Web Search
2804 Trend. Proceedings of the ACM Web Science Conference. Oxford, United Kingdom: Association for
2805 Computing Machinery; 2015. p. Article 65.

2806 318. Wikipedia. Most popular edition of Wikipedia by country.
2807 <https://commons.wikimedia.org/w/index.php?curid=99613651> (accessed March-21.

2808 319. Wikipedia. Wikipedia page views by language over time.
2809 <https://commons.wikimedia.org/w/index.php?curid=99654507> (accessed March-21.

2810 320. Molek-Kozakowska K. Popularity-driven science journalism and climate change: A critical
2811 discourse analysis of the unsaid. *Discourse, Context & Media* 2018; **21**: 73-81.

2812 321. Baturo A, Dasandi N, Mikhaylov SJ. Understanding state preferences with text as data:
2813 Introducing the UN General Debate corpus. *Research & Politics* 2017; **4**(2): 2053168017712821.

- 2814 322. General Assembly of the United Nations. General Debate of the 75th Session 22 to 26
2815 September and 29 September 2020. 2020. <https://gadebate.un.org/generaldebate75/en/> (accessed
2816 13 April 2021).
- 2817 323. UNFCCC. UNFCCC NDC Registry. 2021.
2818 <https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx> (accessed 1 April 2021).
- 2819 324. Voegtlin C, Pless NM. Global Governance: CSR and the Role of the UN Global Compact. *Journal*
2820 *of Business Ethics* 2014; **122**(2): 179-91.

2821