

The Lancet Countdown: tracking progress on health and climate change

Article

Accepted Version

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Watts, N., Adger, W. N., Ayeb-Karlsson, S., Bai, Y., Byass, P., Campbell-Lendrum, D., Colbourn, T., Cox, P., Davies, M., Depledge, M., Depoux, A., Dominguez-Salas, P., Drummond, P., Ekins, P., Flahault, A., Grace, D., Graham, H., Haines, A., Hamilton, I., Johnson, A., Kelman, I., Kovats, S., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Morrissey, K., Murray, K., Neville, T., Nilsson, M., Oreszczyn, T., Parthemore, C., Pencheon, D., Robinson, E. J. Z. ORCID: <https://orcid.org/0000-0002-4950-0183>, Schütte, S., Shumake-Guillemot, J., Vineis, P., Wilkinson, P., Wheeler, N., Xu, B., Yang, J., Yin, Y., Yu, C., Gong, P., Montgomery, H. and Costello, A. (2017) The Lancet Countdown: tracking progress on health and climate change. *Lancet*, 389 (10074). pp. 1151-1164. ISSN 0140-6736 doi: 10.1016/S0140-6736(16)32124-9 Available at <https://centaur.reading.ac.uk/68063/>

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Published version at: [http://dx.doi.org/10.1016/S0140-6736\(16\)32124-9](http://dx.doi.org/10.1016/S0140-6736(16)32124-9)

To link to this article DOI: [http://dx.doi.org/10.1016/S0140-6736\(16\)32124-9](http://dx.doi.org/10.1016/S0140-6736(16)32124-9)

Publisher: Elsevier

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The Lancet Countdown: Tracking Progress on Health and Climate Change

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Abstract

The Lancet Countdown: Tracking Progress on Health and Climate Change is an international, multi-disciplinary research collaboration between academic institutions and practitioners across the world. It follows on from the work of the 2015 Lancet Commission, which concluded that the response to climate change could be “the greatest global health opportunity of the 21st century”.

The Lancet Countdown aims to track the health effects of climate change; health resilience and adaptation; health co-benefits of mitigation; climate finance and economics; and political and broader engagement. These focus areas form the five thematic working groups of the Lancet Countdown and represent different aspects of the complex relationships between health and climate change. These thematic groups will provide indicators for a global overview of health and climate change; national case studies highlighting countries leading the way or going against the trend; and engagement with a range of stakeholders.

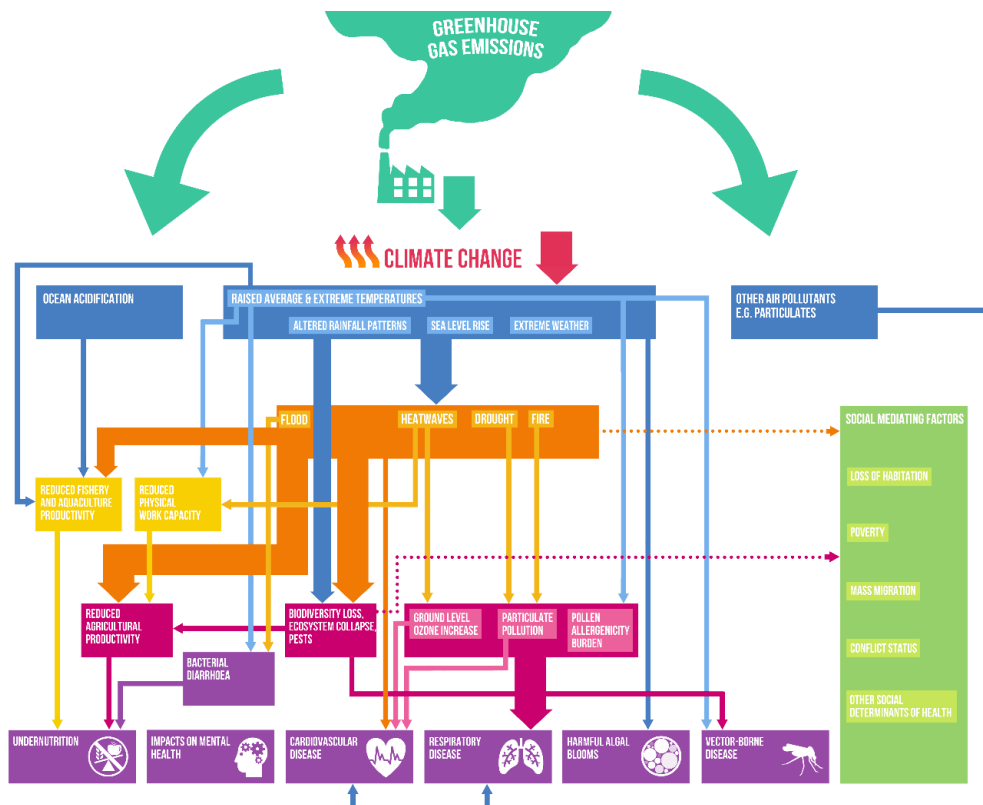
The Lancet Countdown ultimately aims to report annually on a series of indicators across these five working groups. This paper outlines these potential indicators and indicator domains to be tracked by the collaboration, with suggestions on the methodologies, and data sets available to achieve this end. The proposed indicator domains require further refinement, and mark the beginning of an ongoing consultation process – from November 2016 to early 2017 – to develop these domains, identify key areas not currently covered, and change indicators where necessary. It will actively seek to engage with existing monitoring processes, such as the UN Sustainable Development Goals, and the World Health Organization’s Climate and Health Country Profiles. Additionally, the indicators will evolve throughout their lifetime through ongoing collaboration with experts and a range of stakeholders, and dependent on the emergence of new evidence and knowledge. During the course of its work, the Lancet Countdown will adopt a collaborative and iterative process, which aims to complement existing initiatives, welcome engagement with new partners, and be open to developing new research projects on health and climate change.

40 Introduction

41 The World Health Organization (WHO) estimated that in 2012, 12.6 million deaths (23% of all
42 deaths) were attributable to modifiable environmental factors, many of which could be influenced
43 by climate change, or are related to the driving forces of climate change.¹ The *2009 UCL-Lancet*
44 *Commission: Managing the health effects of climate change* described the ways in which climate
45 change acts as a force multiplier for threats to global health.² These initiatives have drawn on long-
46 standing expertise and leadership in the health and climate space from institutions such as the WHO
47 and the Intergovernmental Panel on Climate Change's (IPCC).^{3,4}

48 The *2015 Lancet Commission on Health and Climate Change: policy responses to protect public*
49 *health* built on these foundations and explored the health benefits of climate change mitigation and
50 adaptation policies.⁵ As first described in the 2009 Lancet series, greenhouse gas (GHG) mitigation
51 across a range of sectors can result in significant improvements in public health.⁶⁻¹⁰ Taken together,
52 the potential to avoid significant impacts of climate change and the potential co-benefits of climate
53 mitigation and adaptation led the 2015 Lancet Commission to conclude that "tackling climate
54 change could be the greatest global health opportunity of the 21st century".⁵

55 Direct impacts of climate change result from rising temperatures, heatwaves, and increases in the
56 frequency of complex extreme weather events such as windstorms, floods and droughts.¹¹ The
57 health and social consequences of these events are far-reaching, ranging from reduced labour
58 productivity and heat-related deaths, through to direct injury, the spread of infectious disease, and
59 mental health impacts following wide-spread flooding. The effects of climate change will also be
60 heterogeneously mediated across different environmental and social systems, resulting in changing
61 patterns of the burden and distribution of infectious diseases, changes in food productivity and
62 potential effects on food and water shortages, population displacement, and conflict.³ Climate
63 change places undue burden on countries least responsible and least able to respond, with low- and
64 middle-income countries experiencing multiple impacts simultaneously (see Figure 1).¹²



65 *Figure 1. The health impacts of climate change (source: Lancet Commission, 2015⁵)*

66

67 The Rockefeller Foundation-Lancet Commission on Planetary Health described how sustained human
 68 health and development depend on flourishing natural systems. This Commission and others have
 69 drawn attention to the fact that human activities are breaching environmental limits across a range
 70 of areas, driving terrestrial and marine biodiversity loss, ocean acidification, stratospheric ozone
 71 depletion, soil degradation, and other potentially irreversible processes.^{13,14}

72 At the international level, the Paris Agreement provides the framework for future international
 73 cooperation and national action on climate change. Modelling suggests that the full implementation
 74 of all national government pledged mitigation actions would limit global average warming to around
 75 2.7°C by 2100; an improvement on the high-end 4.8°C or more scenario, but substantially higher
 76 than the agreed United Nations target of “well below 2.0°C”.¹⁵

77 Responsibility for the implementation of the Paris Agreement now falls to national governments.
 78 The next 15 years, from 2016 to 2030, are a crucial window that will determine the trajectory of
 79 climate change and human development for the coming century. As part of this transition, countries
 80 will have to shift from an understanding of climate change solely as a threat, to one which embraces
 81 the response to climate change as an opportunity for human health and wellbeing. Tracking and
 82 communicating this shift will be the central focus of the *Lancet Countdown: Tracking Progress on*
 83 *Health and Climate Change*.

85 Aims of the Lancet Countdown on Health and Climate Change

86 The Lancet Countdown aims to: track the impacts of climate change and the speed of the transition
87 to a decarbonised global economy, a transition that is already underway; analyse and demonstrate
88 the health benefits available; provide a global picture of successes and obstructions in this shift;
89 draw out exemplary case-studies for shared learning; and engage with policymakers and the broader
90 health community to better communicate the opportunities available in responding to climate
91 change both for health and more broadly.

92 To do this, the Lancet Countdown will report annually on key indicators that reflect progress on
93 health and climate change. Published each year, before the UN Framework Convention on Climate
94 Change's (UNFCCC) international negotiations, the annual Lancet paper will consider global, regional,
95 national, and, on a selective basis, city level trends. Five interrelated thematic working groups will
96 cover different aspects of the relationship between health and climate change, including: the health
97 impacts of climate change; health resilience and adaptation; the health co-benefits of mitigation;
98 finance and economics; and policy, politics and public opinion.

99 The Lancet Countdown is an international, multi-disciplinary research collaboration between
100 academic institutions and experts across the world. Where the 2015 Lancet Commission existed as a
101 partnership primarily between European and Chinese academics, the Lancet Countdown will build
102 on these foundations to be more global, both in expertise and outlook.

103

104 Indicators of Progress: A Call for Input and Engagement

105 The work of the Lancet Countdown is divided into five working groups, each of which will be
106 responsible for their own set of indicators. Table 1 and the rest of this paper outlines proposed
107 indicator domains for these working groups. These are presented for consultation with varying
108 degrees of certainty, ranging from the presentation of a specific indicator, through to the description
109 of a broad domain within which a number of indicators might function.

110 The ongoing framing and selection of indicators to mark the progress to a low-carbon and climate
111 resilient society could take a number of forms, such as focusing on the interactions between society
112 and environment (as seen in the DPSEEA framework, adapted in Appendix 1); or vulnerability, risk
113 and adaptive capacity to climate change.¹⁶⁻¹⁸ The selected indicators will need to address the
114 challenges of representing spatial and temporal factors in a summarized form. The framing that will
115 be used to select indicators as part of the Lancet Countdown is primarily from the health
116 perspective. In turn, the focus is on those indicators that capture the greatest effects that climate
117 change has on health; the anthropogenic drivers that have the greatest contribution to climate
118 change and the measures and actions that would substantially reduce the effects climate change or
119 yield health co-benefits of mitigation policies.

120 The proposed indicator domains reflect a pragmatic need to capture markers of progress in the key
121 interactions between health and climate change using the best available data, and those that can be
122 translated to the health community and more widely. They were developed through an iterative
123 process, following an initial, broad consultation process. This sought input from a wide variety of
124 experts working in the field. These were further discussed and refined by the Lancet Countdown's
125 academic working groups at a series of multidisciplinary meetings throughout 2016. Each proposed

126 indicator domain was assessed for its ability to cover a unique part of the relationship between
 127 health and climate change; potential data availability; feasibility given current resource constraints;
 128 applicability to countries across a variety of resource settings; and policy relevance.

129 This collaborative process is intended to work closely with other monitoring initiatives, such as the
 130 information being collected under the WHO’s Climate and Health Country Profiles, the SHUE
 131 (Sustainable Healthy Urban Environments) project, the Sendai Framework, and the ClimateWorks
 132 Foundation’s Carbon Transparency Initiative.¹⁹⁻²² It will also look to draw on the UN SDGs where
 133 appropriate. The potential links between these initiatives and the Lancet Countdown’s indicator
 134 domains have been summarised in Appendix 2. Where relevant cross-over exists, the Lancet
 135 Countdown will look to incorporate this data into its work to provide a more complete, and
 136 standardised overview.

137 This paper marks the beginning of an external consultation process, to further refine the suggestions
 138 below. Indeed, it is expected that, the indicators and metrics used will continuously evolve to make
 139 use of emerging evidence and data availability. To this end, the Lancet Countdown is committed to
 140 maintaining an open approach to further developing its work programme, inviting external input and
 141 actively consulting over the coming months. The research collaboration welcomes engagement with
 142 new academic partners, with the expertise and capacity to make substantial contributions to the
 143 final indicator process. The collaboration is also open to developing new research projects on as-yet
 144 neglected areas of health and climate change, with the possibility to jointly seek additional funding
 145 and capacity for this work in future. We invite direct input on the content, methods, and data for the
 146 proposed indicators and indicator domains, as well as proposals for new partnerships, through the
 147 website here: www.LancetCountdown.org/IndicatorConsultation

148

Thematic Working Group	Indicator Domains
1. Health Impacts of Climate Hazards	1.1 Exposure to temperature change
	1.2 Change in labour productivity
	1.3 Exposure to heatwave
	1.4 Exposure to flood
	1.5 Exposure to drought
	1.6 Spread of infectious disease across sentinel sites
	1.7 Food security and undernutrition
2. Health Resilience and Adaptation	2.1 Integration of health in national adaptation plans
	2.2 Climate services for health
	2.3 Adaptation finance for health
3. Health Co-Benefits of Mitigation	3.1. Coal phase-out
	3.2 Growth in renewable energy resources
	3.3 Energy access
	3.4. Energy access for health facilities
	3.5 Ambient and household air pollution exposure
	3.6 Deployment of low-emission vehicles
	3.7 Active transport infrastructure and uptake
	3.8 Food consumption, production, and waste
	3.9 Carbon footprint of healthcare systems
4. Finance and Economics	4.1 Change in annual investment in renewable energy
	4.2 Change in annual investment in energy efficiency
	4.3 Low-carbon technology patent generation and

	innovation
	4.4 Valuing the health co-benefits of climate change mitigation
	4.5 Direct and indirect fossil fuel subsidies
	4.6 Coverage and strength of carbon pricing
	4.7 Equity of the low-carbon transition
5. Political and Broader Engagement	5.1 Public engagement in health and climate change
	5.2 Academic publications on health and climate change
	5.3 Health and climate change in the UNFCCC and UNGA high-level statements
	5.4 Inclusion of health and climate change within medical and public health curricula
	5.5 Implementation and estimated health benefits of the Nationally Determined Contributions

149

150 *Table 1. Proposed indicator domains for the Lancet Countdown: Tracking Progress on Health and*
151 *Climate Change. Importantly, these indicator domains are heterogeneous in nature – some reflect*
152 *outcomes (GHG emissions or health) and others reflect process indicators with both direct and*
153 *indirect links to climate change. Additionally, some can be modelled at a global or national level,*
154 *whereas others reflect location-specific issues and would depend on data collection at sentinel sites.*

155

156 [Health impacts of climate change](#)

157 The health effects of climate change are projected to become increasingly severe in the future, and
158 threaten to undermine the last half-century of gains in public health and development.^{3,5} These
159 effects are unevenly distributed within and between countries, with all risks having important social,
160 economic, and geographical mediating factors.¹⁹ The first working group of the Lancet Countdown
161 proposes seven indicator domains to be considered and then tracked.

162

163 1.1-1.5: Human exposure to extreme weather

164 These domains will use observed meteorological data to create indicators of exposure to extremes
165 of weather across five areas: annual mean temperature change; heat index relevant for outdoor
166 labour productivity; heatwave; drought; and flood risk. This data will be complemented by a review
167 of the detection and attribution studies linking climate change to specific extreme weather events
168 that have affected human health. These indices are deliberately similar to those presented in the
169 Lancet Commission for consistency and transparency.⁵ For the Lancet Countdown, we will focus on
170 metrics calculated from observational data rather than climate model projections. However, we aim
171 to maintain comparability between these metrics for the monitoring of progress, and the exposure
172 metrics implied by the future projections presented in the Lancet Commission report.⁵

173 Mean temperature increase and changes in the severity and frequency of heatwaves bring
174 substantial and potentially fatal health risks to most populations.^{3,23} These include particularly
175 exposed individuals (ie. those engaged in outdoor physical labour), and individuals with reduced
176 capacity to maintain physiological homeostasis, such as the infirm, neonates, or the elderly. The
177 direct relationship between extremes of heat and heat-related morbidity and mortality is well
178 established, as is the relationship between indicators of thermal stress such as wet bulb globe

179 temperature (WBGT), and reductions in outdoor labour productivity, to a lesser extent.²⁴ Examples
180 of direct and indirect health effects were seen in the 2010 Russian heatwave, which resulted in
181 approximately 11,000 excess deaths from heat and poor air quality from subsequent forest fires.²⁵
182 The Lancet Countdown will utilise the population related metrics developed from the 2015 Lancet
183 Commission to calculate the mean warming experienced by people.⁵ It will also make use of the
184 index proposed by Jacob *et al.*, defining a heatwave as more than three consecutive days where
185 minimum temperature exceeds the 99th percentile for the recent past.²⁶ In addition, changes in
186 labour productivity will be modelled using WBGT, which has been used to identify thresholds of heat
187 stress.²⁷

188 The fourth and fifth indicator domains will follow human exposure to flood and drought. Here, flood
189 refers to meteorological floods, related to rain, storm surges, and sea level rise, rather than due to
190 tsunamis or volcanic eruptions, melting snow and ice. Drought refers to meteorological drought, so a
191 deficit of precipitation, rather than other forms of drought, such as water depletion caused by
192 increasing demand.^{28,29} Observational data suggests that many regions demonstrating rising
193 frequency of meteorological drought over the past 60 years overlap with crucial agricultural zones
194 and regions expecting rapid population expansion in sub-Saharan Africa and South Asia.^{30,31} Analysis
195 in the 2015 Commission projected an additional 1.4 billion person drought exposure events per year
196 by 2100, as a result of population change and climate change.⁵

197 Of particular importance, is the effect that climate change will have on mental health and wellbeing,
198 an issue which is often amplified in low-resource settings which lack the protective social and public
199 health institutions. The Lancet Countdown is currently exploring options to track the mental health
200 impacts of climate change.

201

202 1.6: Human Exposure to Infectious Disease

203 Infectious diseases make significant contributions to the global burden of disease, and many
204 infectious diseases, their vectors and/or reservoirs, are influenced directly or indirectly by climate.³²
205 Distributions and impacts of infectious diseases are already responding to the various dimensions of
206 climate change so far observed, with projections that this will worsen for many infectious diseases in
207 future.³³⁻³⁵

208 Given existing information about climate-sensitive infectious diseases, we will derive a shortlist of
209 'sentinel' diseases or disease groups to road-test the indicator protocol, and then expand the list to
210 include other relevant infectious diseases and following wider input and consultation with infectious
211 disease experts. Examples from three key groups will be tracked: food-borne diseases, and vector-
212 borne and parasitic diseases/zoonotic diseases.³⁶ Each of these groups, and specific diseases within
213 each group, are likely to be affected by climate change in diverse ways. Our aim is to place a finger
214 on the pulse of these impacts at a global scale and facilitate trend tracking through time. For this
215 indicator domain, we will thus leverage surveillance and research networks that monitor and
216 synthesise existing data to model changes in climate change relevant infectious disease impacts
217 and/or risks and exposure.³⁷⁻³⁹ This process will identify sentinel sites (as comprehensive monitoring
218 is not feasible) across a range of geographies. We would welcome suggestions of suitable sites and
219 diseases.

220 A number of sub-indicators will be derived for this purpose, broadly covering the areas of outbreaks,
221 occurrence and spread (of disease, causative agents, or vector or reservoir species), and prevalence
222 and incidence, providing a picture of changing trends in exposure to, and impacts from infectious

223 diseases due to climate change. Four focal metrics proposed for each of these indicators include 1)
224 change in cases observed and predicted in the human population, 2) changes observed or predicted
225 in geographical or temporal extent 3) observed or predicted changes in environmental suitability for
226 sentinel pathogens, vectors or reservoirs, 4) changes in other environmental exposures and
227 confounding factors.

228

229 1.7: Food security and undernutrition

230 Having reliable access to sufficient, affordable and nutritious food can be negatively affected by
231 climate change in many ways. This ranges from the direct impact of drought, flood and heat on
232 harvest yields, through to the health and social impacts of climate change, resulting in unhealthy
233 populations unable to farm or work enough to earn money to purchase food. Furthermore, food
234 trade may be disrupted due to infrastructure damaged by climate shocks.⁴⁰ Populations in low-
235 income countries reliant on rain-fed agriculture are often particularly vulnerable to climate change
236 and weather shocks. These disproportionately affect the availability and cost of staples, as a result of
237 unreliable access to international markets and low food stocks being unable to buffer price spikes.⁴⁰

238 Whilst the health implications of food insecurity are local, international and national drivers are
239 important.⁴¹ Further, measures to ensure climate-resilient food systems also improve food security,
240 public health and community development.⁴⁰ Climate-related food security indicators can address
241 direct availability of food (agricultural production), households' ability to purchase food (rural and
242 urban poverty relative to food prices), and resilience to shocks (food stocks and international trade
243 in grains). The seventh proposed indicator domain will focus on food price indices and food stocks as
244 a proxy for food affordability and availability. Other environmental and socioeconomic factors are
245 likely to be key to understanding food security and undernutrition. To this end, the Lancet
246 Countdown will seek partnership with external activities to fully address this interaction.

247

248

249 [Health Resilience and Adaptation](#)

250 Adaptation interventions designed to minimise the health impacts of climate change are already
251 required, today. The second working group of the Lancet Countdown will focus on the design and
252 deployment of adaptation and resilience interventions. It will particularly draw on data collected for
253 the WHO/UNFCCC Climate and Health Country Profiles, including responses to surveys from national
254 Ministries of Health.⁴²

255

256 2.1: Health adaptation planning

257 Past and ongoing human influence on the atmosphere means we are now committed to climate
258 change for several decades to come. Health and related systems, such as water, sanitation and
259 nutrition, will need to become more resilient and adapt to changing climate conditions, in order to
260 continue to protect and promote health in a changing climate. WHO, UNFCCC and other
261 international agencies are supporting countries to develop the health components of national
262 adaptation plans, and promoting a comprehensive approach to build resilience into the building
263 blocks of health and other relevant systems.^{43,44} This eventual indicator will use the monitoring
264 systems established for SDG indicator 13.2.1, monitoring submissions to the UNFCCC, and survey

265 responses from national Ministries of Health, to track the number of countries that have developed
266 a health adaptation plan, the range of functions covered, and the extent of implementation.

267

268 2.2: Climate services for health

269 Informed adaptation and sustainable development requires the use of climate information for
270 evidence-based decision-making in the health sector. This depends fundamentally upon the
271 availability of relevant, high quality climate and environmental observations, institutional and
272 human capacity to transform climate data into reliable, and relevant climate products and services.
273 The availability, access to, and use of climate services are thus a cornerstone for health adaptation.
274 This should be monitored as an indicator of health sector capacity to help anticipate and prepare for
275 climate risks, appropriately target long- and short-term investments, and avoid potentially
276 maladaptive choices.

277 For the purposes of the Lancet Countdown, we plan to collaborate with the WMO to conduct a
278 periodic survey of National Hydrological and Meteorological Services, to monitor the demand,
279 availability and provision of climate information services provided to the public and national health
280 authorities. Categories of services surveyed may include: sharing of historical climate and
281 hydrological observations, tailored forecasts or monitoring for exposure to hazardous air quality,
282 pollen, extreme heat, floods and storms; or provision of tailored climate scenarios and impact
283 projections. This will also be cross-referenced with WHO surveys of national Ministries of Health to
284 measure the extent to which countries use this information to inform health surveillance and to
285 develop early warning and response systems. An additional dimension to this indicator domain could
286 involve analysing national expenditure on climate information services.

287

288 2.3: Adaptation finance for health

289 Health is widely recognized as a priority for adaptation. For example, over 95% of Least Developed
290 Countries (LDCs) identified health as a priority in their National Adaptation Programmes for Action.⁴⁵
291 However, this is not yet reflected in financial flows, with less than 1.5% of international climate
292 finance for adaptation has been directed to projects specifically addressing health.⁴² This proposed
293 indicator domain will use information from monitoring systems of multilateral and bilateral climate
294 finance, including SDG indicator 13.a.1, as well as survey responses from health ministries, to
295 measure investment of international and domestic resources in health adaptation to climate change.

296

297 [Health co-benefits of mitigation](#)

298 The existence of ancillary health benefits (co-benefits) of climate change mitigation policies provides
299 a powerful incentive to accelerate policy change, since these benefits are experienced in the near-
300 term, as opposed to the long-term benefits of climate change mitigation. As noted, however, such
301 benefits are not automatic, and care is needed to avoid unintended adverse consequences for
302 health. In order to assess progress in climate change mitigation and the potential resultant ancillary
303 health effects (mainly co-benefits), the third working group envisions tracking nine indicators across
304 four systems – energy, transport, food, and healthcare.

305 Here, relevant categories of data include trends in GHG and short lived climate pollutant (SLCP)
306 emissions, indicators relevant to the pathways by which health co-benefits are achieved (air

307 pollution exposures, transport-related physical activity patterns, and dietary survey data), and
308 regulations (e.g. restrictions on polluting vehicles, energy sources, and energy performance) in
309 sectors that are also responsible for GHG/SLCP emissions. Trends in GHG emissions by country can
310 be assessed through the UNFCCC reporting mechanisms and notification is subject to new reporting
311 requirements.

312

313 3.1-3.5: The Energy Sector

314 The energy sector (both production and use) represents the largest single source of anthropogenic
315 GHG emissions globally, producing an estimated two-thirds of such emissions.^{15,46} It is also the
316 predominant source of air pollution, with almost all globally produced sulphur dioxide and nitrogen
317 oxide emissions, as well as around 85% of particulate matter, being produced by energy production
318 and energy use in buildings, industry and transport.⁴⁷

319

320 **3.1: Coal phase-out**

321 Coal use comprises 29% of total global fuel use.⁴⁸ Globally, coal is used to generate 40% of electricity
322 and, among all energy sources for electricity production, coal-fired generation contributes most
323 (50%) to ambient air pollution (and consequently to adverse impacts on health) as well as to CO₂
324 emissions.⁴⁹ Coal is responsible for approximately 60% of global sulphur dioxide emissions. Until
325 recently, coal use grew steadily through to 2014, with China being the major user (over 80% of
326 global growth since 2000 and approximately 50% of total global use).⁴⁹

327 Counts of the number and capacity of coal-fired plants, their use of coal, and their emissions, can be
328 monitored, but more informative would be estimates of the loss of life expectancy attributable to
329 the contribution of coal-fired combustion to ambient air pollution. The estimation of such burdens is
330 theoretically possible, but depends on high quality emissions inventory data, and air pollution
331 modelling of source contributions to human exposure. This is feasible in data rich (primarily OECD)
332 settings, but not universally. The International Energy Agency (IEA) produces Market Reports on coal
333 use and forecasts for both the OECD and non-OECD countries.⁴⁹ The data are derived from country
334 level estimates of installed capacity, fuel consumption or power generation; the fuel mix of coal and
335 emission standards will be used to derive estimates of coal-related air pollution. Initially, this will be
336 feasible in specific geographical locations, with ambition to expand the work globally.

337

338 **3.2: Growth in renewable energy use**

339 Globally, renewable energy from wind, solar thermal, photovoltaic, hydro, tidal, geothermal,
340 biofuels and waste comprised 14% of total primary energy supply, 22% of global electricity
341 generation, and accounted for nearly half of the new generation capacity added in 2014.^{48,50}
342 Renewable energy offers a number of important potential mechanisms for addressing climate
343 change and improving health. Most forms of renewable energy produce no direct emissions related
344 to electricity generation (with the exception of biomass) and therefore help alleviate air pollution
345 exposure. Renewables can also scale and be deployed as decentralised systems, providing greater
346 penetration and provision of modern energy to hard-to-reach populations and health facilities.

347 Renewable energy growth is primarily measured in terms of capacity and total final energy
348 consumption (TFEC). The Lancet Countdown plans to use this as an indicator of growth in renewable

349 energy, using the IEA and International Renewable Energy Agency's (IRENA) regularly published
350 estimates.

351

352 **3.3: Energy access**

353 Access to adequate and clean energy supplies in the household offers numerous benefits to health,
354 and improved life expectancy.^{8,51} In 2013, the IEA estimated that around 1.2 billion people do not
355 have access to electricity and around 2.7 billion people rely on burning unsustainable and inefficient
356 solid fuels for cooking and heating.⁴⁸ The household air pollution that results from these fuels and
357 other sources has an attributable impact of around 4.3 million deaths annually, related to
358 pneumonia, stroke, lung cancer, stroke, heart disease, and COPD.⁵² Although access to electricity is
359 growing, with the current average national electrification rate being 83%, there is enormous
360 variability, with urban access to electricity as low as 1-4% in South Sudan, Liberia, and Central African
361 Republic.^{53,54}

362 For the purposes of the Lancet Countdown on Health and Climate Change, the IEA and World Bank
363 produce national statistics on metrics of energy use based on surveys and data provided by member
364 countries and their own research. These metrics include: energy use per capita, percentage of
365 population with access to non-solid fuels, and percentage of population with access to electricity.
366 The SDG indicators focus on the latter two metrics of energy access. The Lancet Countdown is also
367 exploring the feasibility of monitoring the expansion of micro-grids in low-resource settings, as an
368 important component of the expansion of renewable energy.

369

370 **3.4: Energy access for health facilities**

371 Access to energy is crucial for the delivery of healthcare. Providing adequate lighting, cooling of
372 medicines, controlling indoor thermal exposure, and hot water for washing and sterilization and
373 clinical procedures rely on a consistent delivery of energy. Among low-income countries, healthcare
374 facilities struggle to ensure access to consistent and affordable energy. A review of healthcare
375 facilities in a number of sub-Saharan countries showed on average 26% of those facilities having no
376 access to electricity; 28% had reliable access to electricity, while 7% relied solely on generators.⁵⁵
377 The WHO have proposed a 'multi-tier metric' for assessing electricity access among healthcare
378 facilities and include peak power capacity, daily energy capacity, duration of supply, evening peak
379 hours supply, affordability, quality, reliability, operational sustainability, and environmental
380 sustainability and health.⁵⁶ This metric has yet to be operationalised, but the Lancet Countdown will
381 draw on this measure for reporting on the healthcare sector.

382

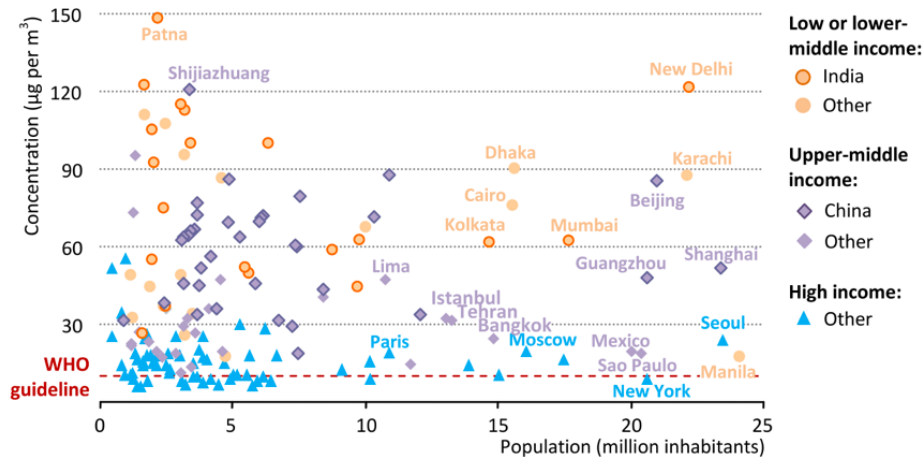
383 **3.5: Ambient and household air pollution exposure**

384 An estimated 18,000 people die every day due to air pollution exposure, making it the world's
385 largest single environmental health risk. This public health emergency is particularly pertinent in
386 urban areas, but also affects non-urban populations here.⁵⁷ As Figure 2 shows, the vast majority
387 (~90%) of Europeans living in urban areas and almost all (98%) of those living in cities in low- and
388 middle-income countries are exposed to air pollution levels in excess of WHO guidelines.^{47,58}
389 Moreover, current evidence suggests health effects at concentrations below guideline levels,

390 without threshold, so that health benefits can be expected the more pollution is reduced regardless
 391 of initial concentrations.

392

Figure 1.7 ▶ Average annual outdoor PM_{2.5} concentrations in selected urban areas



Sources: WHO (2016) Global Urban Ambient Air Pollution Database; Demographia (2015) for population; country groups per income based on World Bank (2016).

393

394 *Figure 2 - Average annual outdoor PM_{2.5} concentrations in selected urban areas (IEA, 2016, Energy*
 395 *and Air Pollution)*⁴⁷

396

397 The WHO's Urban Ambient Air Pollution Database now has annual mean outdoor concentrations of
 398 PM₁₀ and PM_{2.5} for almost 3,000 cities. As part of the Lancet Countdown, this database will provide
 399 an important data source for cities. We propose to track a number of indicators of (urban) air
 400 pollution, primarily annual mean PM_{2.5} and/or PM₁₀ together with selected other pollutants (e.g.
 401 NO₂), using data for individual cities and, where feasible, population weighted averages for other
 402 geographic scales.

403

404

405 3.6-3.7: The Transport Sector

406 Transportation systems – including road vehicles, rail, shipping, and aviation – are a key source of
 407 GHG emissions, contributing 14% of global GHG emissions in 2010.^{47,48,59} It is also a major source of
 408 air pollutants, including particulate matter (PM), nitrogen oxides (NO_x), particulate matter (PM),
 409 sulphur dioxide, carbon monoxide, and volatile organic compounds, and, indirectly, ozone (O₃). The
 410 IEA estimates over half of global NO_x emissions are produced by the transport sector.⁴⁷

411

412 3.6: Deployment of low-emission vehicles

413 Switching to low-emission transport systems is an important component of climate mitigation and
 414 will help reduce concentrations of most ambient air pollutants (though counterintuitively in some

415 settings, may lead to greater concentrations of ozone because of the ‘titration effect’ of NO₂).⁵
416 Personal exposure to traffic-related air pollution is a function of both ambient concentrations (a
417 function of vehicle technology and other factors) and time activity patterns.⁶⁰⁻⁶⁴ The IEA maintains a
418 technical-economic database that includes detailed transport activity, vehicle activity, energy
419 demand, and well-to-wheel GHG and pollutant emissions.⁶⁵ The Global Electric Vehicle Outlook
420 report tracks sales of electric vehicles, and the International Council on Clean Transportation
421 maintains a set of data tables, comparison charts, and a conversion tool for comparing passenger
422 vehicle fuel standards. These types of databases and methods will provide the quantitative backing
423 to this indicator domain for the Lancet Countdown, which will track clean transport technology (e.g.
424 electric vehicles) deployment and sector-specific emission factor trends at a variety of geographic
425 scales.

426

427 **3.7: Active transport infrastructure and uptake**

428 While decarbonizing the vehicle fleet is essential for meeting climate mitigation targets and
429 improving urban air quality, in most settings encouraging the greater uptake of active travel (walking
430 and cycling) for shorter journeys offers the greater opportunity for public health benefit. This is
431 because active travel can lead to appreciable improvement in the levels of physical activity at
432 population level, with all the attendant benefits in terms of reduced risk of cardiovascular disease,
433 selected cancers, dementia, and diabetes, and improvement in mental well-being. Whilst these
434 benefits may be partly offset by increases in exposure to road danger and, in some settings, higher
435 exposure to ambient air pollution, the injury risks can be moderated by policies to improve road
436 safety.⁷

437 Indicators to be considered include (where available) proportion of journeys and distance taken on
438 foot and bicycle in major urban areas. Such data require travel surveys, which are routinely
439 implemented and with comparable methods only in selected (mainly high income) settings. In these
440 cases, data on the duration of active travel, and the number of road crashes that occur could be
441 collected. The contribution of change in active travel to population health could be computed given
442 other population health and activity data, but to date, has seldom been assessed outside research
443 studies.

444

445 **3.8: The Food System**

446 Sub-indicators under this heading will consider how food consumption and production affects and is
447 affected by climate change, and the additional impacts this has on health. There is growing evidence
448 on the benefits to health from more sustainable food systems and dietary change.

449

450 **Consumption**

451 Although all foods contribute to the emission of climate pollutants to different extents, among those
452 with the greatest GHG footprints are meat and dairy products. These also contribute to water
453 scarcity, land use change and erosion, and ultimately increase risks for cardiovascular disease, and
454 some cancers in the case of red and processed meats.⁶⁶ Emissions per unit protein produced are
455 especially high for ruminants (cattle, goat and sheep), as compared to pork and poultry production.
456 Although desirable to track trends in consumption patterns – especially of meat, dairy and

457 vegetables – the calculation of associated GHG emissions in particular, is complex, and so too the
458 computation of health effects. In certain countries, the contribution of livestock to GHG emissions
459 may be less substantial than in most high-income countries. Additionally, in many low- and middle-
460 income countries, animal products may be important, providing an invaluable source of nutrients
461 particularly to children and pregnant women.⁶⁷ We propose measures of consumption of meat,
462 dairy, vegetables and legumes, derived from standardized population dietary surveys and food
463 diaries could be used to track consumption changes. By converting these datasets into *per capita*
464 quantities, these trends could be tracked annually. However, data from (nationally) representative
465 surveys is not widely available. Case-studies may therefore be a useful tool for highlighting the
466 health and climate benefits of reduced meat and dairy consumption.

467

468 **Production**

469 Agricultural production can be a significant contributor to GHG emissions. As such, there is clear
470 room for improvement in water, carbon and nitrogen management in over-fertilized regions (e.g.
471 China and India) to reduce GHG emissions and water pollution from agricultural lands and enhance
472 environmental sustainability.⁶⁸ For example, it is estimated that in the farmlands of China, a nitrogen
473 use efficiency improvement from 31% to 50% would cut synthetic nitrogen use by 41%, and GHG
474 emissions by 39%.⁶⁹ The second element of this indicator domain will track changes in food
475 production and food waste over time and the consequent impacts upon GHG emissions and health.
476 GHG emissions associated with agriculture (including livestock systems and biogeochemical
477 processes) will be quantified using existing models (e.g. DAYCENT or DNDC).⁷⁰⁻⁷²

478 An understanding of the potential for multiple environmental factors to affect food systems, and the
479 nuances within and between countries and cultures is needed. Further work will be required to
480 refine indicators for this area, and the scientific community is invited to suggest potential metrics
481 and data sources.

482

483 3.9: Emissions from the Healthcare System

484 The health sector is a major contributor to GHG emissions, and has both a special responsibility and
485 significant measurable opportunity to lead by example in reducing its carbon footprint.
486 Pharmaceuticals, for example, are associated with high levels of avoidable GHG emissions, and there
487 is nearly always scope for savings in transport and procuring goods needed to support the health
488 system.⁷³ Such actions have already been demonstrated to deliver health, social, environmental, and
489 economic benefits, both immediate and long term. Calculation of the carbon intensity and emissions
490 of the health sector has been achieved in England and the USA (serially in the former), despite
491 complexities in capturing all inputs to provide comparable data over time, place and sub-sector.⁷⁴⁻⁷⁶
492 For the purposes of the Lancet Countdown, we will collect purposive samples from countries where
493 data are available initially to raise the profile of the topic within the health community locally,
494 nationally, and globally.

495

496 **Economics and Finance**

497 Article 2 of the Paris Agreement establishes the importance of ensuring financial flows consistent
498 with a pathway towards a low-carbon economy. The focus of the Lancet Countdown's fourth
499 working group is on the ways in which flows of finance and economic incentives are developing to

500 accelerate progress on health and climate change. Indicators fall into three broad ‘themes’:
501 investment in the low-carbon economy; valuing the health co-benefits of mitigation; and pricing the
502 health externalities of fossil fuels.

503

504 4.1 to 4.3: Investing in the low-carbon economy

505 Having made the case for a comprehensive response to climate change and the resultant health
506 benefits, three of the proposed indicator domains in working group 4 will track investment in the
507 low-carbon economy; specifically in renewable energy, energy efficiency and innovation.

508 The first two are closely linked, measuring changes in annual investments in renewable energy and
509 in energy efficiency. In order to decarbonise the global energy system in order to meet the global
510 climate change commitments in the Paris Agreement, whilst simultaneously managing a rise in
511 demand for energy over the coming decades, low-carbon technologies and energy efficiency must
512 account for around 90% of the \$2.5 trillion global annual investment required by 2035. In 2014, this
513 value stood at 23%.⁷⁷ Data for annual global investment in renewable energy is compiled and
514 reported by Bloomberg New Energy Finance, which may be presented by the Lancet Countdown.
515 Investment in energy efficiency, however, may be more difficult to track, as there is no standard
516 agreed definition on what constitutes energy efficiency investment, which is carried out by a
517 multitude of agents (often without the use of external finance), and is difficult to disaggregate from
518 other activities. One approach is to estimate energy efficiency investment through modelling
519 techniques. Further work will include discussions with the IEA and other organizations to determine
520 the most appropriate definition to employ and how estimates of investment may be calculated.
521 Estimates of total energy system investment are also published frequently by the IEA, allowing a
522 proportional value for low-carbon technologies and energy efficiency to be calculated.

523 The third indicator domain here would track innovation in the low-carbon sector, by measuring
524 annual changes in the generation of patents for low-carbon and energy efficient technologies. The
525 data for such calculations may be found in various databases¹ and would capture the results of a
526 substantial proportion of research and development efforts and funding by both public and private
527 sector actors.

528

529 4.4: Valuing the health co-benefits of climate change mitigation

530 Building on work from working group 3, this indicator domain will aim to capture the costs and
531 savings resulting from the health co-benefits of mitigation, across a variety of sectors. In particular,
532 the health-related economic benefits (or costs) of changes in coal-based electricity generation,
533 conventional car sales (i.e. petrol and diesel), and a rise in active transport. It is estimated that the
534 annual value of the health impacts of ambient air pollution, principally caused by coal-based
535 electricity generation and conventional vehicles, is as high as \$3.5 trillion (~5% Gross World Product)
536 in the OECD (plus India and China).⁷⁸ Estimates of health-related economic benefits that result from
537 mitigation policies would draw on indicators compiled and reported in working group 3 (e.g. coal
538 phase out rates, low-emission vehicle sales and investment in active transport). Depending on the
539 final form of the indicators presented in working group 3, these indicators may be produced either
540 by relatively simple calculations, or through the use of energy system models that consider air
541 pollution aspects of system developments. If the latter approach is required, further development of

¹ For example, the European Patent Office Worldwide Database (PATSTAT).

542 in-house air pollution modelling capabilities, or collaboration with other institutions, would be
543 sought. Furthermore, this indicator domain closely relates to the estimating of health benefits of
544 National Determined Contributions (NDCs) under working group 5; these two indicator domains will
545 be jointly refined to ensure they complement each other.

546

547 4.5-4.7: Pricing the health externalities of fossil fuels

548 The third and final indicator theme within this working group would measure whether we are
549 'getting the prices right' to encourage the development of a low-carbon economy, and the health-
550 related benefits this brings, including ensuring that that inequities are addressed. Three areas of
551 work would fall under this theme. The first concerns the presence of subsidies (such as tax breaks)
552 for fossil fuel production and consumption, which incentivise their use and increase relative costs of
553 renewable alternatives. In 2014, global fossil fuel subsidies stood at around \$490 billion – around
554 four times the level of subsidy afforded to the deployment of renewable energy. Although the
555 reform of such subsidies between 2009 and 2014 means that current subsidy levels are around \$117
556 billion lower than they would otherwise have been, much more needs to be done.⁴⁸ This is
557 recognised by SDG 12c, the indicator for which, when developed, may be employed here. However,
558 further work will be conducted to determine which definition of fossil fuel subsidies may be
559 suitability employed for the purposes of the Countdown.

560 The second indicator domain would cover the spread and strength of carbon pricing, which seeks to
561 internalise the 'market externality' of CO₂ (and other GHG) emissions globally. Carbon pricing
562 instruments currently cover around 12% of global GHG emissions, although with wide ranging values
563 (from under \$1/tCO₂e to around \$130/tCO₂e).⁷⁹ This indicator may consist of two elements; the
564 change in (and absolute level of) the proportion of global GHG emissions to which carbon pricing is
565 applied, and the change in (and absolute value of) the weighted-average global carbon price. These
566 data may be drawn directly from, or calculated based on, the World Bank's annual *State and Trends*
567 *of Carbon Pricing* report.

568 The development of such indicators interact with and complement Indicator domains 4.1-4.3. Whilst
569 the reduction of fossil fuel subsidies and increase in the spread and strength of carbon pricing
570 'pushes' the flow of finances towards the deployment and development of low-carbon and energy
571 efficient technologies and measures, other policies, such as renewable energy subsidies, help to
572 'pull' finance towards such investments. Indicator domains 4.1 - 4.3 implicitly measure the impact
573 generated by both influences.

574 What has been presented thus far do not address potential concerns surrounding the equity of the
575 low-carbon transition, with carbon pricing on fuels having potentially regressive impacts. These
576 impacts may be dampened or avoided with the appropriate public policies, such as environmental
577 tax reform (ETR). ETR involves shifting the burden of tax from 'goods', such as labour or
578 environmentally beneficial products or actions, to 'bads', such as pollution. Such a shift in economic
579 incentives may, when well designed, produce a 'double dividend' of environmental improvement
580 with social and economic benefit.⁸⁰ As such, the third indicator domain under this theme concerns
581 the use of revenue generated by carbon pricing instruments, with qualitative consideration for the
582 intended end-use of this revenue. Further work is required to determine whether revenue from the
583 reduction of fossil fuel subsidies may also be included in this indicator.

584

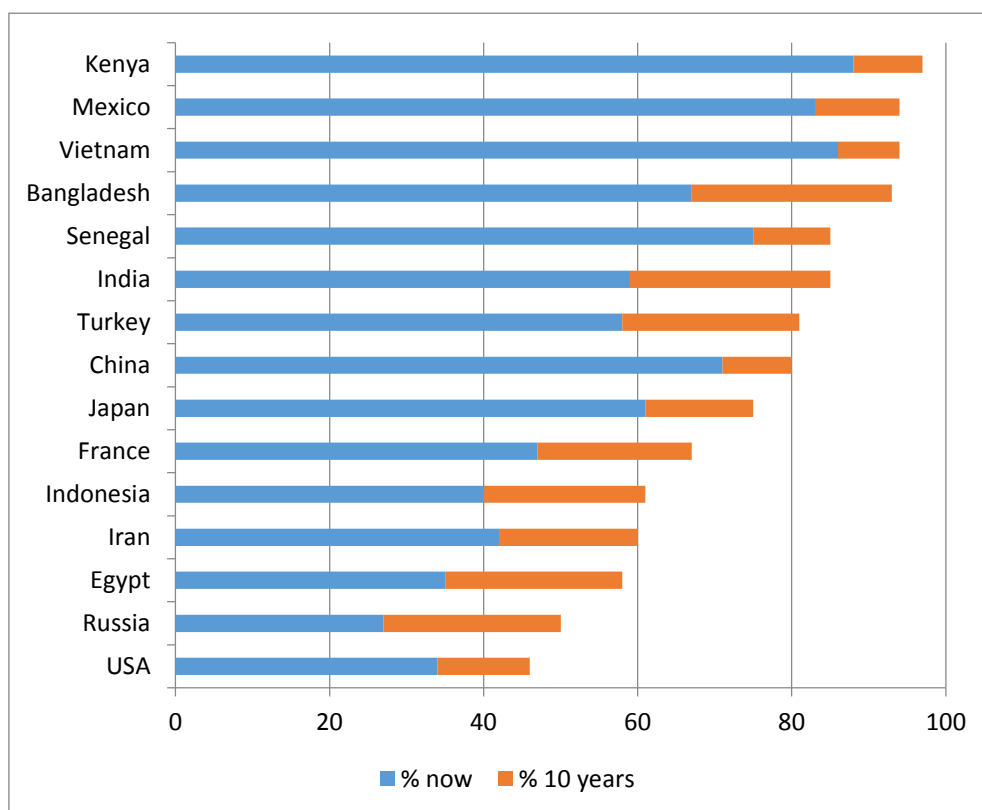
585 Political and Broader Engagement

586 The fifth working group will focus on the broader context within which progress on health and
587 climate change is being made. These indicator domains will track the implementation of political
588 commitments within the UNFCCC, alongside analysis of scientific and public engagement with health
589 and climate change, which both provide background and context for policy implementation.

590

591 5.1: Public engagement in health and climate change

592 Globally, public engagement with climate change is mixed. In two surveys of a range of high-income,
593 middle-income and low-income countries, most people considered that climate change was a 'very
594 serious problem' and 'a major threat', and would impact directly on the conditions for health.^{81,82}
595 Asked when they thought climate change would start to substantially harm people in their country
596 (now, in 10 years, in 25 years, in 50 years, in 100 years, never), the majority of respondents in most
597 countries thought that their citizens were being substantially harmed now. Figure 3 presents the
598 proportions responding 'now' and 'in 10 years'. Given that lack of understanding is one of the largest
599 perceived barriers to individual engagement, the finding that framing climate change as a public
600 health issue enhances engagement, is significant.⁸³⁻⁸⁵



601

602 *Figure 3.* Proportions of the population who regard climate as substantially harming people in their
603 country now or within 10 years (World Bank, 2009⁸²)

604

605 The Lancet Countdown will bring together evidence on changes in public understanding relating to
606 health and climate change – more specifically, in terms of perceptions of threats and opportunities

607 in the response. One possible long-term, but resource-intensive approach would be using phone-
608 and online-based public opinion polling techniques across a range of countries and settings. In the
609 interim, the Lancet Countdown proposes to undertake an annual analysis of social media to build a
610 broad understanding of public perceptions , and track the evolution of public engagement and
611 knowledge. The Lancet Countdown’s social media analysis will track levels of public engagement
612 with health and climate change over time and identify key events that cause spikes in engagement;
613 whether such spikes result in longer-term engagement; and countries where engagement is
614 particularly high or low.

615

616 5.2 and 5.3: Academic publications on health and climate change & its inclusion within
617 the medical curricula

618 The Lancet Countdown will also track scientific engagement with health and climate change. Annual
619 reviews of published scientific articles, using a bibliometric search relating to “climate” and “health”
620 provides a potentially useful indicator, demonstrating research trends and coverage. Historical
621 trends and research gaps including disciplinary and geographical focus could also be explored. This
622 study will provide a more extensive and inclusive overview than previously published reports and
623 reviews, and may also be a useful resource for informing future research funding by gaps and
624 priorities. A study protocol for this scoping review has been written and accepted for publication.⁸⁶

625 To accompany an analysis of the academic literature, the Lancet Countdown will also follow the
626 extent to which health and climate change is incorporated into the educational curricula of health
627 professionals (initially, medical professionals), around the world. This analysis would determine not
628 just the inclusion of climate change in these curricula, but also the emphasis on these issues (for
629 example, whether this subject matter is mandatory or optional). This may be used to provide
630 background context, rather than as an indicator in its own right.

631

632 5.4 and 5.5: Health and climate change in the UNFCCC and UNGA and implementation
633 and estimated health benefits of the NDCs

634 At the international level, the UNFCCC negotiations and the Paris Agreement provide an important
635 framework for mitigation and adaptation policies. Indicator domains 5.4 and 5.5 would both look to
636 provide an overview of the extent to which human health and wellbeing is considered within these
637 political processes. Indicator domain 5.4 would examine the inclusion of health within the transcripts
638 of the high-level statements delivered at the UNFCCC’s annual Conference of the Parties, and the UN
639 General Assembly. The former has previously been compiled on an ad hoc basis and would require
640 additional work, but a database of the latter is readily available. The Lancet Countdown would
641 analyse high-level statements to monitor how the inclusion and framing of health and climate
642 change evolves over time. This work could be back-dated to extend this analysis to historical high-
643 level statements, thus providing a longer time series to analyse.

644 The final indicator domain for the Lancet Countdown would estimate the health benefits or
645 disadvantages of the NDCs. Initially, the NDCs and subsequent communiques to the UNFCCC will be
646 explored for substantive references and considerations of the relationship between public health
647 and climate change. Over time, it is hoped that the potential health co-benefits of mitigation, from a
648 reduction in air pollution, may be modelled. This would be conducted in a similar way to the analysis
649 conducted by the Day, Höhne, and Gonzales in their 2015 assessment.⁸⁷ Many of these changes may

650 be captured by the UNFCCC’s NAZCA (non-state actor zone for climate action) process – a potential
651 source for future indicators and monitoring.

652

653 Conclusion

654 The Lancet Countdown: Tracking Progress on Health and Climate Change is an international, multi-
655 disciplinary research collaboration, dedicated to tracking progress on health and climate change
656 from 2016 to 2030.

657 The Lancet Countdown will be governed by a board comprising the research leads for each working
658 group, and coordinated by a smaller executive team responsible for supporting the working groups
659 to deliver and communicate the academic content. Over the coming months, it will work to establish
660 an international advisory board, to provide strategic direction to the process and assist with policy
661 and stakeholder engagement. This advisory board will be made up of academics and senior health
662 and climate change experts from a broad range of geographies.

663 The indicators and indicator domains proposed in this paper are intended to form the foundation of
664 our process, and will be refined and developed further over the coming months and throughout the
665 Lancet Countdown’s process. We invite ongoing direct input on the content, methods, and data of
666 each of these, through the forms available at www.LancetCountdown.org/IndicatorConsultation

667

668

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671 [Contributors, Declaration of Interests, Acknowledgements]

672

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872 Appendices

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874 Appendix 1: Re-considering the health and climate indicators using an
875 adaptation of the DPSEEA Framework:
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Red indicates available data, orange data which can be obtained by data processing or are available only for selected sites and blue markers which require modelling or special data gathering. Related Sustainable Development Goals are indicated where relevant.

Driving Forces	Pressures	States/Exposures	Effects	Actions (Responses)	
				Specific	General
<i>Dependence on energy from combustion of fossil fuels; other human activities leading to emissions of climate active pollutants (CAPs), including agriculture and land use change</i>	<i>Emission of CAPs → altered concentration in the atmosphere</i>	<i>Increased radiative forcing → global warming, with regional variations</i>	<i>Impacts on:</i> <ul style="list-style-type: none"> • health • productivity 	(1) Measures to adapt to the effects of climate change (2) Measures to mitigate climate change	
MARKERS					
<ul style="list-style-type: none"> • <i>Per capita use of energy (kw.hr.person⁻¹) [national, reported data]</i> • <i>Per capita energy use per US\$ GDP (kw.hr.US\$M⁻¹) [national, reported data]</i> 	<ul style="list-style-type: none"> • <i>Annual total and per capita emissions of climate active pollutants (Gtonne CO₂.e) [country,]</i> • <i>CO₂ concentrations in atmosphere (ppmv) [global, monitored data Mauna Loa]</i> 	<i>Mean of (warm season) daily maximum or mean temperatures [city, observed series]</i>	<i>Heat- (and cold-) related mortality/morbidity [city, requires epi modelling]</i>	<ul style="list-style-type: none"> • <i>Implementation of heatwave plans [national]</i> • <i>Building regulation for protection against heat risks [national]</i> 	<ul style="list-style-type: none"> • <i>Health and climate change in the UNFCCC and UNGA high-level statements</i> • <i>Academic publication and funding on health and climate change</i> • <i>Integration of health in national adaptation plans</i> • <i>Direct and indirect fossil fuel subsidies</i>
		<i>Annual mean of wet bulb globe temperatures for working hours [city, derived variable]</i>	<i>Reduction in labour productivity from excess heat [national, model-based from WBGT]</i>		
		<i>Annual total population and proportion affected by flooding</i>	<i>Flood-related mortality and morbidity (including mental)</i>		

		[national]	health) [national, immediate observed deaths estimable only]		[national] <ul style="list-style-type: none"> Adaptation finance for health [definition] Change in annual investment in energy efficiency Public opinion on health and climate change [national, needs definition]
		Periods of low rainfall resulting in reduced crop yields [national]	Nutrition-related growth and mortality impacts in children [national, requires modelling]		
		Warm season mean of ozone concentrations? [city, not specific to climate change]	Deaths/morbidity from ozone concentrations [city, modelled]		
		Transmissions potential for specific vector-borne diseases (malaria, dengue) [sentinel sites, modelled from weather data only]	Burdens (cases) of specific vector-borne diseases [national, sentinel sites]		<p>Note</p> <p>SDG 12.c.1 Fossil-fuel subsidy per unit GDP</p> <p>SDG 13.2.1 Operationalization of adaptation plan</p>
Fossil fuel combustion for electricity generation (Tera-joule per million population) [national, reported data]	<ul style="list-style-type: none"> Number (net capacity in Gigawatts) of coal fired power stations [national, reported data] Emissions of CAPs from coal fired electricity production [national] 	Ambient concentration (annual mean) of PM _{2.5} from coal fired power generation [city, requires modelling or method of source apportionment]	Mortality/morbidity attributable to ambient PM _{2.5} derived from coal fired generation [city, model based]	<ul style="list-style-type: none"> Growth in renewable energy resources [national, reported data] Renewable energy patent generation and innovation [national, requires definition] 	<ul style="list-style-type: none"> Cost-savings from the health co-benefits Coverage and strength of carbon pricing <p>Note</p> <p>SDG 13.a.1 Mobilized US\$/year towards \$100 billion commitment for CC mitigation</p>
			Note: SDG 3.9.1 mortality attributable to household and ambient AP	Note: SDG 7.1.2 proportion of population with primary reliance on clean fuels	
			SDG 11.6.2		

			annual mean PM _{2.5} in cities	SDG 7.2.1 renewable energy as share of final energy consumption	
<i>Per capita</i> energy consumption, housing sector [national, reported data] Proportion of housing which is energy inefficient [national, requires definition]	Energy efficiency of housing stock (mean energy requirement to maintain standardized heating and/or cooling regime, as well as cooking and other household needs) [national, housing survey + modelling]		Ancillary effects on deaths/morbidity relating to exposures of the indoor environment [national, model-based in selected locations only]	Building regulation for energy efficiency [national]	
<ul style="list-style-type: none"> • Mean <i>per capita</i> energy use for transport (kj.person⁻¹.year⁻¹) [national, reported data] • Transport: <i>per capita</i> distance travelled by motorized transport [national or city, survey data] 	Transport-related emissions of Climate Active Pollutants and ambient air pollutants [city, emissions inventories (where available)]	Ambient air PM _{2.5} concentrations attributable to transport-related emissions [city, requires modelling or method of source apportionment]	Reduction in deaths/morbidity from (transport-related contribution to) physical activity [national or city, definition of counterfactual] Deaths from transport-related PM _{2.5} exposure [city, model-based]	<ul style="list-style-type: none"> • Deployment of low-emission vehicles • Active transport infrastructure and uptake [city, definition] 	
<i>Per capita</i> energy consumption, food and agriculture sector [national, reported data]		<i>Per capita</i> consumption of red meat & dairy products (kilojoules per person) [national, survey based]	Mortality/morbidity attributable to consumption of red meat and dairy products [national, modelled and setting specific]	Note SDG 12.3.1 Global food loss index	
[Carbon footprint of healthcare systems]				Implementation and health benefits of the NDCs [national, requires special data gathering and modelling]	

Appendix 2: Indicators from other monitoring processes relevant to the Lancet Countdown

The table below maps the Lancet Countdown’s indicators with those used for the Sustainable Development Goals, Sendai Framework for Disaster Risk Reduction, ClimateWorks Foundation Carbon Transparency Initiative, and WHO Climate and Health Country Profiles. It is important to note that while the intent of these initiatives is for eventual global coverage, they are still in development and so currently their implementation is limited to some countries. For example, the ClimateWorks Foundation Carbon Transparency Initiative has currently used their indicators for China, the EU, India, Mexico, and the US and WHO have Climate and Health Country Profiles for 40 countries.

Working Group	Lancet Countdown Indicator Domains	Sustainable Development Goals	Sendai Framework for Disaster Risk Reduction	ClimateWorks Foundation Carbon Transparency Initiative	WHO Climate and Health Country Profiles
Health Impacts and Climate Change	Track populations’ exposure to heat	1.5.1 Number of deaths, missing persons and persons affected by disaster per 100,000 people 1.5.3 Number of countries with national and local disaster risk reduction strategies	A-1. Number of deaths and missing due to hazardous events per 100,000. A-2. Number of deaths due to hazardous events. A-3. Number of missing due to hazardous events.		Warmer and/or fewer cold days and nights over most land areas. Warmer and/or more frequent hot days and nights over most land areas. Heat-related mortality.
	Track changes in labour productivity		B-1. Number of affected people per 100,000.		Heat stress and work productivity.
	Track populations’ exposure to heatwaves	6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	B-2. Number of injured or ill people due to hazardous events.		Warm spells/heatwaves. Frequency and/or duration increases over most land areas. Heat-related mortality.
	Track populations’ exposure to floods		B-3. Number of people who left their places of residence due to hazardous events.		Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation.

			<p>B-3a. Number of evacuated people due to hazardous events.</p> <p>B-3b. Number of relocated people due to hazardous events.</p> <p>B-4. Number of people whose houses were damaged due to hazardous events.</p> <p>B-5. Number of people whose houses were destroyed due to hazardous events.</p> <p>B-6. Number of people who received food relief aid due to hazardous events.</p>		<p>Increases in intense tropical cyclone activity.</p> <p>Increased incidence and/or magnitude of extreme high sea level.</p> <p>River flooding.</p> <p>Exposure to flooding due to sea level rise.</p>
	Track populations' exposure to droughts				Increases in intensity and/or duration of drought.
	Track the spread of infectious diseases	<p>3.3.3 Malaria incidence per 1,000 population</p> <p>3.3.5 Number of people requiring interventions against neglected tropical diseases</p>			Populations at risk of infectious and vector-borne diseases for malaria and dengue fever.
	Track populations' food security	<p>2.1.1 Prevalence of undernourishment</p> <p>2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)</p> <p>2.2.1 Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age</p> <p>2.2.2 Prevalence of malnutrition (weight for height >+2 or <-2</p>	<p>C-2. Direct agricultural loss due to hazardous events.</p>		

		standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)			
		2.4.1 Proportion of agricultural area under productive and sustainable agriculture			
Health Resilience and Adaptation	Track the integration of health in National Adaptation Plans	3.d.1 International Health Regulations (IHR) capacity and health emergency preparedness 11.b.1 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030	E-3. Number of countries that integrate climate and disaster risk into development planning.		Governance and policy.
	Track climate services for health	13.2.1 Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other)	D-2. Number of health facilities destroyed or damaged by hazardous events.		Vulnerability, impact and adaptation (health) assessments. Health adaptation strategies and action plans. Preparedness, risk management and integrated risk monitoring.
	Track adaptation finance for health	13.3.2 Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and			Awareness raising and capacity building. Financing.

		technology transfer, and development actions			
Health Co-Benefits of Mitigation	Track the phase-out of coal			Share amount of coal in total final energy consumption—that is, the share of an economy’s energy derived from coal. Share of electricity from coal generation.	
	Track the growth in renewable energy resources	7.1.2 Proportion of population with primary reliance on clean fuels and technology 7.2.1 Renewable energy share in the total final energy consumption		Share amount of renewable energy in total final energy consumption—that is, an economy’s share of energy derived from renewable sources. Share of electricity from renewable energy generation.	
	Track energy access	7.1.1 Proportion of population with access to electricity			
	Track energy access for health facilities	3.8.1 Coverage of essential health services (defined as the average coverage of essential services based on tracer interventions that include reproductive, maternal, newborn and child health, infectious diseases, non-communicable diseases and service capacity and access, among the general and the most disadvantaged population) 3.b.1 Proportion of the population with access to affordable medicines and vaccines on a sustainable basis			
	Track ambient air pollution exposure	3.9.1 Mortality rate attributed to household and ambient air pollution 11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and			Current exposures and health risks due to air pollution, including outdoor air pollution exposure, short-lived climate pollutants, and household air

		PM10) in cities (population weighted)			pollution.
	Track the deployment of low emission vehicles			<p>Share of new vehicles in a particular geography that are electric drive rather than internal combustion engine vehicles.</p> <p>Share of electric drive vehicles for the light-duty fleet in a particular year.</p>	
	Track active transport infrastructure and uptake	11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities		<p>Total terrestrial passenger kilometers, meaning the total number of kilometers that a population travels, including on private, public, and passenger rail.</p> <p>Number of kilometers travelled in terrestrial modes—private, public, and rail—on a per capita basis.</p> <p>Total number of kilometers travelled in private modes—light-duty vehicles, two wheelers, and three-wheelers.</p> <p>Total number of kilometers travelled in private modes—light-duty vehicles, two wheelers, and three-wheelers—on a per capita basis.</p> <p>Total number of kilometers travelled in public modes—bus and rail.</p> <p>Total number of kilometers travelled in public modes—bus and rail—on a per capita basis.</p>	

				<p>Total number of vehicle kilometers travelled in private modes—light-duty vehicles, two-wheelers, and three-wheelers.</p> <p>Share of passenger kilometers associated with public transport—bus and rail.</p> <p>Total share of electricity in the energy mix for all terrestrial transport—private, public, and freight modes.</p> <p>Share of kilometers associated with private modes of transport—light-duty, two wheelers, and three-wheelers.</p>	
	Track food consumption and production	<p>11.3.1 Ratio of land consumption rate to population growth rate</p> <p>12.1.1 Number of countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or a target into national policies</p> <p>12.3.1 Global food loss index</p>		<p>Total amount of greenhouse gas emissions associated with the Agriculture Sector.</p> <p>Total amount of greenhouse gas emissions associated with the Agriculture Sector from direct sources in production and onsite energy use.</p> <p>Total amount of greenhouse gas emissions associated with the Agriculture Sector from electricity.</p> <p>Size of a herd of cattle in a given geography and year on a per capita basis. This metric does not include dairy cattle.</p>	

				Share of agricultural emissions associated with non-dairy cattle.	
				Share of agricultural emissions associated with fertilizers.	
				Greenhouse gas emissions intensity associated with agriculture on a per capita basis.	
	Track the carbon footprint of healthcare systems				Annual greenhouse gas emissions by sector (metric tonnes in CO2-equivalent) – although not for healthcare.
Finance and Economics	Track change in annual investment in renewable energy	7.2.1 Renewable energy share in the total final energy consumption			
	Track change in annual investment in energy efficiency	7.a.1 Mobilized amount of United States dollars per year starting in 2020 accountable towards the \$100 billion commitment for climate finance			
	Track low-carbon technology patent generation and innovation				
	Track the value the health co-benefits of climate change mitigation				
	Track direct and indirect fossil fuel subsidies	12.c.1 Amount of fossil-fuel subsidies per unit of GDP (production and consumption) and as a proportion of total national expenditure on fossil fuels			
	Track the coverage and strength of carbon pricing				
	Equity of the low-carbon transition				

Political and Broader Engagement	Track public, civil society and community mobilisation on health and climate change				
	Track academic publications on health and climate change				
	Track health and climate change in the UNFCCC and UNGA high-level statements				Governance and policy.
	Track the inclusion of health and climate change within medical and public health curricula	<p>12.8.1 Extent to which (i) global citizenship education and (ii) education for sustainable development (including climate change education) are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment</p> <p>13.3.1 Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula</p>			
	Track the implementation and estimated health benefits of the Nationally Determined Contributions	13.2.1 Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan,			Governance and policy.

		nationally determined contribution, national communication, biennial update report or other)			
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