

The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health

Article

Accepted Version

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1 The 2017 Report of
2 The Lancet Countdown on
3 Health and Climate Change
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6 *From 25 years of inaction to a global*
7 *transformation for public health*
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217 List of Abbreviations

218	A&RCC – Adaptation & Resilience to Climate Change	268	NDCs = Nationally Determined Contributions
219	AAP – Ambient Air Pollution	269	NHMSs – National Meteorological and Hydrological Services
220	AUM – Assets Under Management	270	NHS- National Health Service
221	BEV – Battery Electric Vehicle	271	NO _x – Nitrogen Oxide
222	CDP – Carbon Disclosure Project	272	OECD – Organization for Economic Cooperation and Development
223	CFU – Climate Funds Update	273	PHEV – Plug-in Hybrid Electric Vehicle
224	CO ₂ – Carbon Dioxide	274	PM _{2.5} – Fine Particulate Matter
225	COP – Conference of the Parties	275	PV – Photovoltaic
226	COPD – Chronic Obstructive Pulmonary Disease	276	SDG – Sustainable Development Goal
227	CPI – Consumer Price Indices	277	SDU – Sustainable Development Unit
228	DALYs – Disability Adjusted Life Years	278	SHUE – Sustainable Healthy Urban Environments
229	DPSEEA – Driving Force-Pressure-State-Exposure-Effect-Action	279	SO ₂ – Sulphur Dioxide
230	ECMWF – European Centre for Medium-Range Weather Forecasts	280	SSS – Sea Surface Salinity
231	EJ – Exajoule	281	SST – Sea Surface Temperature
232	EM-DAT – Emergency Events Database	282	tCO ₂ – Tons of Carbon Dioxide
233	ERA – European Research Area	283	tCO ₂ /TJ – Total Carbon Dioxide per Terajoule
234	ETR – Environmental Tax Reform	284	TJ – Terajoule
235	ETS – Emissions Trading System	285	TPES – Total Primary Energy Supply
236	EU – European Union	286	TWh – Terawatt Hours
237	EU28 – 28 European Union Member States	287	UN – United Nations
238	FAO – Food and Agriculture Organization of the United Nations	288	UNFCCC – United Nations Framework Convention on Climate Change
239	FAZ – Frankfurter Allgemeine Zeitung	289	UNGA – United Nations General Assembly
240	FISE – Social Inclusion Energy Fund	290	UNGD – United Nations General Debate
241	GBD – Global Burden of Disease	291	VC – Vectorial Capacity
242	GDP – Gross Domestic Product	292	WHO – World Health Organization
243	GHG – Greenhouse Gas	293	WMO – World Meteorological Organization
244	GtCO ₂ – Gigatons of Carbon Dioxide		
245	GW – Gigawatt		
246	GWP – Gross World Product		
247	HAB – Harmful Algal Blooms		
248	HIC – High Income Countries		
249	ICS – Improved Cook Stove		
250	IEA – International Energy Agency		
251	IHR – International Health Regulations		
252	IPC – Infection Prevention and Control		
253	IPCC – Intergovernmental Panel on Climate Change		
254	IRENA – International Renewable Energy Agency		
255	LMICs – Low and Middle Income Countries		
256	LPG – Liquefied Petroleum Gas		
257	Mt – Megaton		
258	MtCO ₂ e – Metric Tons of Carbon Dioxide Equivalent		
259	NAP – National Adaptation Plan		

298

299 Executive Summary

300

301 The Lancet Countdown tracks progress on the relationships between human health and climate
302 change, providing an independent assessment of global progress to implement the Paris Agreement,
303 and the health implications of these actions.

304 It follows on from the work of the 2015 Lancet Commission, which concluded that anthropogenic
305 climate change threatens to undermine the last 50 years of gains in public health, and conversely,
306 that a comprehensive response to climate change could be “the greatest global health opportunity
307 of the 21st century”.

308 The Lancet Countdown exists as a collaboration between 24 academic institutions and inter-
309 governmental organisations, based in every continent, and with representation from a wide range of
310 disciplines, including: climate scientists, ecologists, economists, engineers, experts in energy, food
311 and transport systems, geographers, mathematicians, social and political scientists, public health
312 professionals, and physicians. The collaboration reports annual indicators across five domains:
313 climate change impacts, exposures and vulnerability; adaptation planning and resilience for health;
314 mitigation actions and health co-benefits; economics and finance; and public and political
315 engagement.

316 The 2017 key messages from its 40 indicators in its first annual report are summarised below.

317

318 **The human symptoms of climate change are unequivocal and potentially irreversible – affecting**
319 **the health of populations around the world, today. Whilst these effects will disproportionately**
320 **impact the most vulnerable in society, every community will be affected.**

321 The impacts of climate change are disproportionately affecting the health of vulnerable populations,
322 and those in low- and middle-income countries. By undermining the social and environmental
323 determinants that underpin good health, it exacerbates social, economic and demographic
324 inequalities with the effects eventually felt by all populations.

325 The evidence is clear that exposure to more frequent and intense heatwaves are increasing, with an
326 estimated 125 million additional vulnerable adults exposed to heatwaves from 2000 to 2016
327 (Indicator 1.2). Higher ambient temperatures have resulted in estimated reduction of 5.3% in labour
328 productivity, globally, from 2000 to 2016 (Indicator 1.3). Taken as a whole, a 44% increase in
329 weather-related disasters has been observed since 2000, with no clear upward or downward trend
330 in the lethality of these extreme events (Indicator 1.4), potentially suggesting the beginning of an
331 adaptive response to climate change. Yet, the impacts of climate change are projected to worsen
332 over time, with current levels of adaptation becoming insufficient in the future. The total value of
333 economic losses that resulted from climate-related events has been increasing since 1990, and
334 totalled \$129 billion in 2016, with 99% of these losses in low-income countries uninsured (Indicator
335 4.4). Additionally, over the longer-term, altered climatic conditions are contributing to growing
336 vectorial capacity for the transmission of dengue fever by *Aedes aegypti*, reflecting an estimated
337 9.4% increase since 1950 (Indicator 1.6).

338 If governments and the global health community do not learn from the past experience of HIV/AIDS
339 and the recent outbreaks of Ebola and Zika virus, another slow response will result in an irreversible
340 and unacceptable cost to human health.

341

342 **The delayed response to climate change over the past 25 years has jeopardised human life and**
343 **livelihoods.**

344 Since the UN Framework Convention on Climate Change (UNFCCC) commenced global efforts to
345 tackle climate change in 1992, most of the indicators tracked by the Lancet Countdown have either
346 shown limited progress, particularly with regards to adaptation, or moved in the wrong direction,
347 particularly in relation to mitigation. Most fundamentally, carbon emissions, and global
348 temperatures, have continued to rise..

349 A growing number of countries are assessing their vulnerabilities to climate change, and are
350 increasingly developing adaptation and emergency preparedness plans, and providing climate
351 information to health services (Indicators 2.1, 2.3-2.6). The same is seen at the city-level, with over
352 449 cities around the world reporting having undertaken a climate change risk assessment (Indicator
353 2.2). However, the coverage and adequacy of such measures in protecting against the growing risks
354 of climate change to health remains uncertain. Indeed, health and health-related adaptation funding
355 accounts for 4.6% and 13.3% of total global adaptation spending, respectively (Indicator 4.9).

356 Whilst there has been some recent progress in strengthening health resilience to climate impacts, it
357 is clear that adaptation to new climatic conditions can only protect up to a point; an analogy to
358 human physiology is useful here. The human body can adapt to insults caused by a self-limiting
359 minor illness with relative ease. However, where disease steadily worsens, positive feedback cycles
360 and limits to adaptation are quickly reached. This is particularly true when many systems are
361 affected, and where the failure of one system may impact on the function of another, as is the case
362 for 'multi-organ system failure', or where the body has already been weakened through repeated
363 previous diseases or exposures. The same is true for the health consequences of climate change. It
364 acts as a threat multiplier, compounding many of the issues communities already face, and
365 strengthening the correlation between multiple health risks, making them more likely to occur
366 simultaneously. Indeed, it is not a 'single system disease', instead, often acting to compound existing
367 pressures on housing, food and water security, poverty, and many of the determinants of good
368 health. Adaptation has limits, and prevention is better than cure to prevent potentially irreversible
369 effects of climate change.

370 Progress in mitigating climate change since the signing of the UNFCCC has been limited across all
371 sectors, with only modest improvements in carbon emission reduction from electricity generation.
372 Whilst there are increasing levels of sustainable travel in Europe and some evidence of decline in
373 dependence on private motor vehicles in cities in the USA and Australia, the situation is generally
374 less favourable in cities in emerging economies (Indicator 3.7). This, and a slow transition away from
375 highly-polluting forms of electricity generation, has yielded a modest improvement in air pollution in
376 some urban centres. However, global population-weighted PM_{2.5} exposure has increased by 11.2%
377 since 1990 and some 71.2% of the 2971 cities in the WHO air pollution database exceed
378 recommendations of annual fine particulate matter exposure (Indicator 3.5). The strength and
379 coverage of carbon pricing covers only 13.1% of global anthropogenic CO₂ emissions, with the
380 weighted average carbon price of these instruments at 8.81USD/tCO₂e in 2017 (Indicator 4.7).
381 Furthermore, responses to climate change have yet to fully take advantage of the health co-benefits

382 of mitigation and adaptation interventions, with action taken to-date only yielding modest
383 improvements in human wellbeing. In part, this reflects a need for further evidence and research on
384 these ancillary effects and the cost-savings available. However, it also reflects a need for more
385 joined-up policymaking across health and non-health ministries of national governments.

386 This delayed mitigation response puts the world on a 'high-end' emissions trajectory, resulting in
387 global warming of between 2.6°C and 4.8°C of warming by the end of the century.

388

389 **The voice of the health profession is essential in driving forward progress on climate change and**
390 **realising the health benefits of this response.**

391 This report, and previous Lancet Commissions, have argued that the health profession has not just
392 the ability but the responsibility to act as public health advocates, communicating the threats and
393 opportunities to the public and policymakers, and ensuring climate change is understood as being
394 central to human wellbeing.

395 There is evidence of growing attention to health and climate change in the media and in academic
396 publications, with global newspaper coverage of the issue increasing 78% and the number of
397 scientific papers more than tripling, since 2007 (Indicator 5.1.1 and 5.2). However, despite these
398 positive examples, the 2017 indicators make it clear that further progress is urgently required.

399

400 **Whilst progress has historically been slow, the last five years have seen an accelerated response,**
401 **and the transition to low-carbon electricity generation now appears inevitable, suggesting the**
402 **beginning of a broader transformation. In 2017, momentum is building across a number of sectors,**
403 **and the direction of travel is set, with clear and unprecedented opportunities for public health.**

404 In 2015, the Lancet Commission made 10 recommendations to governments, to accelerate action
405 over the following five years. The Lancet Countdown's 2017 indicators track against these 2015
406 recommendations, with results suggesting that discernible progress has been made in many of these
407 areas, breathing life into previously stagnant mitigation and adaptation efforts. Alongside the Paris
408 Agreement, these provide reason to believe that a broader transformation is under way.

409 *Recommendation 1) Invest in climate change and public health research:* since 2007, the number of
410 scientific papers on health and climate change has more than trebled (Indicator 5.2).

411

412 *Recommendation 2) Scale-up financing for climate-resilient health systems:* spending on health
413 adaptation is currently at 4.63% (16.46 billion USD) of global adaptation spend; and in 2017, health
414 adaptation from global development and climate financing mechanisms is at an all-time high –
415 although absolute figures remain low (Indicators 4.9 and 4.10).

416

417 *Recommendation 3) Phase-out coal-fired power:* In 2015, more renewable energy capacity (150GW)
418 than fossil fuel capacity was added to the global energy mix. Overall, annual installed renewable
419 generation capacity (almost 2000 GW) exceeds that for coal, with about 80% of this recently added
420 renewable capacity located in China (Indicator 3.2). Whilst investment in coal capacity has increased
421 since 2006, in 2016 this turned and declined substantially (Indicator 4.1) and several countries have
422 now committed to phasing-out coal.

423

424 *Recommendation 4) Encourage a city-level low-carbon transition, reducing levels of urban pollution:*

425 Despite historically modest progress over the last two decades, the transport sector is approaching a
426 new threshold, with electric vehicles expected to reach cost-parity with their non-electric
427 counterparts by 2018 – a phenomenon that was not expected to occur until 2030 (Indicator 3.6).

428
429 *Recommendation 6) Rapidly expand access to renewable energy, unlocking the substantial economic*
430 *gains available from this transition:* Every year since 2015, more renewable energy has been added
431 to the global energy mix than all other sources, and in 2016, global employment in renewable energy
432 reached 9.8 million, over one million more than are employed in fossil fuel extraction. The transition
433 has become inevitable. However, in the same year, 1.2 billion people still did not have access to
434 electricity, with 2.7 billion people relying on the burning of unsafe and unsustainable solid fuels
435 (Indicators 3.3, 4.6 and 3.4).

436
437 *Recommendation 9) Agree and implement an international treaty which facilitates the transition to a*
438 *low-carbon economy:* In December 2015, 195 countries signed the Paris Agreement, which provides
439 a framework for enhanced mitigation and adaptation, and pledges to keep the global mean
440 temperature rise to “well below 2°C”. Going forward, a formal Health Work Programme within the
441 UNFCCC would provide a clear and essential entry point for health professionals at the national
442 level, ensuring that the implementation of the Paris Agreement maximises the health opportunities
443 for populations around the world.

444
445 Following the United States government’s announced intention to withdraw from the Paris
446 Agreement, the global community has demonstrated overwhelming support for enhanced action on
447 climate change, affirming clear political will and ambition to reach the treaty’s targets. The
448 mitigation and adaptation interventions committed to under the Paris Agreement have
449 overwhelmingly positive short- and long-term health benefits, but greater ambition is now essential.
450 Whilst progress has been historically slow, there is evidence of a recent turning point, with
451 transitions in sectors crucial to public health accelerating towards a low-carbon world. Whilst these
452 efforts must be greatly accelerated and sustained over the coming decades in order meet these
453 commitments, recent policy changes and the indicators presented here suggest that the direction of
454 travel is set.

455 From 2017 until 2030, the Lancet Countdown: Tracking Progress on Health and Climate Change will
456 continue its work, reporting annually on progress implementing the commitments of the Paris
457 Agreement, future commitments that build on them, and the health benefits that result.

458 Introduction

459 Climate change has serious implications for our health, wellbeing, livelihoods and the structure of
460 organised society. Its direct effects result from rising temperatures, and changes in the frequency
461 and strength of storms, floods, droughts, and heatwaves – with physical and mental health
462 consequences. Its impacts will also be mediated through less direct pathways, including changes in
463 crop yields, the burden and distribution of infectious disease, and in climate-induced population
464 displacement and violent conflict.¹⁻³ Whilst many of these effects are already being experienced,
465 their progression in the absence of climate change mitigation will greatly amplify existing global
466 health challenges and inequalities.⁴ It threatens to undermine many of the social, economic and
467 environmental drivers of health, which have contributed greatly to human progress.

468 Urgent and substantial climate change mitigation will help to protect human health from the worst
469 of these impacts, with a comprehensive and ambitious response to climate change potentially
470 transforming the health of the world's populations.⁴ The potential benefits and opportunities are
471 enormous, including cleaning up the air of polluted cities, delivering more nutritious diets, ensuring
472 energy, food and water security, and alleviating poverty and social and economic inequalities.

473 Monitoring this transition – from threat to opportunity – is the central role of the Lancet
474 Countdown: Tracking Progress on Health and Climate Change.⁵ The collaboration exists as a
475 partnership of 24 academic institutions from every continent, and brings together individuals with a
476 broad range of expertise across disciplines (including climate scientists, ecologists, mathematicians,
477 geographers, engineers, energy, food, and transport experts, economists, social and political
478 scientists, public health professionals, and physicians). The Lancet Countdown aims to track a series
479 of indicators of progress, publishing an annual 'health check', from now until 2030, on the state of
480 the climate, progress made in meeting global commitments under the Paris Agreement, and
481 adapting and mitigating to climate change (Panel 1). The initiative was formed following the 2015
482 Lancet Commission, which concluded that "tackling climate change could be the greatest global
483 health opportunity of the 21st century".⁴ It builds on, and reinforces, the work of the expanding
484 group of researchers, health practitioners, national governments, and the World Health Organization
485 (WHO), who are working to ensure that this opportunity becomes a reality.

486

487 Indicators of Progress on Health and Climate Change

488 In 2016, the Lancet Countdown proposed a set of potential indicators to be monitored, launching a
489 global consultation to define a conclusive set for 2017.⁵ A number of factors determined the
490 selection of indicators, including: (i) their relevance to public health, both in terms of the impacts of
491 climate change on health, and the health effects of the response to climate change; (ii) their
492 relevance to the main anthropogenic drivers of climate change; (iii) their geographical coverage and
493 relevance to a broad range of countries and income-groups; (iv) data availability; and (v) resource
494 and timing constraints. Table 1 divides these into broad themes, aligned with the global action
495 agenda on climate change and health, agreed at the Second WHO Global Conference on Health and
496 Climate, Paris, July 2016: climate change impacts, exposures, and vulnerabilities; adaptation
497 planning and resilience for health; mitigation actions and health co-benefits; economics and finance;
498 and public and political engagement.⁶

499 Panel 1 Developing Lancet Countdown's Indicators: An Iterative and Open Process.

500 The development of the Lancet Countdown's indicators took a pragmatic approach, taking in to
501 account the considerable limitations in data availability, resources, and time. Consequently, the

502 indicators presented here represent what is feasible for 2017 and will evolve over time in response
 503 to feedback and data improvements.

504 The purpose of this collaboration is to track progress on the links between public health and climate
 505 change, and yet, much of the data analysed here was originally collected for purposes not directly
 506 relevant to health. Initial analysis therefore principally captures changes in exposure, states, or
 507 processes, as proxies for health outcomes – the ultimate goal. Employing new methodologies to
 508 improve attribution to climate change is a particular priority. Subsequent reports will see the Lancet
 509 Countdown set 2030 targets for its indicators which align more directly with the Paris Agreement,
 510 allowing an assessment of its implementation over the course of the next 13 years.

511 The indicators presented thus far are the beginning of an ongoing, iterative and open process, which
 512 will work to continuously improve as capacity, data quality, and methods evolve. The objectives of
 513 the Lancet Countdown are both ambitious and essential, requiring support from a broad range of
 514 actors. To this end, the collaboration welcomes support from academic institutions and technical
 515 experts able to provide new analytical methods and novel data sets with appropriate geographical
 516 coverage. Appendix 1 provides a short overview of several parallel and complementary processes
 517 currently underway.

518 Throughout this report, the results and analysis of each indicator are presented alongside a brief
 519 description of the data sources and methods. A more complete account of each indicator can be
 520 found in the corresponding appendices. For a number of areas – such as the mental health impacts
 521 of climate change, or hydrological mapping of flood exposure – a robust methodology for an annual
 522 indicator has not been reported, reflecting the complexity of the topic and the paucity of data,
 523 rather than its lack of importance. Table 1 provides a summary of the 2017 indicators, with a more
 524 complete overview of these indicators provided in the supplementary online material. The thematic
 525 groups and indicator titles provide an overview of the domain being tracked, allowing for the growth
 526 and development of these metrics – for example, to more directly capture health outcomes – in
 527 subsequent years.

528

Thematic Group	Indicators	
1. Climate Change Impacts, Exposures and Vulnerability	1.1. Health effects of temperature change	
	1.2. Health effects of heatwaves	
	1.3. Change in labour capacity	
	1.4. Lethality of weather-related disasters	
	1.5. Global health trends in climate-sensitive diseases	
	1.6. Climate-sensitive infectious diseases	
	1.7. Food security and undernutrition	1.7.1. Vulnerability to undernutrition 1.7.2. Marine primary productivity
	1.8. Migration and population displacement	
2. Adaptation Planning and Resilience for Health	2.1. National adaptation plans for health	
	2.2. City-level climate change risk assessments	
	2.3. Detection and early warning of, preparedness for, and response to health emergencies	
	2.4. Climate information services for health	
	2.5. National assessment of vulnerability, impacts and adaptation for health	
	2.6. Climate-resilient health infrastructure	
3. Mitigation Actions and Health Co-Benefits	3.1. Carbon intensity of the energy system	
	3.2. Coal phase-out	
	3.3. Zero-carbon emission electricity	

	3.4. Access to clean energy	
	3.5. Exposure to ambient air pollution	3.5.1. Exposure to air pollution in cities
		3.5.2. Sectoral contributions to air pollution
		3.5.3. Premature mortality from ambient air pollution by sector
	3.6. Clean fuel use for transport	
	3.7. Sustainable travel infrastructure and uptake	
	3.8. Ruminant meat for human consumption	
	3.9. Healthcare sector emissions	
4. Economics and Finance	4.1. Investments in zero-carbon energy and energy efficiency	
	4.2. Investment in coal capacity	
	4.3. Funds divested from fossil fuels	
	4.4. Economic losses due to climate-related extreme events	
	4.5. Employment in low-carbon and high-carbon industries	
	4.6. Fossil fuel subsidies	
	4.7. Coverage and strength of carbon pricing	
	4.8. Use of carbon pricing revenues	
	4.9. Spending on adaptation for health and health-related activities	
	4.10. Health adaptation funding from global climate financing mechanisms	
5. Public and Political Engagement	5.1. Media coverage of health and climate change	5.1.1. Global newspaper reporting on health and climate change
		5.1.2. In-depth analysis of newspaper coverage on health and climate change
	5.2. Health and climate change in scientific journals	
	5.3. Health and climate change in the United Nations General Assembly	

529 Table 1 Thematic groups and indicators for the Lancet Countdown's 2017 report.

530

531

532 [Delivering the Paris Agreement for Better Health](#)

533 The Paris Agreement has been ratified at the national level by 153 of 197 parties to the UNFCCC, and
534 currently covers 84.7% of greenhouse gas (GHG) emissions. It set out a commitment of ambitious
535 GHG emissions reduction to limit climate change to well below a global average temperature rise of
536 2°C above pre-industrial levels, with an aim to limit temperature increases to 1.5°C.⁷

537 Most countries (187) have committed to near-term GHG emission reduction actions up to 2030,
538 through their Nationally Determined Contributions (NDCs). Article 4 paragraph 2 of the Paris
539 Agreement states that each signatory "shall prepare, communicate and maintain successive
540 nationally determined contributions that it intends to achieve".⁷ However, the NDCs of the 153
541 parties that have ratified the agreement currently fall short of the necessary reductions by 2030 to
542 meet the 2°C pathway.⁸

543 The Lancet Countdown's indicators place national decisions within a broader context. They highlight
544 the fact that globally, total power capacity of 'pre-construction' coal (commitments for new coal
545 power plants) has halved from 2016 to 2017 alone; that every year since 2015, more renewable
546 energy has been added to the global energy mix than all other sources combined; its installed costs
547 continue to fall (with solar photovoltaic (PV) electricity generation now being cheaper than
548 conventional fossil fuels in an ever growing number of countries); electric vehicles are poised to
549 reach cost-parity with their petrol-based counterparts; and in 2016 global employment in renewable
550 energy reached 9.8 million, over one million greater than that in fossil fuel extraction.

551 These positive examples in recent years must not mask the dangerous consequences of failing to
552 meet the Paris Agreement, the past two decades of relative inaction, the economies and sectors
553 currently lagging behind, and the enormity of the task ahead, which leave achieving the Agreement's
554 aims in a precarious position. Indeed, much of the data presented should serve as a wake-up call to
555 national governments, businesses, civil society, and the health profession.

556 However, as this report demonstrates, the world has already begun to embark on a path to a low-
557 carbon and healthier world. Whilst the pace of action must greatly accelerate, the direction of travel
558 is set.

559 1. Climate Change Impacts, Exposures and Vulnerability

560

561 Introduction

562 This section provides a set of indicators that track health impacts related to anthropogenic climate
563 change. Such impacts are dependent upon the nature and scale of the hazard, the extent and nature
564 of human exposure to them, and the underlying vulnerability of the exposed population.⁹ Thus,
565 these indicators aim to measure exposure to climatic hazards and vulnerabilities of people to them,
566 and over time, quantify the health impacts of climate change. These, in turn, inform protective
567 adaptation and mitigation interventions (sections two and three), the economic and financial tools
568 available to enable such responses (section four), and the public and political engagement that
569 facilitates them (section five).

570 Climate change affects human health primarily through three pathways: direct; ecosystem-
571 mediated; and human-institution-mediated.¹⁰ Direct effects are diverse, being mediated, for
572 instance, by increases in the frequency, intensity, and duration of extreme heat, and by rises in
573 average annual temperature experienced (leading to, for instance, increased heat-related mortality).
574 Rising incidence of other extremes of weather, such as flood and storms, increase the risk of
575 drowning and injury, damage to human settlements, the spread of water-borne disease, and mental
576 health sequelae.¹⁰ Ecosystem-mediated impacts include changes in the distribution and burden of
577 vector-borne diseases (such as malaria and dengue) and food and water-borne infectious disease.
578 Human undernutrition from crop failure, population displacement from sea-level rise, and
579 occupational health risks are examples of human-institution-mediated impacts.

580 Whilst the literature, and indeed some of the data presented here has traditionally focused on
581 impacts such as the spread of infectious diseases and mortality from extremes of weather, the
582 health effects from non-communicable diseases are just as important. Mediated through a variety of
583 pathways, they take the form of cardiovascular disease and acute and chronic respiratory disease
584 from worsening air pollution and aero-allergens, or the often-unseen mental health effects of
585 extreme weather events, or of population displacement.^{11,12} Indeed, emerging evidence is exploring
586 links between a rising incidence of chronic kidney disease, dehydration, and climate change.^{13,14}

587 Eight indicators were selected and developed for this section:

- 588 1.1 Health effects of temperature change
- 589 1.2 Health effects of heatwaves
- 590 1.3 Change in labour capacity
- 591 1.4 Lethality of weather-related disasters
- 592 1.5 Global health trends in climate-sensitive diseases
- 593 1.6 Exposure to climate-sensitive infectious diseases
- 594 1.7 Food security and undernutrition
- 595 1.8 Migration and population displacement

596

597 Appendix 2 provides a more detailed discussion on the data and methods used, as well as the
598 limitations and challenges encountered in the selection of each indicator. The indirect indicators (1.5
599 to 1.8) each provide a 'proof of concept', rather than being fully comprehensive, focusing variably on
600 a specific diseases, populations, or locations. Additionally, future iterations of the Lancet
601 Countdown's work will seek to capture indicators of the links between climate change and air
602 pollution, and with mental ill-health.

603 [Indicator 1.1: Health effects of temperature change](#)

604 **Headline Finding:** *People experience far more than the global mean temperature rise. Between 2000*
605 *and 2016, human exposure to warming was about 0.9°C - more than double the global area average*
606 *temperature rise over the same period.*

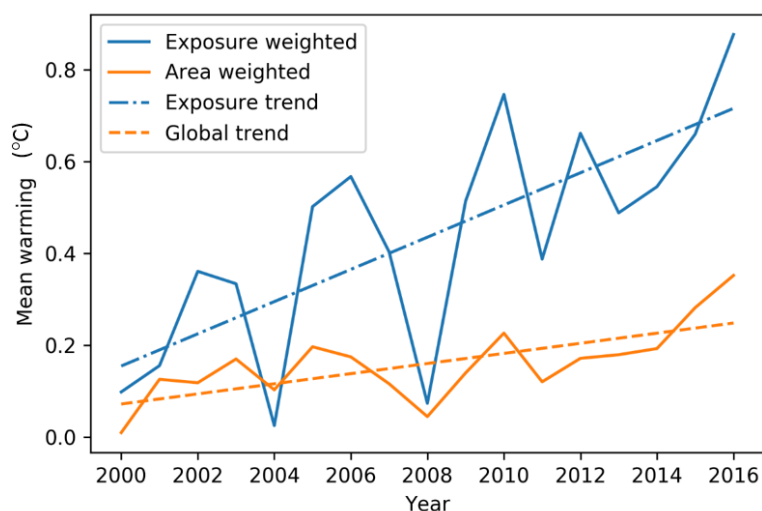
607 Rising temperatures can exacerbate existing health problems among populations and also introduce
608 new health threats (including cardiovascular disease and chronic kidney disease). The extent to
609 which human populations are exposed to this change, and thus the health implications of
610 temperature change, depend on the detailed spatial-temporal trends of population and temperature
611 over time.

612 Temperature anomalies were calculated relative to 1986 to 2008, from the European Research Area
613 (ERA) produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).¹⁵ This
614 dataset uses climate reanalysis to give a description of recent climate, produced by combining
615 models with observations.¹⁶ The time series shown in Figure 1.1 are global mean temperatures
616 calculated from the gridded data, weighted by area (to avoid bias from measurements near the
617 poles) and by population (to show the number of people exposed); these are described as “area
618 weighted” and “exposure weighted”, respectively.

619 Changes in population were obtained per country and the data projected onto the gridded
620 population.¹⁷ Figure 1.1 shows area- (yellow lines) and exposure-weighted (blue lines) changes in
621 mean summer temperatures since 2000. Exposure-weighted warming from 2000 to 2016 (0.9°C) is
622 much higher than the area-weighted warming (0.4°C) over the same period. Hence, mean exposure
623 to warming is more than double the global warming since 2000.

624 The increase in exposure relative to the global average is driven partly by growing population
625 densities in India, parts of China and Sub-Saharan Africa. Accounting for population when assessing
626 temperature change provides a vital insight into how human wellbeing is likely to be affected by
627 temperature change, with the analysis here showing that temperature change where people are
628 living is much higher than average global warming. Details of the global distribution of this warming
629 can be found in Appendix 2.

630



631
 632 Figure 1.1 Mean summer warming from 2000 to 2016 area weighted and exposure weighted, relative to the
 633 1986-2008 recent past average.

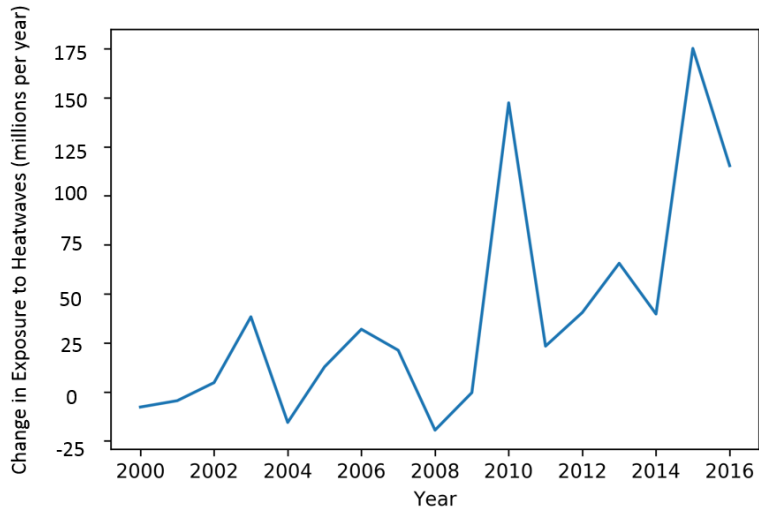
634
 635 **Indicator 1.2: Health effects of heatwaves**
 636 **Headline Finding:** Between 2000 and 2016, the number of vulnerable people exposed to heatwave
 637 events has increased by approximately 125 million, with a record 175 million more people exposed to
 638 heatwaves in 2015.

639 The health impacts of extremes of heat range from direct heat stress and heat stroke, through to
 640 exacerbations of pre-existing heart failure, and even an increased incidence of acute kidney injury
 641 resulting from dehydration in vulnerable populations. The elderly, children under the age of 12
 642 months, and people with chronic cardiovascular and renal disease are particularly sensitive to these
 643 changes.¹⁰

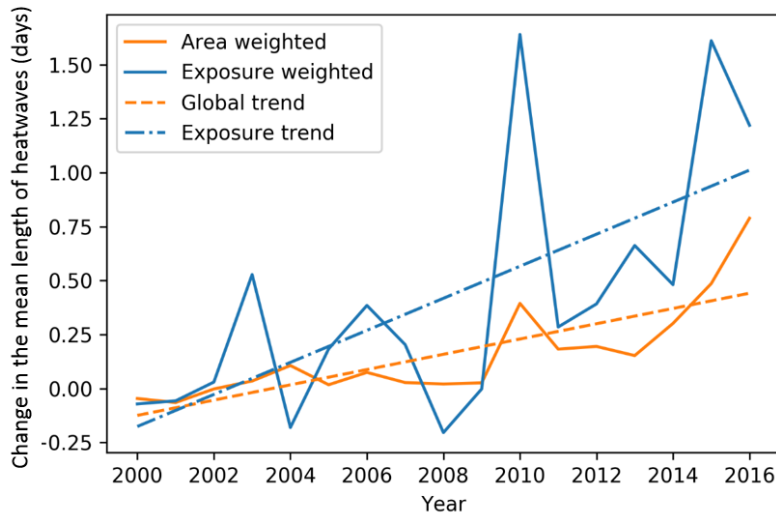
644 Here, a heatwave is defined as a period of more than 3 days where the minimum temperature is
 645 greater than the 99th percentile of the historical minima (1986-2008 average).¹⁸ This metric
 646 therefore focuses on periods of high night-time temperatures, which are critical in denying
 647 vulnerable people vital recuperation between hot days. Heatwave data were calculated against the
 648 historical period 1986-2008. The population for the exposure calculations was limited to people over
 649 the age of 65 (as this age group is most vulnerable to the health impacts of heatwaves), which was
 650 obtained on a per-country basis from the UN World Population Prospects archives for each year
 651 considered.

652 Figure 1.2 shows the increase in total exposure to heatwaves over the 2000-2016 period (one
 653 heatwave experienced by one person). In 2015, the highest number of exposure events was
 654 recorded, with approximately 175 million additional people exposed to heatwaves. Figure 1.3 shows
 655 how the mean number of heatwave days experienced by people during any one heatwave
 656 (exposure-weighted) increases at a much faster rate than the global mean (area-weighted) number

657 of heatwave days per heatwave; this is due to high populations densities in areas where heatwaves
658 have occurred.
659



660
661 Figure 1.2 The change in exposure (in people aged over 65 years) to heatwaves from 2000 to 2016, relative to
662 the heatwave exposure average from 1986-2008.
663



664

665 Figure 1.3 The area and exposure weighted change in mean heatwave lengths globally from 2000 to 2016 (in
666 people aged over 65 years), relative to the 1986-2008 recent past average.

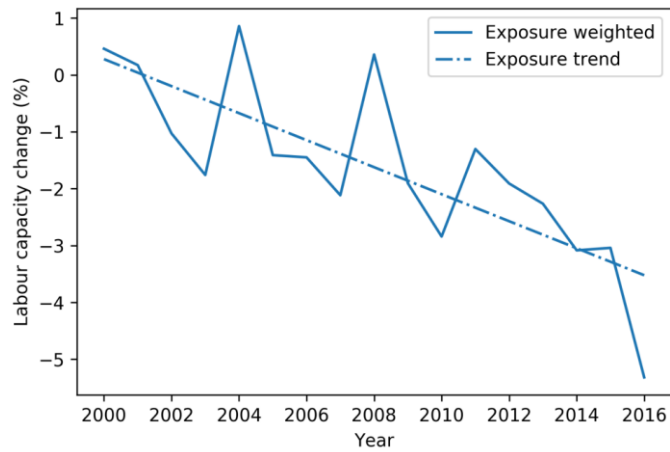
667

668 **Indicator 1.3: Change in labour capacity**

669 **Headline Finding:** Global labour capacity in populations exposed to temperature change is estimated
670 to have decreased by 5.3% from 2000 to 2016.

671 Higher temperatures pose significant threats to occupational health and labour productivity,
672 particularly for those undertaking manual labour outside in hot areas. This indicator shows the
673 change in labour capacity (and thus productivity) globally and specifically for rural regions, weighted
674 by population (see Appendix 2 for details). Reductions in labour capacity have important
675 implications for the livelihoods of individuals, families, and communities, with particular impacts on
676 those relying on subsistence farming.

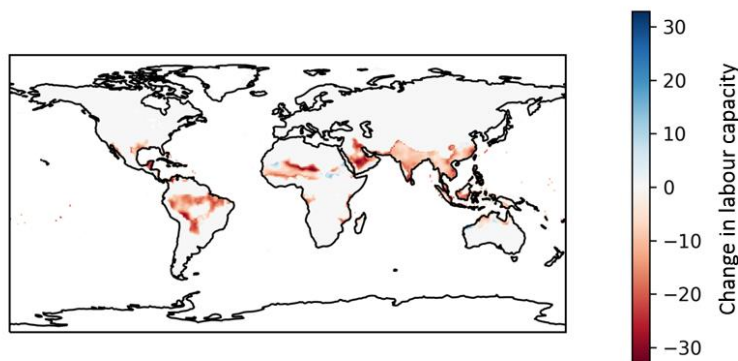
677 Labour capacity was estimated in the manner documented by Watts et al. (2015), based on wet bulb
678 globe temperatures.⁴ Figure 1.4 shows the estimated change in outdoor labour productivity
679 represented as a percentage relative to the reference period (1986-2008), with 0% implying no
680 change. Labour capacity is estimated to have decreased by 5.3% between 2000 and 2016, with a
681 dramatic decrease of over 2% between 2015 and 2016. Although there are some peaks of increased
682 labour capacity (notably 2000, 2004 and 2008), the overwhelming trend is one of reduced capacity
683 (Figure 1.4). These effects are most notable in some of the most vulnerable countries in the world
684 (Figure 1.5).



685

686 Figure 1.4 The exposure weighted labour capacity change (%) globally from 2000 to 2016, relative to the recent
 687 past (1986-2008) average

688



689

690 Figure 1.5 Map of the change in labour capacity loss from 2000 to 2016, relative to the recent past (1986-2008)
 691 average.

692

693 This indicator currently only captures the effects of heat on rural labour capacity. The Lancet
 694 Countdown will work to expand this metric in the future to capture impacts on labour capacity in
 695 other sectors, including manufacturing, construction, transportation, tourism and agriculture.
 696 Through collaboration with HEAT-SHIELD, the Lancet Countdown will work to develop this process
 697 going forward, providing more detailed analysis of labour capacity loss and the health implications of
 698 heat and heatwaves, globally.^{19,20}

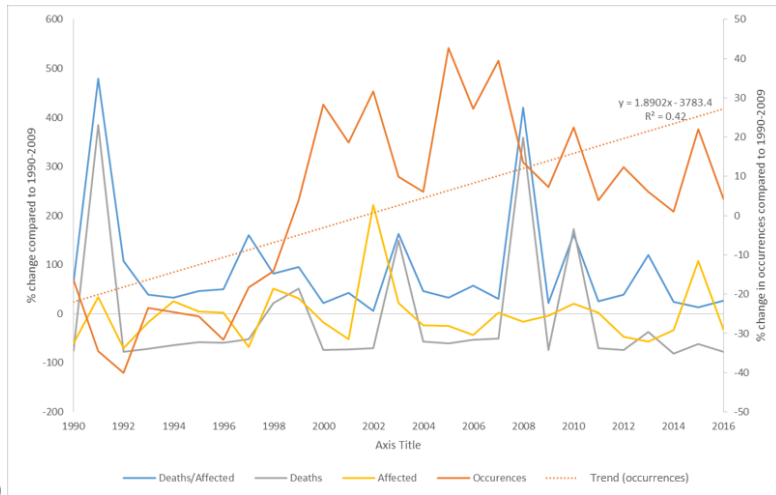
699 **Indicator 1.4: Lethality of weather-related disasters**

700 **Headline Finding:** *Despite a 46% increase in annual weather-related disasters from 2007 to 2016,*
701 *compared with the 1990-1999 average, there has been no accompanying increase in the number of*
702 *deaths, nor in those affected by disasters, nor in the ratio of these two outcomes.*

703 Weather-related events have been associated with over 90% of all disasters worldwide over the last
704 twenty years. As expected, considering its population and area, the continent most affected by
705 weather-related disasters is Asia, with some 2,843 events between 1990-2016 affecting 4.8 billion
706 people and killing 505,013. Deaths from natural hazard-related disasters are largely concentrated in
707 poorer countries.²¹ Crucially, this must be understood in the context of potentially overwhelming
708 health impacts of future climate change, worsening significantly over the coming years. Indeed, the
709 2015 Lancet Commission estimated an additional 1.4 billion drought exposure events, and 2.3 billion
710 flood exposure events occurring by the end of the century – demonstrating clear public health limits
711 to adaptation.⁴

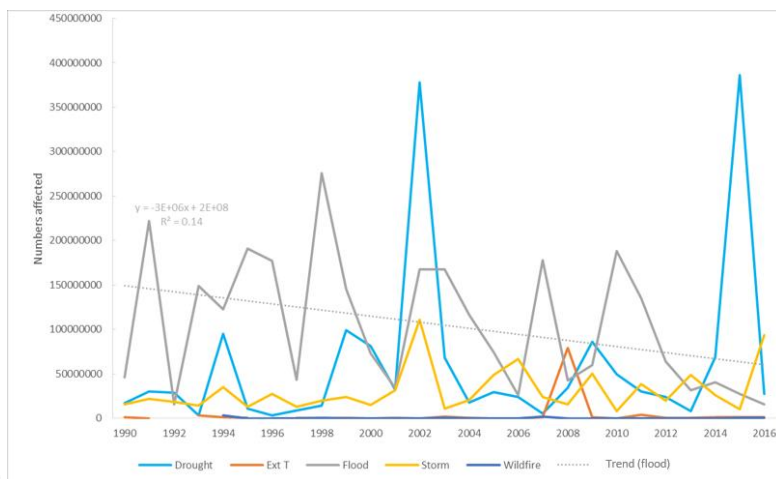
712 Disaster impact is a function of hazard and vulnerability, with vulnerability from a climate change
713 perspective sometimes defined as a function of exposure, sensitivity, and adaptive capacity.²² This
714 indicator measures the ratio of the number of deaths, to the number of people affected by weather-
715 related disasters. Weather-related disasters included are: droughts, floods, extreme temperature
716 events, storms and wildfires. The health impacts of weather-related disasters expand beyond
717 mortality alone, including injuries, mental health impacts, spread of disease, and food and water
718 insecurity. Data for the calculations for this indicator come from the Emergency Events Database
719 (EM-DAT).^{23,24} Here, in line with the EM-DAT data used for analysis, a disaster is defined as either: 1)
720 10 or more people reported killed, 2) 100 or more people affected, 3) a declaration of a state of
721 emergency, or 4) a call for international assistance.

722 Between 1994 and 2013, the frequency of reported weather-related events (mainly floods and
723 storms) increased significantly. However, this trend may be partially accounted for by information
724 systems having improved in the last 35 years, and statistical data are now more available as a result
725 of increased socio-cultural sensitivity to disaster consequences and occurrence.²⁵ From 2007 to
726 2016, EM-DAT recorded an average of 306 weather-related disasters per annum, up 46% from the
727 1990-1999 average. However, owing to impressive poverty reduction and health adaptation efforts,
728 this has not yet been accompanied by any discernible trend in number of deaths, nor in those
729 affected by disasters, nor in the ratio of these two (Figure 1.6a). Indeed, separating out the disasters
730 by the type of climate and weather hazard associated with the disaster (Figure 1.6b) shows there has
731 been a statistically significant global decrease in the numbers affected by floods, equating to a
732 decrease of 3 million people annually. Importantly, best available estimates and projections expect a
733 sharp reversal in these trends over the coming decades, and it is notable that a number of countries
734 have experienced increases in deaths associated with weather-related disasters, with many of these
735 being high-income countries, illustrating that no country is immune to the impacts of climate change
736 (see Appendix 2 for more details).A



737

a)



738

b)

739 Figure 1.6 Deaths and people affected by weather-related disasters. 1.6a) Percentage change over time in the
 740 global number of deaths, the number of those affected, and the ratio of these (measured against 1990-2009).
 741 1.6b) Change over time in the number of people affected globally by different weather-related disasters.

742

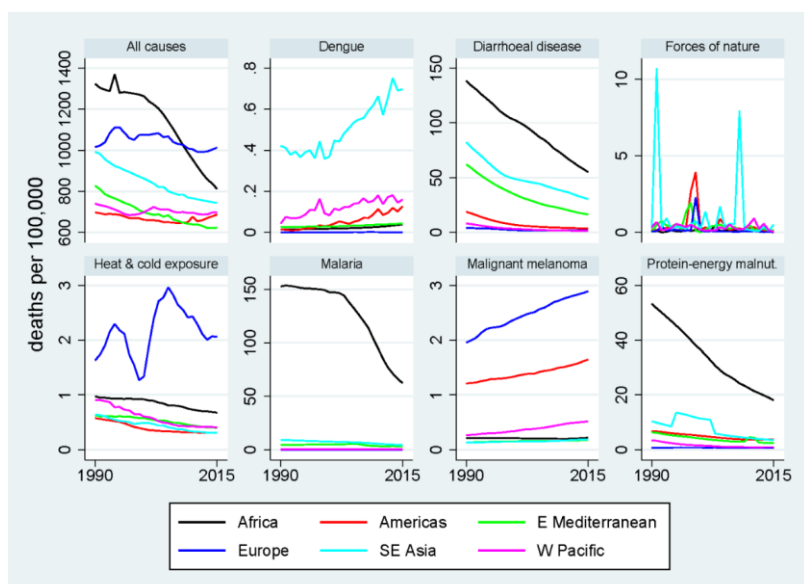
743 The relative stability of the number of deaths in a disaster as a proportion of those affected, despite
 744 an increase in the number of disasters, could be interpreted in a number of ways. One plausible
 745 conclusion is that this represents an increase in health service provision and risk reduction. However,
 746 although weather-related disasters have increased in number over the past three to four decades,
 747 the data here does not capture the severity of such events – a factor directly relevant to a country's
 748 vulnerability and ability to adapt.²²It is also important to note the difficulties in discerning overall
 749 trends, owing to the stochastic nature of the data and the relatively short time series. This poses

750 limitation on the significance of findings that can be drawn from analysis to date. Improving the
751 validity of this indicator will be a focus going forward.

752 **Indicator 1.5: Global health trends in climate-sensitive diseases**

753 **Headline Finding:** Global health initiatives have overwhelmingly decreased deaths associated with
754 climate-sensitive diseases since 1990, owing to important economic and public health advances over
755 the last three decades.

756 Disease occurrence is determined by a complex composite of social and environmental conditions
757 and health service provision, all of which vary geographically. Nonetheless, some diseases are
758 particularly sensitive to variations in climate and weather, and may thus be expected to vary with
759 both longer-term climate change and shorter-term extreme weather events.¹⁰ This indicator draws
760 from Global Burden of Disease (GBD) mortality estimates to show trends in deaths associated with
761 seven climate-sensitive diseases since 1990 (Figure 1.7).²⁷



762 Figure 1.7 Trends in mortality from selected causes of death as estimated by the Global Burden of Disease
763 2015, for the period 1990 to 2015, by WHO region.²⁷ (Created using Global Burden of Disease, 2016 data).
764

765 The disease trends above reveal global increases in dengue mortality, particularly in the Asia-Pacific
766 and Latin America and Caribbean regions, with some peak years (including 1998) known to be
767 associated with El Niño conditions.²⁸ Beyond climate, likely drivers of dengue mortality include trade,
768 urbanization, global and local mobility and climate variability; the association between increased
769 dengue mortality and climate change is therefore complex.²⁹ It naturally follows that an increase
770 spread of the disease resulting from climate change will be a significant contributing factor in the
771 increased likelihood of an associated increase in mortality. Malignant melanoma is a distinctive
772 example of a non-communicable disease with a clear link to ultraviolet exposure, with mortality
773 increasing steadily despite advances in surveillance and treatment; although it is important to
774 recognise that increased exposures also occur as a result of changing lifestyles (for example, a rise in
775 sun tanning). Heat and cold exposure is a potentially important aspect of climate-influenced
776 mortality, although the underlying attribution of deaths to these causes in the estimates is

777 uncertain.³⁰⁻³⁵ Deaths directly related to forces of nature have been adjusted for the effects of the
778 most severe seismic events. Of the ten highest country-year mortality estimates due to forces of
779 nature, seven were directly due to specific seismic activity, and these have been discounted by
780 replacing with the same countries' force of nature mortality for the following year. The remaining
781 major peaks relate to three extreme weather events (Bangladesh cyclone of 1991, Venezuela floods
782 and mudslides of 1999 and Myanmar cyclone of 2008), which accounted for over 300,000 deaths.

783 Overall, the findings here highlight the effectiveness and success of global health initiatives since
784 1990, in largely reducing deaths associated with these diseases. Furthermore, these trends provide a
785 proxy for the global health profile of climate-sensitive diseases and thus to some degree, indication
786 of existing vulnerabilities and exposures to them.

787 **Indicator 1.6: Climate-sensitive infectious diseases**

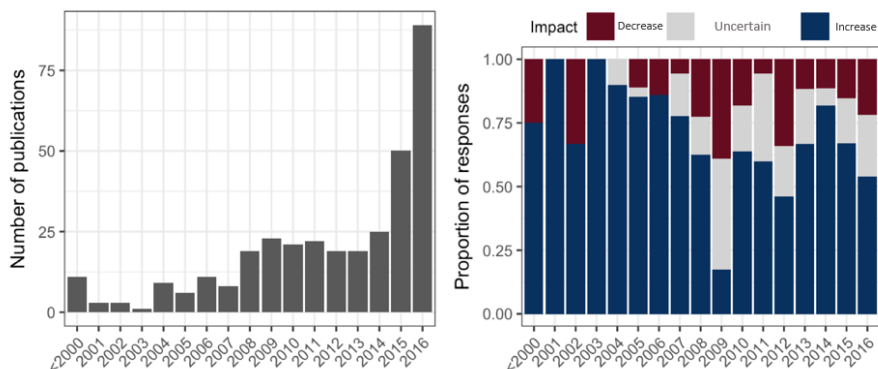
788 **Headline Finding:** *Vectorial capacity for the transmission of dengue by the mosquito vectors *Aedes**
789 *aegypti and *Aedes albopictus* in regions where these vectors are currently present has increased*
790 *globally due to climate trends by an average of 3% and 5.9%, respectively, compared to 1990 levels,*
791 *and by 9.4% and 11.1%, respectively, compared to 1950s levels.*

792 Despite a declining overall trend, infectious diseases still account for around 20% of the global
793 burden of disease and underpin more than 80% of international health hazards as classified by the
794 World Health Organization (WHO).^{36,37} Climatic factors are routinely implicated in the epidemiology
795 of infectious diseases, and they often interact with other factors, including behavioural,
796 demographic, socio-economic, topographic and other environmental factors, to influence infectious
797 disease emergence, distribution, incidence and burden.^{2,38} Understanding the contribution of
798 climate change to infectious disease risk is thus complex, but necessary for advancing climate
799 change mitigation and adaptation policies.¹⁴ This indicator is split into two components: a systematic
800 literature review of the links between climate change and infectious diseases, and a vectorial
801 capacity model for the transmission of dengue virus by the climate-sensitive vectors.

802 For the first component, a systematic review of the climate change infectious disease literature was
803 performed (see Appendix 2 for details), in which trends in the evolution of knowledge and direction
804 of impact of climate change disease risk associations were measured (Figure 1.8). The number of
805 new publications fitting the search criteria in 2016 (n=89) was the highest yet reported, almost
806 double the number published in 2015 (n=50) and more than triple the number published in 2014
807 (n=25) (Figure 1.8, left). Over this period, the complexity of interactions between climate change and
808 infectious disease has been increasingly recognised and understood (Figure 1.8, right).

809

810

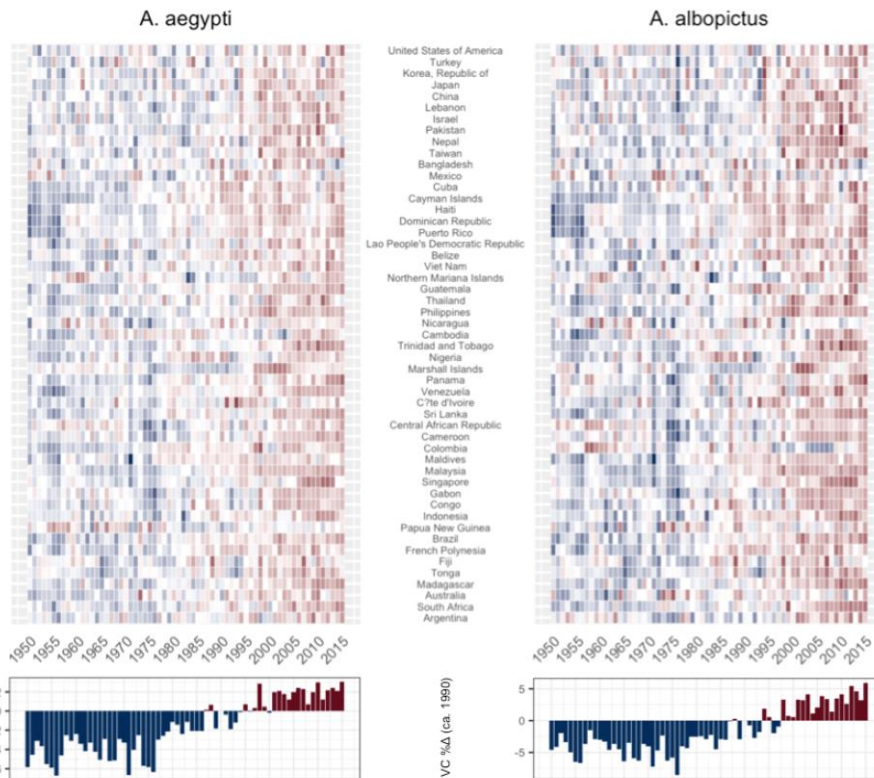


811

812 Figure 1.8 Left: Academic publications reporting climate-sensitive infectious diseases by year. Right: proportion
813 of responses reported in publications by year and direction of impact.

814

815 Trends in the global potential for dengue virus transmission (as represented by vectorial capacity
816 (VC) in the mosquito vectors *Aedes aegypti* and *Aedes albopictus*) are presented. VC is “the rate
817 (usually daily) at which a bloodsucking insect population generates new inoculations from a
818 currently infectious case”.³⁹ A global, mechanistic investigation was conducted of changes in annual
819 transmission potential for a model, high burden, climate-sensitive vector-borne disease, dengue
820 fever (Figure 1.9). For both vectors, VC in locations where these vectors are currently present
821 reached its highest or equal highest average level in 2015 over the period considered (Figure 1.9,
822 bottom panel). This consolidates a clear and significant increase in VC starting in the late 1970s
823 (+3.0% and +6.0% compared to 1990 levels for *A. aegypti* and *A. albopictus*, respectively). Nearly all
824 *Aedes*-positive countries showed relative increases in VC for both vectors over the period considered
825 (Figure 1.9, top panel). Annual numbers of cases of dengue have doubled every decade since 1990,
826 with 58.4 million (23.6 million–121.9 million) apparent cases in 2013, accounting for over 10,000
827 deaths and 1.14 million (0.73 million–1.98 million) disability-adjusted life-years.⁴⁰ Climate change has
828 been suggested as one potential contributor to this increase in burden.⁴¹ *Aedes aegypti* and *Aedes*
829 *albopictus*, the principal vectors of dengue, also carry other important emerging or re-emerging
830 arboviruses, including Yellow Fever, Chikungunya, Mayaro and Zika viruses, which are likely similarly
831 responsive to climate change.



832
 833 Figure 1.9 Average annual vectorial capacity (VC) for dengue in *Aedes aegypti* and *Aedes albopictus*
 834 for selected *Aedes*-positive countries (countries with *Aedes* present) (top panel; matrix coloured relative to
 835 country mean 1950-2015; red = relatively higher VC, blue = relatively lower VC; countries ordered by centroid
 836 latitude (north to south)). Bottom panel: average vectorial capacity (VC) for both vectors calculated globally
 837 (results shown relative to 1990 baseline).

838

839 **Indicator 1.7: Food security and undernutrition**
 840 Isolating the impact of climate change on health through the indirect impacts on food security is
 841 complicated, as policies, institutions, and the actions of individuals, organisations, and countries,
 842 strongly influence the extent to which food systems are resilient to climate hazards or can adapt to
 843 climate change, and whether individual households are able to access and afford sufficient nutritious
 844 food. For example, with respect to undernourishment, vulnerability has been shown to be more
 845 dependent on adaptive capacity (such as infrastructure and markets) and sensitivity (such as forest
 846 cover and rain-fed agriculture) than exposure (such as temperature change, droughts, floods,
 847 storms).⁴² Given the role of human systems in mediating the links between climate, food, and health,
 848 the chosen indicators focus on abiotic and biotic indicators and current population vulnerabilities,
 849 considering both terrestrial and marine ecosystems. Undernutrition has been identified as the
 850 largest health impact of climate change in the 21st century.^{10,43-46}

852 Indicator 1.7.1: Vulnerability to undernutrition

853 **Headline Finding:** *The number of undernourished people in the 30 countries located in Africa and*
854 *Southern Asia with the highest prevalence (>15%) has increased from 398 million in 1990 to 422*
855 *million in 2016. These are countries located in regions which are highly dependent on regional*
856 *production for their food needs and where climate change is predicted to have the greatest negative*
857 *impact on yields.*

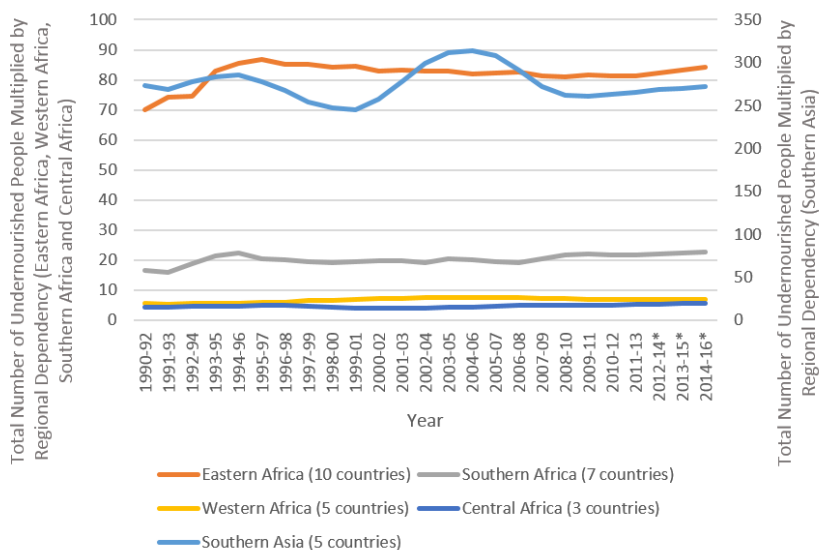
858 The purpose of this indicator is to track the extent to which health will be compromised by climate
859 change in countries where both current dependence on domestic production of food, and current
860 level of undernourishment (which is strongly related to undernutrition) is already high. Climate
861 change could further compromise health through changes in localised temperature and
862 precipitation, manifested in falling yields.

863 Food markets are increasingly globalised, and food security is increasingly driven by human systems.
864 In response to falling yields caused by temperature increases, governments, communities, and
865 organisations can and will undertake adaptation activities that might variously include breeding
866 programmes, expansion of farmland, increased irrigation, or switching crops. However, the greater
867 the loss of yield potential due to temperature increases, the more difficult adaptation becomes for
868 populations dependent upon domestic food supply.

869 Rising temperatures have been shown to reduce global wheat production, which has been estimated
870 to fall 6% for each degree Celsius of additional temperature increase.⁴⁷⁻⁴⁹ Rice yields are sensitive to
871 higher night temperatures, with each 1°C increase in growing-season minimum temperature in the
872 dry season resulting in a fall in rice grain yield of 10%.⁵⁰ Higher temperatures have been
873 demonstrated rigorously to have a negative impact on crop yields in lower-latitude countries.⁵¹⁻⁵³
874 Moreover, agriculture in lower-latitudes tends to be more marginal, and more people are food
875 insecure.

876 This indicator, using data from the Food and Agriculture Organization of the United Nations (FAO),
877 focuses on vulnerability to undernutrition.⁵⁴ Countries are selected for inclusion based on three
878 criteria: the presence of moderate or high level of undernourishment, reflecting vulnerability; their
879 physical location, focusing on geographies where a changing climate is predicted with high
880 confidence to have a negative impact on the yields to staples produced; and dependence on regional
881 production for at least half of its cereal consumption, reflecting high exposure to localised climate
882 hazards. Based on these criteria, 30 countries, all located in Africa or Southern Asia, are included.
883 Figure 1.10 presents the aggregated indicators, which shows the total number within the population
884 undernourished in these 30 countries, multiplied by total dependence on regional production of
885 grains. This gives a measure of how exposed already undernourished populations, who are highly
886 dependent on regionally produced grains, are to localized climate hazards.

887



888
 889 Figure 1.10 Total number of undernourished people multiplied by regional dependency on grain production for
 890 countries.

891 The regions with the highest vulnerability to undernutrition also coincide with areas where yield
 892 losses due to warming are predicted to be relatively high, thus increasing the vulnerability of these
 893 populations to the negative health consequences of undernutrition. High dependence on one crop
 894 increases the vulnerability of individual countries further. For example, Kenya, which has a domestic
 895 production dependency for cereals of almost 80%, 69% dependent on maize, is experiencing high
 896 levels of undernutrition, and is particularly vulnerable to climate-related yield losses. Going forward,
 897 these data will be refined through country-level exploration, incorporation of the predicted impact
 898 of warming on yield losses, and incorporation of key temperature indicators such as ‘growing degree
 899 days’ above critical crop-specific thresholds.^{55,56}

900
 901 **Indicator 1.7.2: Marine primary productivity**
 902 Declining fish consumption provides an indication of food insecurity, especially in local shoreline
 903 communities dependent upon marine sources for food, and hence are especially vulnerable to any
 904 declines in marine primary productivity affecting fish stocks.⁵⁷ This is particularly concerning for the
 905 1 billion people around the world who rely on fish as their principal source of protein, placing them
 906 at increased risk of stunting (prevented from growing or developing properly) and malnutrition from
 907 food insecurity.⁵⁸ In addition, fish are important for providing micronutrients, such as zinc, iron,
 908 vitamin A, vitamin B12, and Omega-3 fatty acids. If current fish declines continue, as many as 1.4
 909 billion people are estimated to become deficient and at elevated risk of certain diseases, particularly
 910 those associated with the cardiovascular system.^{59,60}

911 Marine primary productivity is determined by abiotic and biotic factors; measuring these globally
 912 and identifying relevant marine basins is complex. Factors such as sea surface temperature (SST), sea
 913 surface salinity (SSS), coral bleaching and phytoplankton numbers are key determinants of marine

914 primary productivity. Other local determinants have particularly strong influences on marine primary
915 productivity. For example, harmful algal blooms (HAB) occur as a result of uncontrolled algal growth
916 producing deadly toxins. The consumption of seafood contaminated with the toxins of harmful algal
917 blooms, such as those produced by *Alexandrium tamarense*, is often very dangerous to human
918 health, and potentially fatal.⁶¹

919 Changes in SST and SSS from 1985 to present, for twelve fishery locations essential for aquatic food
920 security are presented here. Data was obtained from NASA's Earth Observatory Databank, and
921 mapped across to the significant basins outlined in Appendix 2. From 1985 to 2016, a 1°C increase in
922 SST (from an annual average of 22.74°C to 23.73°C) was recorded in these locations.⁶² This indicator
923 requires significant further work to draw out the attribution to climate change and the health
924 outcomes that may result. A case study on food security and fish stocks in the Persian Gulf is
925 presented in Appendix 2.

926

927 **Indicator 1.8: Migration and population displacement**

928 **Headline Finding:** *Climate change is the sole contributing factor for at least 4,400 people already*
929 *being forced to migrate, globally. The total number for which climate change is a significant or*
930 *deciding factor is significantly higher.*

931 Climate change-induced migration may occur through a variety of different social and political
932 pathways, ranging from sea level rise and coastal erosion, through to changes in extremes and
933 averages of precipitation and temperature decreasing the arability of land and exacerbating food
934 and water security issues. Estimates of future "climate change migrants" up to 2050 vary widely,
935 from 25 million to 1 billion.⁶³ Such variation indicates the complexity of the multi-factorial nature of
936 human migration, which depends on an interaction of local environmental, social, economic, and
937 political factors. For example, in Syria, many attribute the initial and continued conflict to the rural-
938 to-urban migration that resulted from a climate change-induced drought.^{64,65} However, the factors
939 leading to the violence are wide-ranging and complex, with clear quantifiable attribution particularly
940 challenging. Indeed, climate change is often thought of as playing an important role in exacerbating
941 the likelihood of conflict, and as a threat multiplier and an accelerant of instability. Nonetheless,
942 migration driven by climate change has potentially severe impacts on mental and physical health,
943 both directly and through the disruption of essential health and social services.⁶⁶

944 Despite the methodological difficulties in proving a direct causal relationship between climate
945 change and population displacement, there are areas where this is methodologically possible. This
946 indicator focuses on these situations, attempting to isolate instances (as exemplars) where climate
947 change is the sole contributory factor in migration decisions. Sea level rise provides the clearest
948 example of this, although other examples exist as shown in Table 1.1. Estimating the number of
949 people who have involuntarily migrated (both internally and internationally) as a result of climate
950 change alone helps overcome the complexity of accounting for other societal, economic and
951 environmental factors that also influence migration.

952 Based on data derived from peer-reviewed academic publications (see Appendix 2 for full details). A
953 minimum of 4,400 people have been forced to migrate due solely to climate change (Table 1.1). This
954 will be an underestimate, as it excludes cases where more than one factor may be contributing to a
955 migration decision – such as a combination of both climate-related sea level rise and coastal erosion
956 not associated with climate change (possibly such as the village of Vunidogola, relocated by the

957 Fijian Government in 2014 for such reasons, and the planned relocation of the Fijian village of
 958 Narikoso by 2018).⁶⁷⁻⁶⁹

959

Location	Population	Citation	Notes on causes
Carteret Islands, PNG	1,200	Connell (2016) ⁷⁰ Strauss (2012) ⁷¹	Migrating due to sea-level rise
Alaska (need to migrate as soon as possible)*		Bronen and Chapin III (2013) ⁷² Shearer (2012) ⁷³	Migrating due to changing ice conditions leading to coastal erosion and due to permafrost melt, destabilising infrastructure
Kivalina	398-400		
Newtok	353		
Shaktolik	214		
Shismaref	609		
Alaska (need to migrate gradually)*		Bronen and Chapin III (2013) ⁷²	Migrating due to changing ice conditions leading to coastal erosion and due to permafrost melt, destabilising infrastructure
Allakaket	95		
Golovin	167		
Hughes	76		
Huslia	255		
Koyukuk	89		
Nulato	274		
Teller	256		
Unalakleet	724		
Isle de Jean Charles, Louisiana	25 homes		Coastal erosion, wetland loss, reduced accretion, barrier island erosion, subsidence, and saltwater intrusion were caused by dredging, dikes, levees, controlling the Mississippi River, and agricultural practices. Climate change is now bringing sea-level rise

960 Table 1.1 Locations migrating now due to only climate change. *The village names and populations are sourced
 961 from the US Government Accountability Office's report, "Alaska Native Villages: Limited Progress Has Been
 962 Made on Relocating Villages Threatened by Flooding and Erosion".⁷⁰⁻⁷³

963

964 Over the long-term, human exposure and vulnerability to ice sheet collapse is increasing, as the
 965 number of people living close to the coast and at elevations close to sea level are also increasing. In
 966 1990, 450 million people lived within 20 km of the coast and less than 20 metres above sea level.⁷⁴
 967 In 2000, 634 million (~10% of the global population), of whom 360 million are urban, lived below 10
 968 metres above sea level, (the highest vertical resolution investigated).⁷⁵ With 2000 as a baseline, the
 969 population living below 10 metres above sea level will rise from 634 million to 1,005-1,091 million by
 970 2050 and 830-1,184 million by 2100.⁷⁶ From 2100 and beyond, without mitigation and adaptation

971 interventions, over one billion people may need to migrate due to sea level rise caused by any ice
972 sheet collapse which occurs.^{76,77}

973 Whilst this indicator is not yet able to capture the true number of people being forced to migrate
974 due to climate change, that at least 4,400 people are already being forced to migrate as a result of
975 climate change only is concerning and demonstrates that there are limits to adaptation. The fact
976 that this is a significant underestimate further highlights the need to mitigate climate change and
977 improve the adaptive capacity of populations to reduce future forced migration. Significantly, only
978 instances of migration where climate change is isolated as the only factor are captured. Moving
979 forward, new approaches will be required to more accurately reflect the number of people forced to
980 migrate due to climate change, looking to capture situations where climate change plays an
981 important contributory role alongside other social and economic considerations.

982

983 Conclusion

984 Climate change impacts health through diverse direct and indirect mechanisms. The indicators
985 captured here provide an overview of a number of these effects, capturing exposure, impact, and
986 underlying vulnerabilities. Going forward, indicators will be developed to better measure direct
987 health outcome from climate change, in addition to exposure and vulnerabilities.

988 The indicators presented here will be continuously developed over time in order to more directly
989 capture mortality and morbidity outcomes from communicable and non-communicable diseases.
990 Indeed, work is already underway to produce new indicators to capture these concepts for
991 subsequent reports. Panel 1.1 and Appendix 2 describe one such ongoing process focused on mental
992 health and climate change.

993 Adaptation pathways can help to minimise some of the negative health impacts of global warming,
994 especially for the lower range of projected average temperature rises. However, there are powerful
995 limits to adaptation, and this section has drawn attention to the non-linearity and the spatial
996 distribution of the health impacts of climate change. The indicators presented here demonstrate
997 clearly that these impacts are being experienced across the world today, and provide a strong
998 imperative for both adaptation and mitigation interventions to protect and promote public health.

999

1000 Panel 1.1 Mental Health and Climate Change

1001 Measuring progress in the effects of climate change on mental health and wellbeing is difficult.
1002 Whilst this is partly due to problems of attribution, the main measurement difficulty lies in the
1003 inherently complicated nature of mental health, which embraces a diverse array of outcomes (for
1004 instance, anxiety and mood disorders), many of which co-occur and all of which vary over contexts
1005 and lifetimes. They are products of long and complex causal pathways, many of which can be traced
1006 back to distal but potent root causes, such as famine, war and poverty, of which climate change is
1007 both an example and an accelerator.⁷⁸

1008 Mental health, with its inherent intricacy, is a field where *systems thinking* is likely to be particularly
1009 valuable. A first step, therefore, in tracking progress on mental health and climate change is to build
1010 a conceptual framework using systems thinking. Initial work in partnership with the University of
1011 Sydney has begun to trace through the many direct and indirect causal pathways, in order to aid the
1012 identification of indicators. A number of challenges (e.g. how to gather and interpret highly

1013 subjective measures across cultures and income settings) are immediately apparent. Whilst further
1014 work, and engagement with other partners will be required, potential indicators may focus on a
1015 range of issues, including: national and local mental health emergency response capacity to climate-
1016 related extreme events; the extent to which climate change is considered within national mental
1017 health strategies; or the social and psychological impact of uninsured economic losses that result
1018 from extreme weather events.

1019 2. Adaptation Planning and Resilience for Health

1020

1021 Introduction

1022

1023 Climate change adaptation is defined by the IPCC as the “adjustment in natural or human systems in
1024 response to actual or expected climatic stimuli or their effects, which moderates harm or exploits
1025 beneficial opportunities”.⁸⁰ With respect to health, adaptation consists of efforts to reduce injury,
1026 illness, disability, and suffering from climate-related causes. Resilience has been defined as “the
1027 capacity of individuals, communities and systems to survive, adapt, and grow in the face of stress
1028 and shocks, and even transform when conditions require it”.⁸¹ In the context of climate change and
1029 health, resilience is an attribute of individuals, communities, and health care systems; resilience at
1030 all levels can reduce adverse health outcomes of climate change and should be a goal of adaptation
1031 planning.

1032 Indicators of resilience and adaptation are challenging to identify. Resilience is related to
1033 preparedness, response, resource management and coordination capacity, but it is not synonymous
1034 with them. Understanding the current resilience of a population’s health and health systems
1035 provides some indication of resilience to climate change, although direct indicators measuring this
1036 have not yet been developed by the Lancet Countdown. The indicators presented here are
1037 predominantly process-based, focusing on health adaptation planning, capacity, and response.
1038 Whilst the underlying resilience of communities is present to some extent in all of the indicators in
1039 this section, it is currently only captured directly for health systems, and hence most indicators that
1040 follow will focus more specifically on health adaptation.

1041

1042 The indicators presented here are:

- 1043 2.1 National adaptation plans for health
- 1044 2.2 City-level climate change risk assessments
- 1045 2.3 Detection and early warning of, preparedness for, and response to health emergencies
- 1046 2.4 Climate information services for health
- 1047 2.5 National assessment of vulnerability, impacts and adaptation for health
- 1048 2.6 Climate-resilience health infrastructure

1049

1050 Corresponding Appendix 3 provides more detailed discussion of the data and methods used.

1051

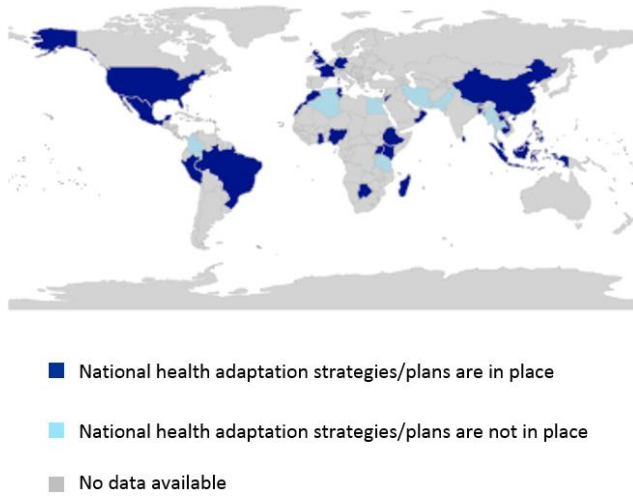
1052 Indicator 2.1: National adaptation plans for health

1053 **Headline finding:** 30 out of 40 responding countries have a national health adaptation plan or
1054 strategy approved by the relevant national health authority.

1055 Effective national responses to climate risks require that the health sector identify strategic goals in
1056 response to anticipated – and unanticipated – threats. A critical step in achieving these strategic
1057 goals is the development of a national health adaptation plan, outlining priority actions, resource
1058 requirements and a specific timeline and process for implementation. This indicator tracks the policy
1059 commitments of national governments for health and climate change adaptation. Data are drawn
1060 from the recent WHO Climate and Health Country Survey (Panel 2.1).

1061 Of the 40 countries responding to this baseline survey, 30 reported having a national adaptation
1062 strategy for health, approved by their Ministry of Health or relevant health authority (Figure 2.1).
1063 This number includes countries with a health component of their National Adaptation Plan (NAPs),
1064 which was established by the UNFCCC to help nations identify medium- and long-term adaptation
1065 needs and develop and implement programmes to address those needs.⁸² There is a need for
1066 caution in extrapolating the results to global level, as many of the respondent countries have
1067 received support from WHO in developing and implementing their plans.^{83,84} Nonetheless, with 75%
1068 of respondents in the survey having an approved national health adaptation plan there is evidence
1069 of the recognition of the need to adapt to climate change. Countries with national health adaptation
1070 plans are found across all regions and, perhaps most significantly, among some of the most
1071 vulnerable countries across Africa, South East Asia and South America. In future iterations of the
1072 survey, data will be gathered on the content and quality of these adaptation plans, their level of
1073 implementation, the main priorities for health adaptation, internal monitoring and review processes,
1074 and the level of funding available to support policy interventions.

1075
1076
1077



1078
1079 Figure 2.1 Countries with national health climate adaptation strategies or plans.
1080

1081 **Panel 2.1: WHO-UNFCCC Climate and Health Country Profiles.**
1082 The WHO-UNFCCC Climate and Health Country Profile Project forms the foundation of WHO’s
1083 national level provision of information, and monitoring of progress, in this field. The profiles,
1084 developed in collaboration with ministries of health and other health determining sectors, support
1085 evidence-based decision making to strengthen the climate resilience of health systems and promote

1086 actions that improve health while reducing carbon emissions. In part, the data used in the
1087 development of the climate and health country profiles is collected through a biennial WHO Climate
1088 and Health Country Survey. Data from this survey is reported on for indicators 2.1, 2.5 and 2.6

1089 The 2015 baseline survey findings for 40 responding nations are presented in this report (for a
1090 complete list of country respondents, see Appendix 3). The findings include countries from all WHO
1091 regions (high, middle and low income groups) and with varying levels of risks and vulnerabilities to
1092 the health impacts of climate change. The 2015 survey data were validated as part of the national
1093 consultation process seeking input on respective WHO UNFCCC Climate and Health Country Profiles
1094 from key in-country stakeholders, including representatives of the Ministry of Health, Ministry of
1095 Environment, meteorological services and WHO country and regional technical officers.

1096 The validated data presented in this report tended to include a high number of countries that are
1097 actively working on climate and health with WHO; as such, the results here are indicative and are
1098 not meant to be inferred as an exact indicator of global status. The number of country respondents
1099 is expected to double in subsequent iterations of the survey. As such, the results presented here
1100 represent the beginning of the development of a more comprehensive survey, presenting results
1101 available at the start of this process.

1102

1103 [Indicator 2.2: City-level climate change risk assessments](#)

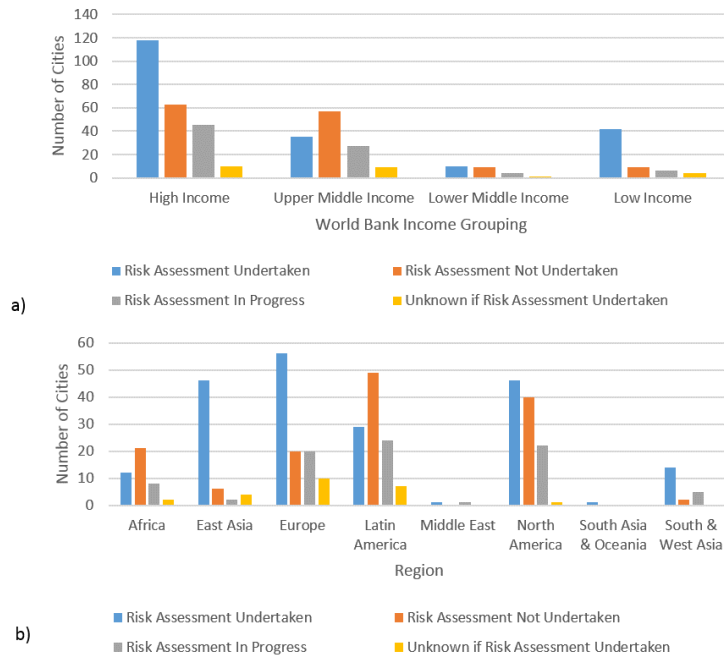
1104 **Headline Finding:** *Of the 449 self-reporting cities, 45% have climate change risk assessments in*
1105 *place.*

1106 Globally, 54.5% of people live in cities, where key health infrastructure is often concentrated.⁸⁵
1107 These urban centres are increasingly at risk from climate change, with negative impacts predicted
1108 for human health and health services. These risks require city-level responses to complement NAPs,
1109 in order to improve cities' ability to adapt to climate change. Indeed, cities have a unique
1110 opportunity to provide adaptation measures that help improve the resilience of urban populations,
1111 whilst also helping mitigate the impacts of climate change on public health.⁸⁶

1112 Data for this indicator comes from the 2016 global survey of the Compact of Mayors and the Carbon
1113 Disclosure Project (CDP).^{87 88} Of the 449 cities with public responses (533 cities responded overall),
1114 45% reported to "have undertaken a climate change risk or vulnerability assessment for [their] local
1115 government" (Figure 2.2).⁸⁹

1116 The highest number of cities with climate change risk assessments are in high income countries
1117 (HICs) (118 cities), with only 42 cities in low-income countries. This partly reflects the fact that more
1118 cities in HICs were surveyed, and partly the fact that these cities have a greater capacity to develop
1119 such plans. There were a higher number of respondents from cities in HICs compared with low
1120 income (236 versus 61).

1121 European cities in this survey have the highest number of climate change risk assessments (56
1122 cities), representing 83% of European cities surveyed. Conversely, only 28% of surveyed African cities
1123 have climate change risk assessments. This has serious implications for the adaptive capacity of
1124 some of the most vulnerable populations to climate change in low income countries. A concerted
1125 effort must be made to increase the number of climate change risk assessment in cities in low-
1126 income countries, in order to better understand their vulnerability to climate change impacts and
1127 implement adaptation actions.



1128

1129 Figure 2.2 Number of global cities undertaking climate change risk assessments by a) income grouping, and b)
 1130 WHO region.

1131

1132 Indicator 2.3: Detection and early warning of, preparedness for, and response to climate
 1133 related health emergencies

1134 **Headline Finding:** Due to focused investment in the implementation of the International Health
 1135 Regulations (2005), national capacities relevant to climate adaptation and resilience, including
 1136 disease surveillance and early detection, multi-hazard public health emergency preparedness and
 1137 response, and the associated human resources to perform these public health functions, have
 1138 increased markedly from 2010 to 2016 in all world regions.

1139 Many initiatives at community, national, regional and global levels support strengthening country
 1140 capacities for health emergency and disaster risk management and complement the implementation
 1141 of the Sendai Framework for Disaster Risk Reduction, Sustainable Development Goal 3D, the Paris
 1142 Agreement on Climate Change and the International Health Regulations (2005). Under the
 1143 International Health Regulations (IHR (2005)), all States Parties should report to the World Health
 1144 Assembly annually on the implementation of IHR (2005).^{91,92} In order to facilitate this process, WHO
 1145 developed an IHR Monitoring questionnaire, interpreting the Core Capacity Requirements in Annex 1

1146 of IHR (2005) into 20 indicators for 13 capacities (Panel 2.2). These metrics can serve as important
1147 proxies of health system adaptive capacity and system resilience, since they measure the extent to
1148 which health systems demonstrate a range of attributes necessary to detect, prepare for and
1149 respond to public health emergencies, some of which are climate sensitive. Four capacities reflecting
1150 seven indicators from IHR Monitoring questionnaire are reported here: surveillance, preparedness,
1151 response, and human resources. Additional details of all four of these IHR Capacities can be found in
1152 Appendix 3.

1153 **Panel 2.2: The International Health Regulations (2005).**

1154 The current IHR (2005), which entered into force in 2007, is legally binding on 196 States Parties,
1155 including all WHO member states. It requires States Parties to detect, assess, notify and report, and
1156 respond promptly and effectively to public health risks and public health emergencies of
1157 international concern (IHR Article 5, 13) and to develop, strengthen and maintain the capacity to
1158 perform these functions (IHR Article 5). Examples of required core capacities include national
1159 legislation, policy and financing; public health surveillance; preparedness and response; risk
1160 communication; human resources; and laboratory services. Under the International Health
1161 Regulations (IHR (2005)), all States Parties should report to the World Health Assembly annually on
1162 the implementation of IHR (2005). In order to facilitate this process, WHO developed an IHR
1163 Monitoring questionnaire.⁹³ The method of estimation calculates the proportion/percentage of
1164 attributes (a set of specific elements or functions that reflect the performance or development of a
1165 specific indicator) reported to be in place in a country. Since 2010, 195 States Parties have submitted
1166 self-reports at least once. Indicator 2.3 is drawn from the results of these questionnaires to which
1167 129 of 196 States Parties responded in 2016.⁹⁴

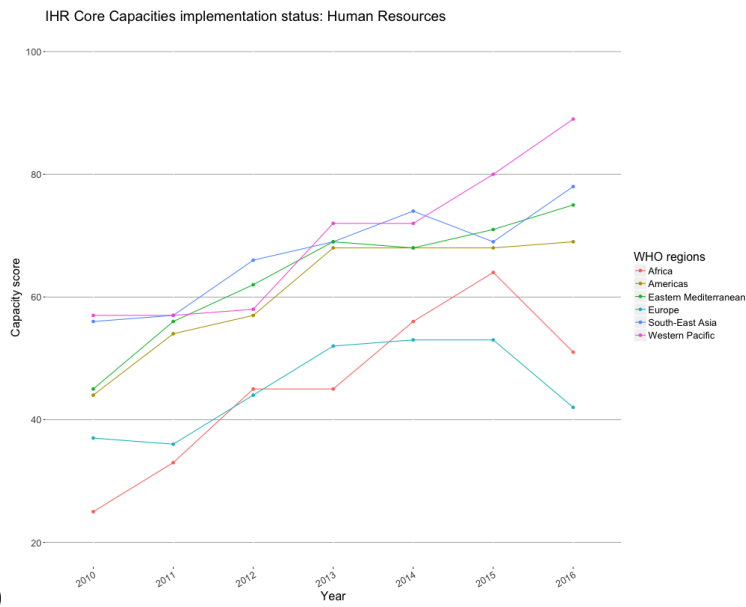
1168

1169 The first of these capacities is human resources, which reflects a single indicator: 'human resources
1170 available to implement the International Health Regulations Core Capacities'. This is a useful proxy in
1171 lieu of an indicator that looks at specific capacity for health adaptation to climate change (Figure
1172 2.3a). In 2010, capacity scores ranged from 25% in Africa to 57% in Western Pacific. Human resource
1173 capacity has improved markedly by 2016, where on the average the capacity score is 67% (with the
1174 lowest score in the Africa region reporting 51% and the highest in the Western Pacific Region 89%).

1175 Secondly, surveillance capacity, summarizes two indicators in the IHR questionnaire 'Indicator-based
1176 surveillance includes an early warning function for early detection of a public health event', and
1177 'Event-Based Surveillance is established and functioning'. This capacity score is used as a proxy for a
1178 health system's ability to anticipate and identify outbreaks and changing patterns of climate-
1179 sensitive infectious diseases, such as zoonosis and food-related outbreaks. Globally, 129 reporting
1180 States Parties scored 88% for this capacity in 2016 (Figure 2.3b). This proportion has increased
1181 steadily since 2010 (average score of 63%), indicating that health systems have increasing capacity
1182 for early detection of public health events.

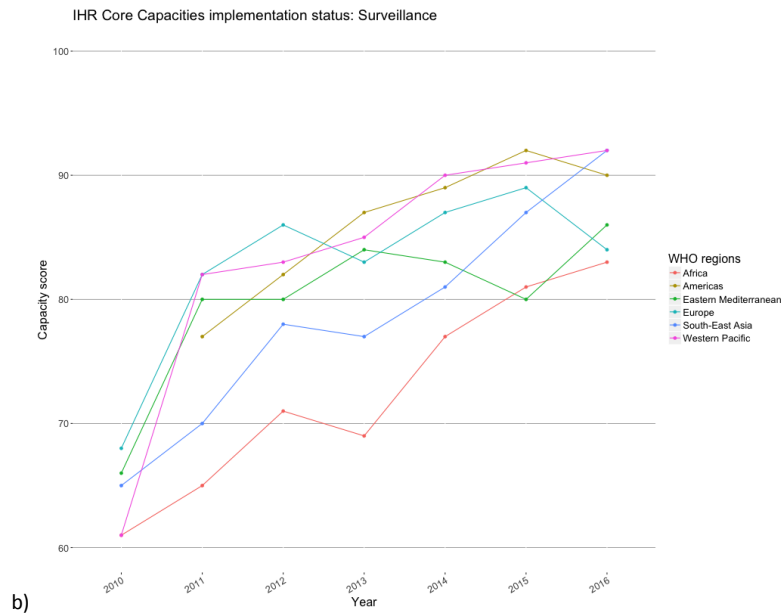
1183 Thirdly, preparedness capacity reflects 'Multi-hazard National Public Health Emergency
1184 Preparedness and Response Plan is developed and implemented', comprised of the presence of a
1185 plan, the implementation of the plan, and the ability for this plan to operate under unexpected
1186 stress, and 'priority public health risks and resources are mapped and utilized'. Of responding
1187 countries, progress can be seen in all world regions from 49% in 2010 to a 2016 global average of
1188 76% (Figure 4.3c).

1189 Finally, response capacity, reflects the availability and functioning of public health emergency
 1190 response mechanisms, and Infection Prevention and Control (IPC) at national and hospital levels.
 1191 This capacity is an important proxy for the ability of the health system to mobilize effective
 1192 responses when shocks or stresses are detected. All countries demonstrate between 73-91%
 1193 response capacity in 2016, with notable progress seen in Africa between 2010 (47%) and 2016 (73%)
 1194 (Figure 2.3d).



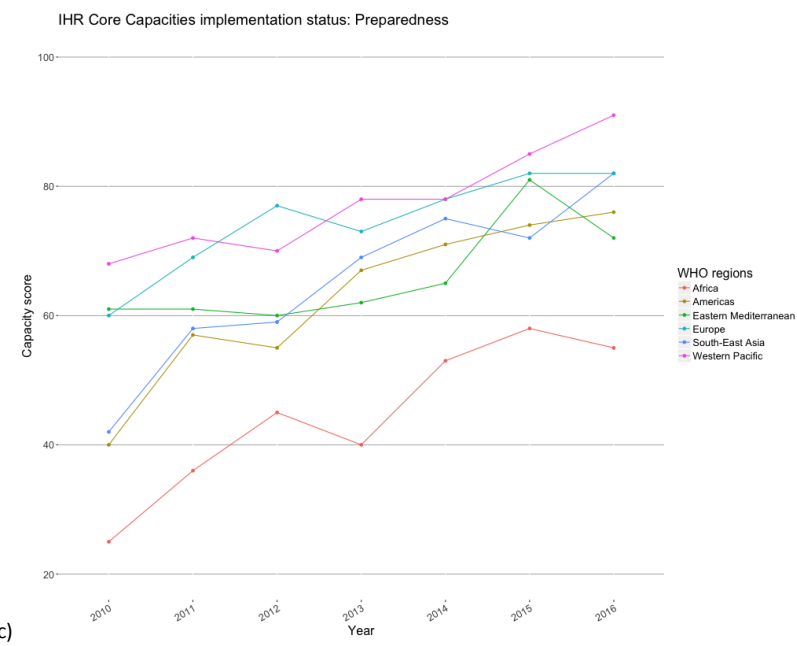
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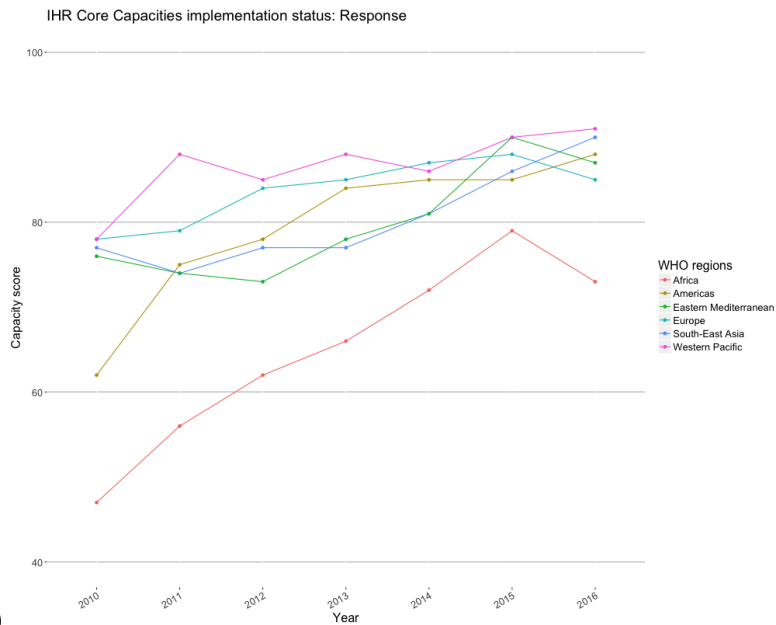


b)

1197



c)



1198

d)

1199 Figure 2.3: IHR capacity scores by WHO region. 2.3a) Human Resources capacity score. 2.3b) Surveillance
 1200 capacity score. 2.3c) Preparedness capacity score. 2.3d) Response capacity score.

1201 There are some limitations to considering these capacities. Most importantly, IHR survey responses
 1202 are self-reported; although national-level external verification has begun it currently remains
 1203 relatively limited. Additionally, these findings capture potential capacity – not action. Finally, the
 1204 quality of surveillance for early detection and warning is not shown, nor is the impact of that
 1205 surveillance on public health. Response systems have been inadequate in numerous public health
 1206 emergencies and thus the presence of such plans is not a proxy for their effectiveness.

1207

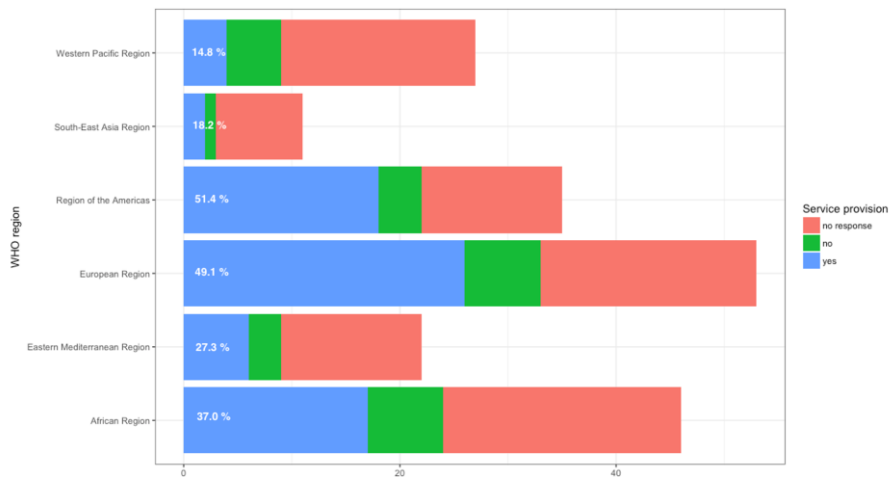
1208 [Indicator 2.4: Climate information services for health](#)

1209 **Headline Finding:** Out of the 100 WHO Member States responding to the WMO Survey, 73% report
 1210 providing climate information to the health sector in their country.

1211 This indicator measures the proportion of countries whose Meteorological and Hydrological services
 1212 self-reported to the World Meteorological Organization (WMO), providing tailored climate
 1213 information, products and services to their national public health sector.⁹⁵ Response rates for the
 1214 2015 WMO survey were: 71% in the African region, 67% in the Eastern Mediterranean Region, 79%
 1215 in the European Region, 81% in the Region of the Americas, 67% in the South-East Asia Region and
 1216 44% in the Western Pacific Region.

1217 Taking into account the total number of WHO members (respondent and non-respondent) per WHO
 1218 region, only between 14.8 % and 51.4% are known to provide climate information to the health
 1219 sector (Figure 2.4) and between 18% and 55% did not provide information.

1220



1221

1222 Figure 2.4: National Meteorological and Hydrological Services (NHMSs) of WHO member states reporting to
 1223 provide targeted/tailored climate information, products and services to the health sector.

1224 However, it is important to note that this sample is not representative of all countries (49% non-
 1225 response rate) and these are self-reported results. Crucially, this indicator does not capture the type
 1226 of climate products made available, quality of the data provided, the ways in which the health sector
 1227 makes use of this data (if at all), and whether the data is presented in a format and timely fashion
 1228 relevant to public health. Future WMO surveys will aim to provide greater insight to the specific
 1229 applications of climate information. See Appendix 3 for more information.

1230

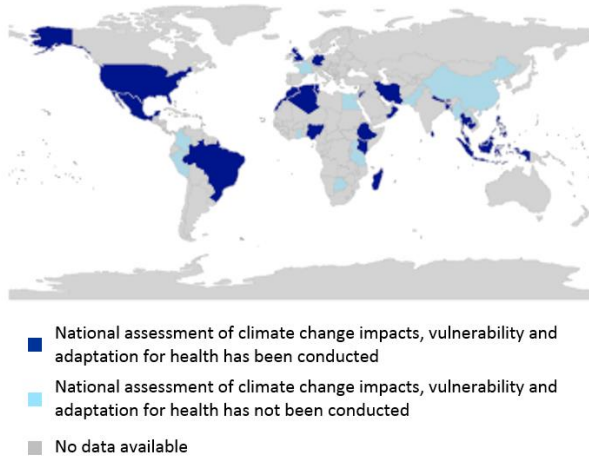
1231 **Indicator 2.5: National assessments of climate change impacts, vulnerability, and adaptation**
 1232 **for health**

1233 **Headline Finding:** *Over two thirds of responding countries report having conducted a national*
 1234 *assessment of climate change impacts, vulnerability, and adaptation for health.*

1235 National assessments of climate change impacts, vulnerability, and adaptation for health allow
 1236 governments to understand more accurately the extent and magnitude of potential threats to health
 1237 from climate change, the effectiveness of current adaptation and mitigation policies and future
 1238 policy and programme requirements. Although national assessments may vary in scope between
 1239 countries, the number of countries that have conducted a national assessment of climate change
 1240 impacts, vulnerability, and adaptation for health is a key indicator to monitor the global availability
 1241 of information required for adequate management of health services, infrastructure and capacities
 1242 to address climate change. This indicator tracks the number of countries that have conducted
 1243 national assessments, based on responses to the 2015 WHO Climate and Health Country Survey
 1244 (Panel 2.1).

1245 Over two-thirds of countries sampled (27 out of 40) reported having conducted a national
 1246 assessment of impacts vulnerability, and adaptation for health (Figure 2.5). These countries cover all
 1247 regions and include countries that are particularly vulnerable; for instance, of the nine responding
 1248 countries in the South-East Asia Region, eight countries (Bangladesh, Bhutan, Indonesia, Maldives,
 1249 Nepal, Sri Lanka, Thailand and Timor-Leste) reported having national assessments of impacts,

1250 vulnerability, and adaptation for health. Increasing global coverage of countries with national
1251 vulnerability and adaptation assessments for health is the result of WHO's support to countries
1252 through projects and technical guidance.⁹⁶

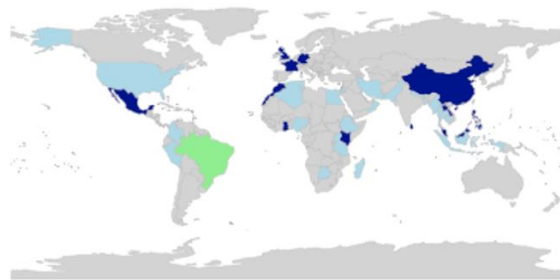


1253
1254 Figure 2.5 Countries with national assessment of climate change impacts, vulnerability and adaptation for
1255 health.

1256
1257 **Indicator 2.6: Climate-resilient health infrastructure**
1258 **Headline Finding:** Only 40% (16 out of 40) of responding countries reported implementing activities
1259 to increase the climate resilience of their health infrastructure.

1260 Functioning health infrastructure is essential during emergencies. Climate-related events, such as
1261 severe storms and flooding, may compromise electrical and water supplies, interrupt supply chains,
1262 disable transportation links, and disrupt communications and IT networks, contributing to reduced
1263 capacity to provide medical care. This indicator measures efforts by countries to increase the climate
1264 resilience of health infrastructure. The climate resiliency of health infrastructure reflects the extent
1265 to which these systems can prepare for and adapt to changes in climate impacting the system. Data
1266 is drawn from the WHO Climate and Health Country Survey (Panel 2.1). Only 40% of countries (16
1267 out of 40) reported having taken measures to increase the climate resilience of their health
1268 infrastructure (Figure 2.6). These results suggest widespread vulnerability of health system
1269 infrastructure to climate change. For example, only two out of nine responding countries in the
1270 African Region report efforts to improve the climate resiliency of health infrastructure. Similar trends
1271 were found across other WHO regions.

1272



- Measures to increase the climate-resilience of health infrastructure have been taken
- Measures to increase the climate-resilience of health infrastructure have not been taken
- Measures to increase the climate-resilience of health infrastructure are unknown
- No data

1273

1274 Figure 2.6 Countries taking measures to increase the climate resilience of health infrastructure.

1275

1276 This indicator does not capture the quality or effectiveness of efforts to build climate-resilient health
 1277 system infrastructure. Nonetheless, it highlights the importance of ensuring that countries work to
 1278 implement climate-resilient health infrastructure, as these findings suggest this is generally lacking.

1279

1280 Conclusion

1281 This section has presented indicators across a range of areas relevant to health adaptation and
 1282 resilience. It is clear that the public, and the health systems they depend upon, are ill-prepared to
 1283 manage the health impacts of climate change.

1284 In many cases, the data and methods available provide only a starting-point for an eventual suite of
 1285 indicators that capture health-specific adaptation, and include both process-and outcome-based
 1286 indicators. New indicators will also be required to better capture important indicators of resilience.

1287

1288

1289

1290 3. Mitigation Actions and Health Co-Benefits

1291

1292 [Introduction](#)

1293 Sections one and two have covered the health impacts of climate change, the adaptation available
1294 and currently being implemented, and the limits to this adaptation.¹⁰ This third section presents a
1295 series of indicators relevant to the near-term health co-benefits of climate mitigation policies.
1296 Accounting for this enables a more complete consideration of the total cost and benefits of such
1297 policies, and is essential in maximising the cumulative health benefits of climate change mitigation.

1298 The health co-benefits of meeting commitments under the Paris Agreement are potentially
1299 immense, reducing the burden of disease for many of the greatest global health challenges faced
1300 today and in the future.⁹⁷ The indicators presented in this section describe a clear and urgent need
1301 to increase the scope of mitigation ambition if the world is to keep global average temperatures
1302 “well below 2°C”.⁷

1303 Countries are accelerating their response to climate change, with Finland, the UK, China, France,
1304 Canada and the Netherlands making strong commitments to phase-out or dramatically reduce their
1305 dependence on coal.⁹⁸⁻¹⁰¹ By 2017, electric vehicles are poised to be cost-competitive with their
1306 petroleum equivalents, a phenomenon that was not expected until 2030. Globally, more renewable
1307 energy capacity is being built every year than all other sources combined.^{101,102} Consequently,
1308 renewable energy is now broadly cost-competitive with fossil fuels, with electricity from low-latitude
1309 solar PV being cheaper than natural gas.¹⁰¹⁻¹⁰³

1310

1311 [Tracking the health co-benefits of climate change mitigation](#)

1312 Meeting the Paris Agreement will require global GHG emissions to peak within the next few years
1313 and undergo rapid reduction thereafter, implying near-term actions and medium- and long-term
1314 cuts through country-level activities.⁸ Global CO₂ emissions from fossil fuels and industry were 36.3
1315 GtCO₂ in 2015 (60% higher than in 1990), while emissions from land use change – which is
1316 intrinsically difficult to estimate – was approximately 4.8 GtCO₂. In the same year, 41% of the total
1317 fossil fuel and industry emissions were estimated to come from coal, 34% from oil, 19% from gas,
1318 and 6% from cement.¹⁰⁴ In 2015, the largest emitters of CO₂ were China (29%), the USA (15%), the
1319 European Union’s (EU) 28 member states ((EU28); 10%) and India (6.3%). However, per capita
1320 emissions of CO₂ belie the disparity driven by consumption, with global mean emissions at 4.8 tCO₂
1321 per person per year compared to 16.8 in the USA, 7.7 in China, 7.0 in EU28, and 1.8 in India.¹⁰⁴

1322 The actions needed to embark on rapid decarbonisation include avoiding the ‘lock-in’ of carbon
1323 intensive infrastructure and energy systems, reducing the cost of ‘scaling-up’ low-carbon systems,
1324 minimising reliance on unproven technologies, and realising opportunities of near-term co-benefits
1325 for health, security, and the environment.⁸ These actions will need to also be cost-effective and
1326 supported by non-state actors and industry.

1327 Indicators in this section are broadly considered within the framework of Driving Force-Pressure-
1328 State-Exposure-Effect-Action (DPSEEA). The DPSEEA framework is recognized as being suitable for
1329 the development of environmental health indicators, and identification of entry points for policy
1330 intervention.¹⁰⁵ An adaptation of the framework for examination of the health co-benefits of climate
1331 change mitigation is explained in Appendix 4.

1332 Here, health co-benefit indicators are captured for four sectors: 1) energy, 2) transport, 3) food, and
1333 4) healthcare. Appendix 4 provides more detailed discussion of the data and methods used.

1334 **Energy Supply and Demand Sectors**

1335 Fossil fuel burning comprises the largest single source of GHG emissions globally, producing an
1336 estimated 72% of all GHG emissions resulting from human activities.^{106,107} The majority (66%) of
1337 these emissions arise in the energy sector from the production of thermal and electric power for
1338 consumption across a range of sectors including industry, commercial, residential and transport.

1339 To meet the climate change mitigation ambitions of the Paris Agreement, it is widely accepted that
1340 the energy system will need to largely complete the transition towards near zero-carbon emissions
1341 by, or soon after, 2050, and then to negative emissions in the latter part of the century.^{108,109} Recent
1342 analysis has framed the necessary action as a halving of CO₂ emissions every decade.¹¹⁰

1343 The potential short-term health benefits of such strategies are substantial, with significant
1344 improvements from a reduction in indoor and outdoor air pollution; more equitable access to
1345 reliable energy for health facilities and communities; and lower costs of basic energy services for
1346 heating, cooking, and lighting to support higher quality of life.

1347

1348 **Indicator 3.1: Carbon intensity of the energy system**

1349 **Headline Finding:** *Globally, the carbon intensity of total primary energy supply (TPES) has remained*
1350 *stable since 1990, between 55-56 tCO₂/TJ, reflecting the significant global challenge of energy*
1351 *system decarbonisation. This has occurred because countries, which have achieved a reduction in*
1352 *carbon intensity (USA, UK, Germany), have been offset by those which have increased the carbon*
1353 *intensity of their energy supply (India and China).*

1354 To achieve the 2°C target (at a 66% probability), the global energy sector must reduce CO₂ emissions
1355 to more than 70% below current levels by 2050. This means a large reduction in the carbon intensity
1356 of the global energy system, which can be measured as the tonnes of CO₂ for each unit of total
1357 primary energy supplied (tCO₂/TJ). TPES reflects the total amount of primary energy used in a
1358 specific country, accounting for the flow of energy imports and exports.¹¹¹ Commitments under the
1359 Paris Agreement should begin to lower the overall carbon intensity of TPES, with the aim of reducing
1360 to near-zero by 2050.

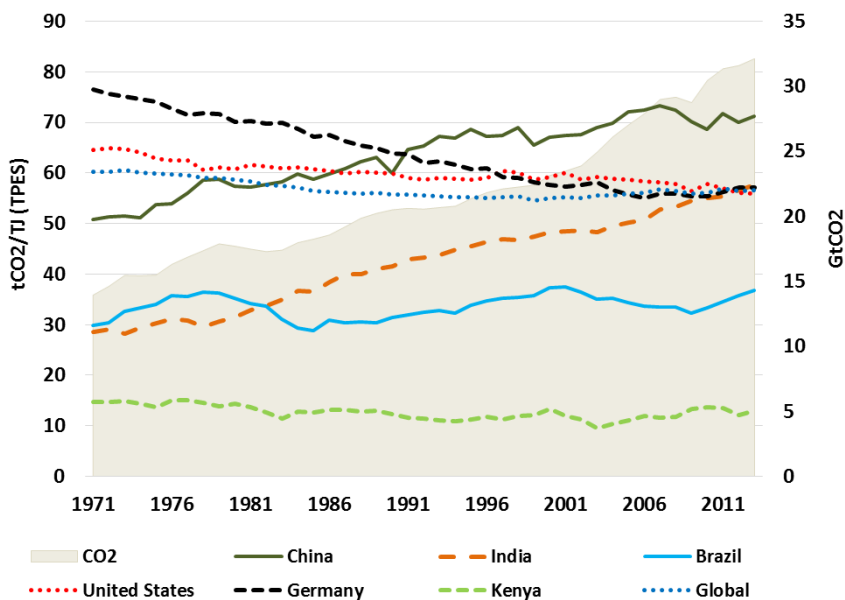
1361 Drawing on data from the International Energy Agency (IEA), this indicator shows that globally, since
1362 the 1990s, the carbon intensity of primary energy supply has remained between 55-56 tCO₂/TJ.¹¹²
1363 However, a 53% growth in energy demand over the period has meant that global CO₂ emissions have
1364 grown significantly. Rapidly, low and middle income countries (LMICs) have seen an increase in
1365 carbon intensity since the 1970s, driven by increased coal use (Figure 3.1). For example, India's TPES
1366 has almost tripled since 1980, with the share of coal in the mix doubling (from 22% to 44%). Over the
1367 same period, 1980-2014, a fourfold increase in China's TPES, combined with increasing carbon
1368 intensity due to the coal share of TPES increasing from 52% to 66%, has led to strong growth in
1369 emissions.

1370 High-income countries have seen carbon intensity fall since the 1970s (for example, the USA and
1371 Germany in [Figure Figure-3.1](#)). This decrease has resulted from a move away from coal use in
1372 energy production and use, reduced heavy industrial output, and increased use of lower carbon
1373 fuels, notably moving from coal to natural gas in the power sector and the use of renewable energy.

1374

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1375

1376 Figure 3.1 Carbon intensity of Total Primary Energy Supply (TPES) for selected countries, and total CO₂
 1377 emissions (shaded area against secondary y-axis), 1971-2013.

1378

1379 **Indicator 3.2: Coal phase-out**

1380 **Headline Finding:** Globally, total primary coal supply has increased from 92 EJ in 1990, to 160 EJ in
 1381 2015. However, the 2015 supply level represents a reduction from the high point of 164 EJ in 2013,
 1382 providing an encouraging indication that global coal consumption has peaked and is now in decline.

1383 The primary means of reducing carbon intensity of the energy system within necessary timescales
 1384 will be the phase-out of coal. Worldwide, coal supplies 30% of energy use and is the source of 44%
 1385 of global CO₂ emissions. The dirtiest form of coal produces almost twice the carbon per unit of
 1386 primary energy than the least carbon intensive fossil fuel – natural gas.¹¹² Given that a large share of
 1387 coal is used for power generation, it is an important sector of focus, both to reduce CO₂ emissions
 1388 and mitigate a major source of air pollution.¹¹²

1390 This indicator of coal phase-out is the total primary coal supply (EJ) in the energy system (Figure 3.2),
 1391 which makes use of recent data from the IEA.¹¹²

1392 Globally, coal use has increased by just under 60% since 1990. This is due to strong growth in global
 1393 energy demand, and an increasing share of TPES coming from coal, rising from 26% to 29% between
 1394 1990 and 2014.¹¹² This growth has largely been driven by China's increasing use of coal in industry
 1395 and for electricity production, particularly in the 2000s (see East Asia trend in [Figure Figure Figure](#)
 1396 3.2). Crucially, growth in coal use has plateaued and reduced since 2013, in large part due to a
 1397 recognition of the health effects of air pollution, slower growth and structural changes in China's
 1398 economy, and a slowing in energy sector expansion.¹¹³ India has also seen significant growth in coal
 1399 use, with the share of coal in TPES increasing from 31% in 1990 to 46% in 2015. The other large coal

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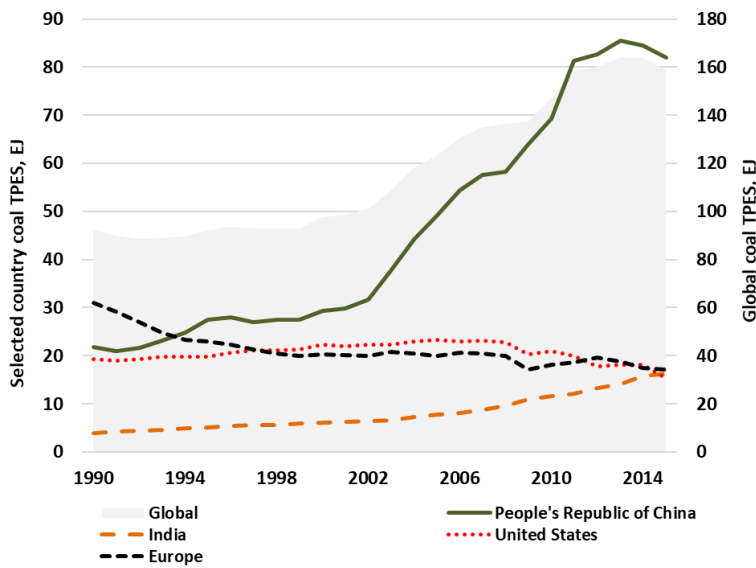
1400 consuming regions are the USA and Europe. The USA has had a stable level of consumption since the
 1401 1990s, but experienced a recent fall in use, particularly in energy production and use, due to the
 1402 cost-competitiveness of shale gas. Europe has seen a steady decline in coal use since the 1990s,
 1403 again through a move to gas in economies such as the UK, although this overall downward trend has
 1404 transitioned to a plateau in recent years.

1405 Today, China and India both have similar shares of electricity generate by coal, at around 75% of
 1406 total generation. Whilst this trend is plateauing in China, this is not observed in other parts of Asia,
 1407 and the rapidly-emerging economies of Indonesia, Vietnam, Malaysia, and the Philippines see strong
 1408 growth from coal.¹¹²

1409 Meeting the IEA's 2°C pathway and the Paris Agreement requires that no new coal-fired plants be
 1410 built (beyond those with construction currently underway), with a complete phase-out of unabated
 1411 plants (not fitted with carbon capture and storage) occurring by 2040. Crucially, such a transition
 1412 may have started, with the amount of coal power capacity in pre-construction planning at 570
 1413 gigawatts (GW) in January 2017, compared to 1,090 GW in January 2016.¹¹⁴ There are a range of
 1414 reasons for this large reduction, including decreasing planned capacity expansion, a desire to tackle
 1415 air pollution, and active efforts to expand renewable investment.

1416

1417



1418

1419 Figure 3.2 Total primary coal supply by country or region, and globally (shaded area against secondary y-axis),
 1420 1990-2015.

1421

1422

1423 Indicator 3.3: Zero-carbon emission electricity

1424 **Headline Finding:** Globally, renewable electricity as a share of total generation has increased by over
1425 20% from 1990 to 2013. In 2015, renewable energy capacity added exceeded that of new fossil fuel
1426 capacity, with 80% of recently added global renewable energy capacity currently located in China.
1427 Where renewables displace fossil fuels, in particular coal, it represents the beginning of reductions in
1428 morbidity and mortality from air pollution, and a potentially remarkable success for global health.

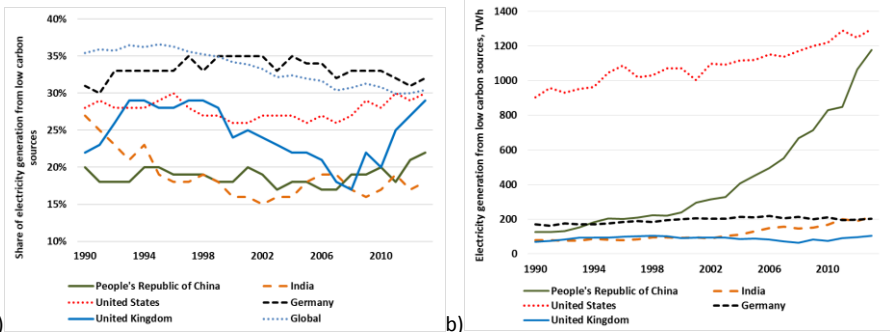
1429 As coal is phased out of the energy system, in particular in electricity production, the rapid scaling up
1430 of zero-carbon energy production and use will be crucial. To remain on a 2°C pathway, renewables-
1431 based capacity additions will need to be sustained over the next 35 years, reaching 400 GW per year
1432 by 2050, which is two and a half times the current level. Critical renewable technologies for
1433 achieving this will be solar, wind and hydroelectric.

1434 Indicator 3.3 draws on IEA data, and considers both renewable and other zero-carbon electricity.¹¹²
1435 Conversely, renewable energy refers to “all forms of energy produced from renewable sources in a
1436 sustainable manner, which include: bioenergy, geothermal, hydropower, ocean energy (tidal, wave,
1437 thermal), solar energy and wind energy”.¹¹⁵ By comparison, zero-carbon energy means no GHG
1438 emissions (i.e. zero-carbon and carbon equivalent) at the point of energy production and use, which
1439 therefore also includes nuclear-powered electricity, but excludes biomass.

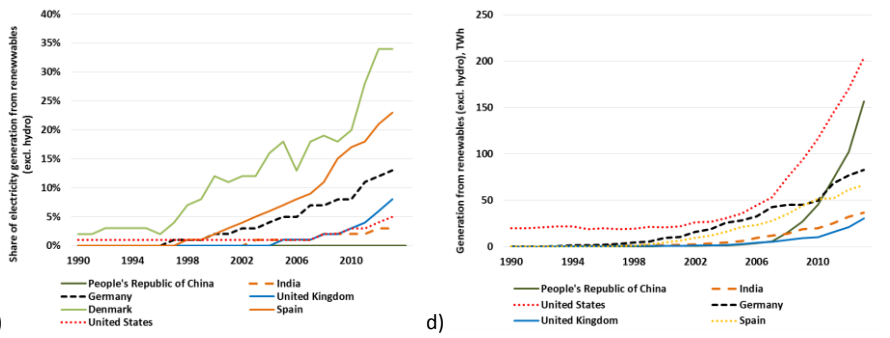
1440 Both displace the use of fossil fuels (although notably fossil capacity tends to have annual higher
1441 load factors than renewables), reducing air pollution and GHG emissions, and so are important
1442 indicators for climate change and for health. One caveat is that the combustion of solid biomass
1443 fuels such as wood, sometimes promoted for climate change mitigation purposes, may increase fine
1444 particulate air pollution exposure and may not be carbon-neutral.¹¹⁶

1445 As a share of total generation, renewable energy has increased by over 20% from 1990 to 2013.
1446 Renewable energy continues to grow rapidly, mainly from increasing wind and solar PV investment,
1447 most notably in the USA, China and Europe (Figure 3.3). In 2015, more renewable energy capacity
1448 (150GW) was added than fossil fuel plant capacity added globally. Overall, there is now more added
1449 renewable generation capacity installed globally (almost 2000 GW) than coal, with about 80% of this
1450 newly installed capacity located in China.¹¹²

1451



1452



1453

1454 Figure 3.3 Renewable and zero-carbon emission electricity generation a) Share of electricity generated from
 1455 zero carbon sources; b) Electricity generated from zero carbon sources, TWh; c) Share of electricity generated
 1456 from renewable sources (excluding hydro); d) Electricity generated from renewable sources (excl. hydro), TWh.

1457

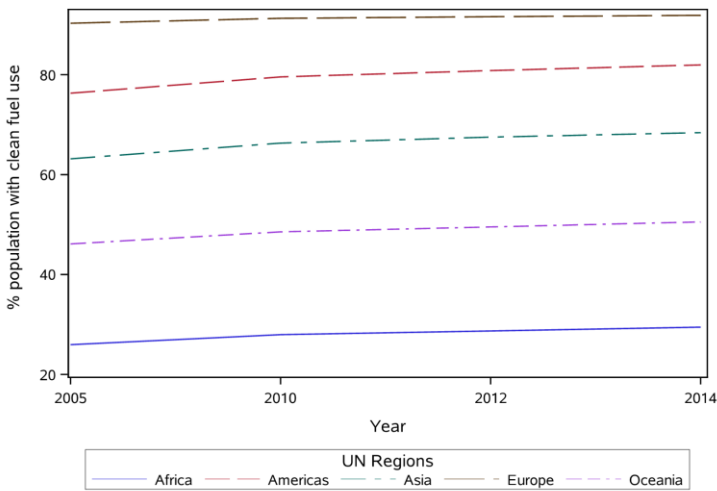
1458 **Indicator 3.4: Access to clean energy**

1459 **Headline Finding:** In 2016, it was reported that 1.2 billion people did not have access to electricity,
 1460 with 2.7 billion people relying on the burning of unsafe, unsustainable, and inefficient solid fuels.

1461 Increased access to clean fuels and clean energy technologies will have the dual benefit of reducing
 1462 indoor air pollution exposure, and reducing GHG emissions by displacing fossil fuels.¹¹⁷ The use of
 1463 clean energy for heating, cooling, cooking and lighting plays an important role in improving global
 1464 health and wellbeing, economic productivity, and reducing the risk of harm from living in energy
 1465 poverty.¹¹⁸

1466 It is estimated that globally, 1.2 billion people do not currently have access to electricity and 2.7
 1467 billion people rely on burning unsustainable and inefficient solid fuels, which contributes to poor
 1468 indoor air quality (see Panel 3.1), estimated to result in 4.3 million premature deaths related to
 1469 pneumonia, stroke, lung cancer, heart disease, and chronic obstructive pulmonary disease (COPD)
 1470 each year.^{119,120} Access to electricity, an energy source that emits no direct airborne particles
 1471 (though particles may be emitted indirectly through the fuel used to generate the electrical power),
 1472 is currently 85.3% globally but varies widely among countries and urban and rural settings.

1473 This indicator draws on and aligns with the proposed Sustainable Development Goal (SDG) indicator
 1474 7.1.2, defining ‘clean energy’ in terms of emission rate targets and specific fuel recommendations
 1475 (i.e. against unprocessed coal and kerosene) included in the WHO normative guidance.¹²¹ It
 1476 estimates the proportion of the population who primarily rely on clean fuels (including liquefied
 1477 petroleum gas, which, while still a fossil fuel, is cleaner than many solid fuels) and technologies for
 1478 cooking, heating and lighting compared to all people accessing those services. The data used for this
 1479 indicator comes from estimates of fuel use from WHO household survey data from roughly 800
 1480 nationally representative surveys and censuses, and is modelled to estimate the proportion of their
 1481 reliance on clean fuels (Figure 3.4).¹²²



1482
 1483 Figure 3.4 Proportion of population relying primarily on clean fuels and technology.

1484

1485 **Indicator 3.5: Exposure to ambient air pollution**

1486 **Headline Finding:** 71% of the 2,971 cities in the WHO’s database do not satisfy WHO annual fine
 1487 particulate matter exposure recommendations.

1488 Air pollutants directly harmful to health are emitted by combustion processes that also contribute to
 1489 emissions of GHGs. As such, properly designed actions to reduce GHG emissions will lead to
 1490 improvements in ambient air quality, with associated benefits for human wellbeing.¹²³ Current
 1491 estimates suggest that global population-weighted fine particulate matter (PM_{2.5}) exposure has
 1492 increased by 11.2% since 1990.^{123,124} To represent levels of exposure to air pollution, this indicator
 1493 collects information on annual average urban background concentrations of PM_{2.5} in urban settings
 1494 across the world.

1495

1496 **3.5.1: Exposure to air pollution in cities**

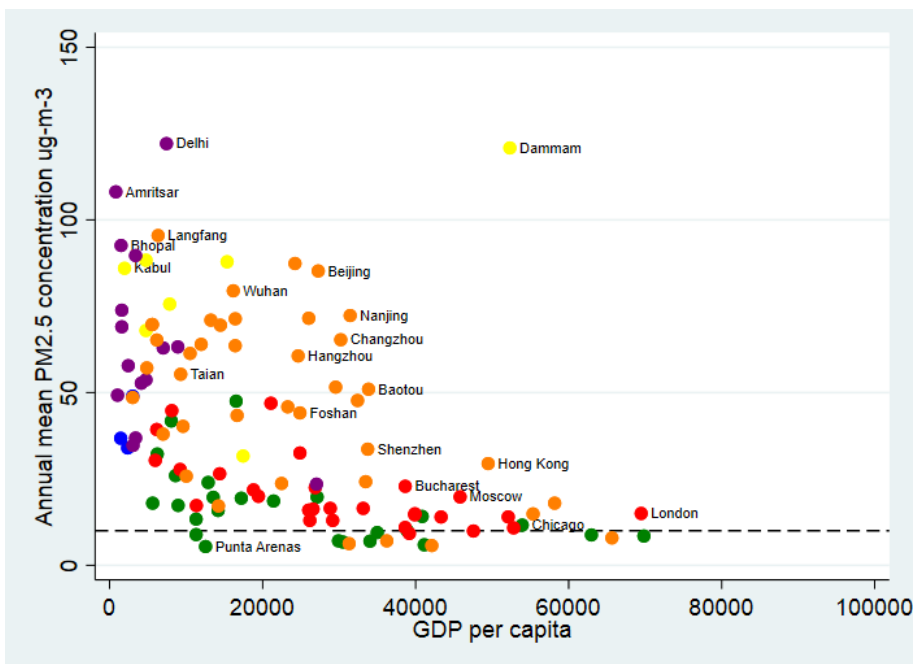
1497 The data for this indicator makes use of the WHO’s Urban Ambient Air Pollution Database, which
 1498 compiles information from a range of public sources, including national and subnational reports and
 1499 websites, regional networks, intergovernmental agencies, and academic publications.¹²⁵ The air
 1500 pollution measurements are taken from monitoring stations located in urban background,

1501 residential, commercial, and mixed areas. The annual average density of emission sources in urban
 1502 areas and the proximity of populations to those sources led the Lancet Countdown to focus on
 1503 exposure in cities.

1504 For this indicator, the Lancet Countdown has combined the WHO database with the Sustainable
 1505 Healthy Urban Environments (SHUE) database, presenting data on 246 randomly sampled cities
 1506 across the world (stratified by national wealth, population size, and Bailey's Ecoregion) (Figure
 1507 3.5).¹²⁶

1508

1509



1510
 1511 Figure 3.5 Annual mean PM2.5 concentration vs per capita GDP for 246 cities in the SHUE database. Colours
 1512 indicate WHO regions: blue – Africa; red – Europe; green – the Americas; Lime – Eastern Mediterranean;
 1513 orange – Western Pacific; purple – South East Asia. The dotted line marks the WHO recommended guidance
 1514 level of 10 $\mu\text{g}\cdot\text{m}^{-3}$.

1515
 1516 $\text{PM}_{2.5}$ levels in the majority of global cities are currently well above the WHO's annual guideline level
 1517 of 10 $\mu\text{g}\cdot\text{m}^{-3}$, with particularly high levels in cities in central, South and East Asia. Of almost 3,000
 1518 cities in the WHO database, levels in 71.2% are above the guideline level. However, since monitoring
 1519 is more common in high income settings, this is likely to represent an underestimation; for
 1520 randomly-selected cities in the SHUE database, 87.3% of cities are above the guideline. The data
 1521 suggests that air pollution levels have generally decreased in high income settings over recent
 1522 decades, although it has marginally increased, globally.¹²⁷

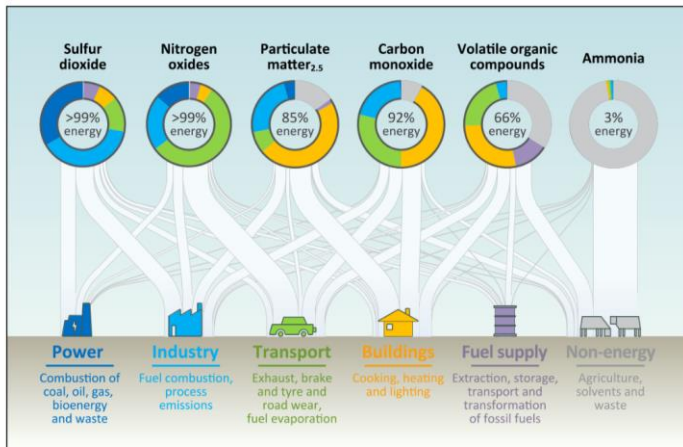
1523 **Panel 3.1. Energy and Household Air Pollution in Peru.**

1524 Universal access to energy is a major challenge in most LMICs and access to clean energy or energy
 1525 sources that do not adversely affect health is a considerable problem. In Peru, low-income families
 1526 spend a higher percentage (5%-18%) of average monthly income on energy services than those with
 1527 higher-incomes.¹²⁸ Furthermore, a large portion of Peru’s rural population (83%) use firewood, dung,
 1528 or coal for cooking, making indoor air pollution one of the main environmental risk factors
 1529 experienced.¹²⁹

1530 Since the 1990s, the Peruvian government and various NGOs have promoted programmes and
 1531 policies oriented towards addressing the problem of solid fuels’ use for lighting, cooking and heating
 1532 and lack of access to energy sources in low-income sectors. In 2009, legislative changes enabled sub-
 1533 national governments to invest up to 2.5% of the national mining revenues in improved cook stove
 1534 (ICS) deployment, resulting in more than 280,000 ICS installed nationwide (52% public and 43%
 1535 private) as part of the multi-sectorial campaign “Half Million ICS for a Smokeless Peru”. This
 1536 campaign to help improve quality of life and health through the instalment of certified ICS.
 1537 Studies show that well-kept and certified ICS can reduce personal exposure to particulate matter
 1538 (PM_{2.5}).

1539 Peru released its 2010-2040 National Energy Policy in 2010. Of the nine goals, two discuss access to
 1540 energy services to low-income sectors. Special programmes have been developed in rural high
 1541 altitude and Amazonian regions in Peru to address energy access issues. In 2012, programmes were
 1542 established to substitute kerosene and other contaminating stoves with liquefied petroleum gas
 1543 (LPG) and ICS; and the Social Inclusion Energy Fund (FISE) was established, promoting access to LPG
 1544 for the most vulnerable populations through subsidies. By 2015, according to FISE, more than 1.3
 1545 million families had received an LPG stove, mitigating 91% of their CO₂ emissions and leading to a
 1546 corresponding reduction of 553,000 tons of CO₂ in using cleaner sources of energy.^{130,131}

1547
 1548 **3.5.2: Sectoral contributions to air pollution**
 1549 The energy sector –both production and use - is the single largest source of man-made air pollution
 1550 emissions, producing 85% of particulate matter and almost all of the sulphur oxides and nitrogen
 1551 oxides emitted around the world (Figure 3.6).¹¹²



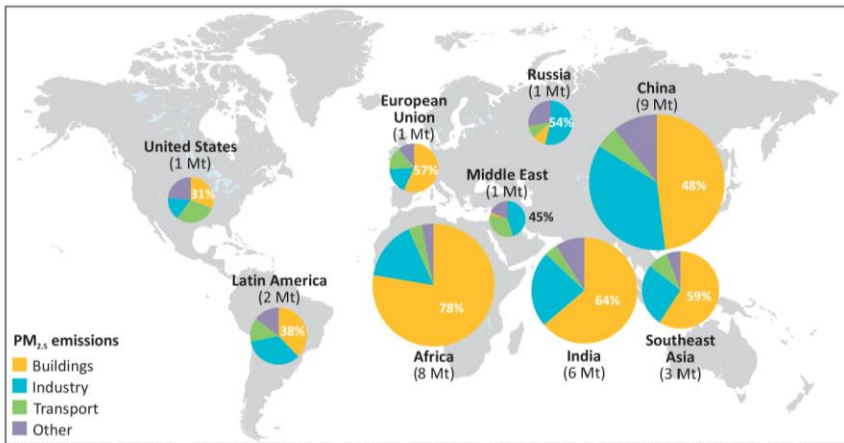
1553 Figure 3.6 Selected primary air pollutants and their sources globally in 2015.¹¹² (Source: IEA, 2016)

1554

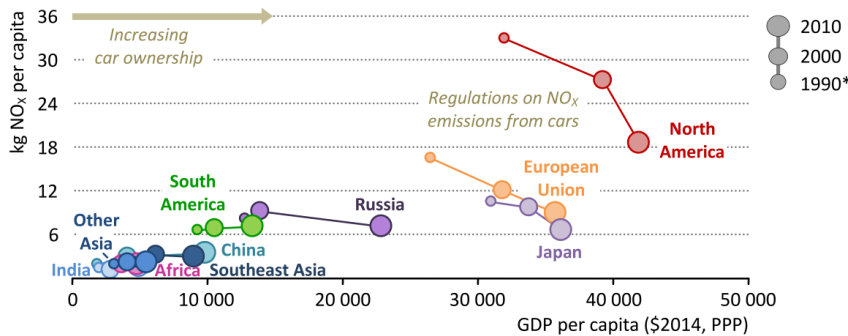
1555 Of this, coal power is responsible for three-quarters of the energy production and use sector's
 1556 Sulphur Dioxide (SO₂) emissions, 70% of its Nitrogen Oxide (NO_x) emissions and more than 90% of its
 1557 PM_{2.5} emissions.¹¹² However, over the past decade, these emissions have largely decoupled from
 1558 increases in coal-fired generation in several geographies, due to the introduction of emission
 1559 standards for coal power plants.^{132,133}

1560 In 2015, manufacturing and other industries (for example, refining and mining) were responsible for
 1561 about half of global energy-related emissions of SO₂ as well as 30% of both NO_x (28 Mt) and PM_{2.5}.¹¹²
 1562 Furthermore, transport was responsible for around half of all energy-related NO_x emissions in 2015
 1563 as well as 10% of PM_{2.5}. Within this sector, road vehicles were by far the largest source of the
 1564 sector's NO_x and PM_{2.5} emissions (58% and 73%, respectively), while the largest portion of SO₂
 1565 emissions came from shipping.¹¹² Trends in NO_x emissions from the transport sector (1990 to 2010)
 1566 are shown in Figure 3.7.

1567



1568 a) This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.



1569 b)

1570 Figure 3.7 a) Energy related PM_{2.5} emissions in 2015 and b) NO_x emissions from transport from 1990-2010 by
1571 region.¹¹² (Created using IEA, 2016 data)

1572

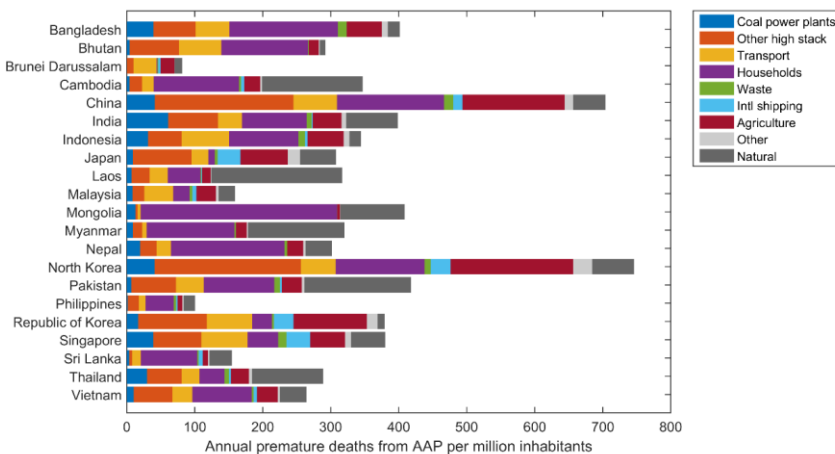
1573 3.5.3: Premature mortality from ambient air pollution by sector

1574 The extent to which emissions of different pollutants from different sectors contribute to ambient
1575 PM_{2.5} levels depends on atmospheric processes, such as the dispersion of primary particles and the
1576 formation of secondary aerosols from precursor emissions. Sources with low stack heights located
1577 close to populations, such as household combustion for cooking and heating as well as road vehicles,
1578 typically play a disproportionately larger role for total population exposure in relation to their
1579 absolute emissions.

1580 Long-term exposure to ambient PM_{2.5} is associated with increased mortality and morbidity from
1581 cardiovascular and pulmonary diseases.¹³⁴⁻¹³⁶ A recent WHO assessment estimated that ambient air
1582 pollution (AAP) is responsible for roughly three million premature deaths worldwide every year.¹³⁷
1583 As the sources of air pollution and greenhouse gases are overlapping in many cases, greenhouse gas
1584 mitigation measures can have large co-benefits for human health.

1585 Figure 3.8 shows an attribution of estimated premature mortality from AAP to the sources of
1586 pollution as calculated in the GAINS model for the year 2015 in a set of South and East Asian
1587 countries, using emissions data as published by the IEA.¹³⁸ Here, the contributions of individual
1588 source sectors to ambient PM_{2.5} concentrations have been calculated using linearized relationships
1589 based on full atmospheric chemistry transport model simulations, and premature deaths are
1590 calculated following the methodology used by the WHO and the GBD 2013 study.^{136,137}

1591 In some countries, such as China, North Korea and the Republic of Korea, agriculture is a large
1592 contributor to premature deaths. Significant direct benefits for human health can therefore be
1593 expected if these emission sources are addressed by climate policies. Significant benefits could also
1594 be available if, for instance, coal fired power plants were replaced by wind and solar.
1595 Replacement of household combustion of coal, for example in China, would result in health benefits
1596 not only from ambient (outdoor) but also household (indoor) exposure to air pollution.



1597

1598 Figure 3.8 Health impacts of exposure to ambient PM_{2.5} in terms of annual premature deaths per million
1599 inhabitants in South and East Asian countries in 2015, broken down by key sources of pollution.

1600

1601

1602 Transport Sector

1603 Transportation systems – including road vehicles, rail, shipping, and aviation – are a key source of
1604 GHG emissions, contributing 14% of global emissions in 2010.^{111,112} In order to meet the 2°C target,
1605 the global transport sector must reduce its total GHG emissions by more than 20% below current
1606 levels, by 2050, and to be on a trajectory to zero carbon emissions in the second half of the
1607 century.¹³⁹ Compared to other energy demand sectors, key sub-sectors of transportation (urban
1608 personal and freight transport, long distance road transport, shipping, short haul aviation, and long
1609 haul aviation) are more difficult to decarbonise because of the high energy density of fossil fuels,
1610 thus emissions reductions targets are lower for transport than the energy sector as a whole.

1611 The transport sector is also a major source of air pollutants, including particulate matter, nitrogen
1612 oxides, sulphur dioxide, carbon monoxide, volatile organic compounds, and indirectly, ozone.
1613 Furthermore, exposure to air pollution from road transport is particularly challenging in cities where
1614 vehicles emit street-level air pollution. In turn, significant opportunities for health exist through the
1615 reduction of GHG emissions from transport systems, both in the near-term through cleaner air and
1616 increased physical activity, and the long-term through the mitigation of climate change.

1617

1618 Indicator 3.6: Clean fuel use for transport

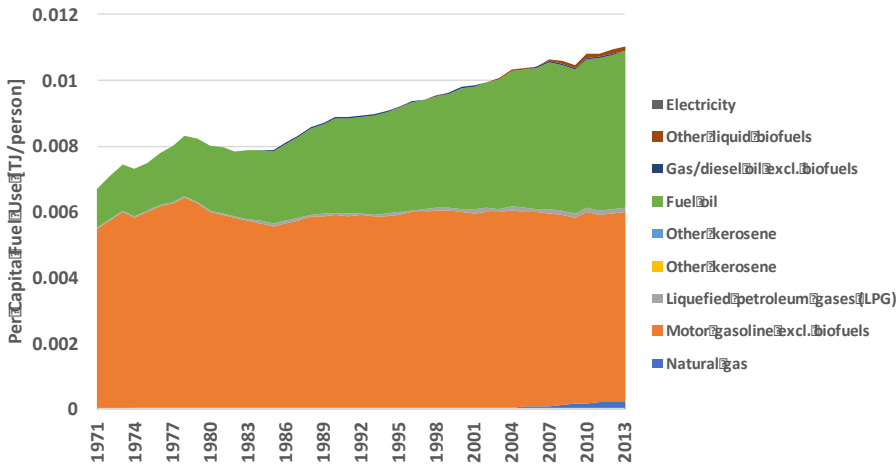
1619 **Headline Finding:** *Global transport fuel use (TJ) has increased by almost 24% since 1990 on a per*
1620 *capita basis. While petrol and diesel continue to dominate, non-conventional fuels have been rapidly*
1621 *expanding, with more than 2 million electric vehicles being sold between 2010 and 2016.*

1622 Fuels used for transport produce more than half the nitrogen oxides emitted globally and a
1623 significant proportion of particulate matter.^{111,112} Switching to low-emission transport systems is an
1624 important component of climate change mitigation and will help to reduce concentrations of most
1625 ambient air pollutants. However, the transport sector's extremely high reliance on petroleum-based
1626 fuels makes this transition particularly challenging.

1627 This indicator focuses on monitoring global trends in levels of fuel efficiency, and on the transition
1628 away from the most polluting and carbon intensive transport fuels. More specifically, this indicator
1629 follows the metric of fuel use for transportation on a per capita basis (TJ/person) by type of fuel. To
1630 develop this indicator, the Lancet Countdown draws on transport fuel data from the IEA and
1631 population data from the World Bank.¹¹²

1632 While some transition away from carbon-intensive fuel use, towards increasing levels of fuel
1633 efficiency has occurred in select countries, transport is still heavily dominated by gasoline and diesel.
1634 Global transport fuel use has increased by almost 65% since 1970 on a per capita basis (Tj/person)
1635 (Figure 3.9). However, non-conventional fuels (for example, electricity, biofuels, and natural gas)
1636 have been rapidly gaining traction since the 2000s, with more than two million electric vehicles
1637 having been sold around the globe since 2010, mostly in the US, China, Japan and some European
1638 countries (Figure 3.10).¹⁴⁰ These figures remain modest when compared to the overall number of
1639 cars sold per year, 77 million in 2017, and the total global fleet of 1.2 billion cars.

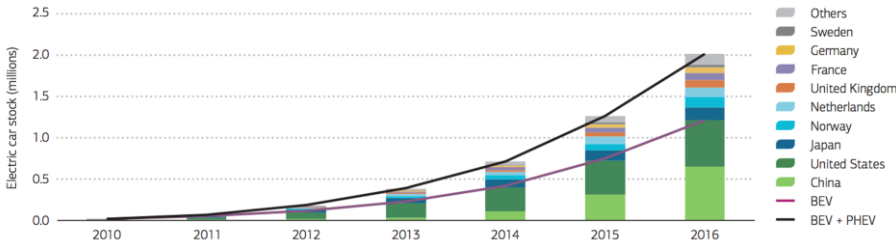
1640



1641

1642 Figure 3.9 Per capita fuel use by type (TJ/person) for transport sector with all fuels.

1643



1644

1645 Figure 3.10 Cumulative Global Electric Vehicle Sales. Note: BEV is Battery Electric Vehicle and PHEV is Plug-in
1646 Hybrid Electric Vehicle.^{141,142} (Source: IEA, 2017)

1647

1648 **Indicator 3.7: Sustainable travel infrastructure and uptake**

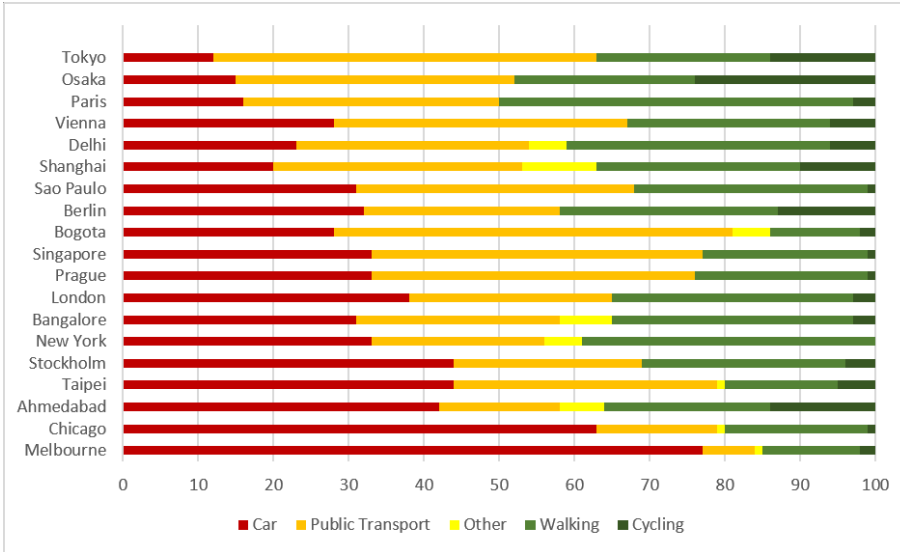
1649 **Headline Finding:** Levels of sustainable travel appear to be increasing in many European cities, but
1650 cities in emerging economies are facing sustainable mobility challenges. While levels of private
1651 transport use remain high in many cities in the USA and Australia, evidence suggests that they are
1652 starting to decline.

1653 Global trends of population growth and increasing urbanization suggests that demand for mobility in
1654 urban areas will increase. Moving from private motorized transport to more sustainable modes of
1655 travel (such as public transport, walking and cycling) in urban areas not only helps to reduce
1656 emissions from vehicles, but also has several health co-benefits. This indicator tracks trends in
1657 sustainable travel infrastructure and uptake in urban areas.

1658 Whilst this indicator would ideally track the proportion and distance of journeys undertaken by
1659 different modes of transport over time, data availability for city-level trends in modal share is
1660 particularly scarce. Therefore, the Lancet Countdown will instead present data for selected locations,

1661 across a limited time-scale. Figure 3.11 presents data on current modal shares (i.e. recent year
 1662 estimates of the proportion of trips by different modes of transport) in world cities (see Appendix 4
 1663 for details). The data, collated by the Land Transport Authority come from travel surveys of
 1664 individual cities and national census data (see Appendix 4 for details).¹⁴³

1665



1666

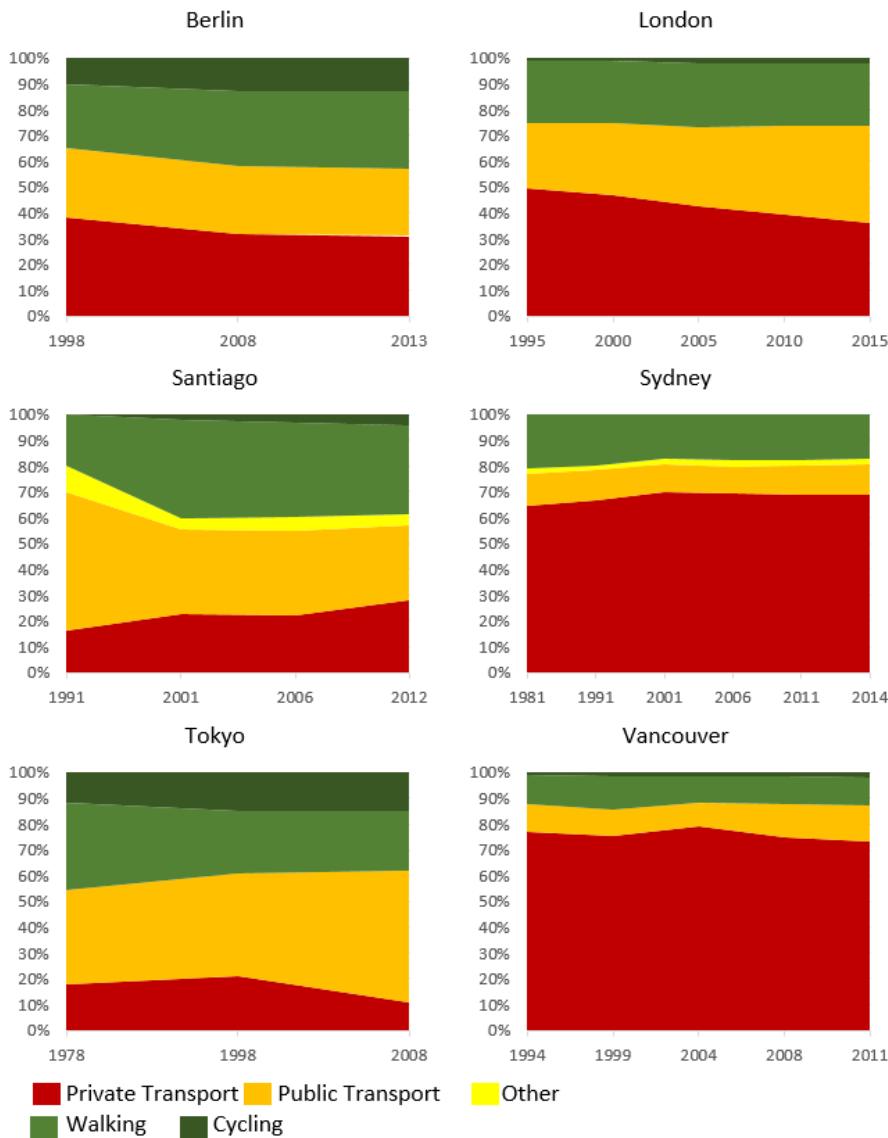
1667 Figure 3.11 Modal Shares in world cities. Note: 'Other' typically includes paratransit (transport for people with
 1668 disabilities) and/or electric bikes.

1669

1670 Figure 3.12 collates data on trends in modal share in select cities, where data from at least three
 1671 time points (including one pre-2000 time point) is available. While many cities have started to collect
 1672 this information in the past decade, there is a paucity of data on trends from before 2000, with
 1673 particularly wide gaps in data availability from cities in Asia, Africa and South America.¹⁴⁴

1674 In Berlin, London and Tokyo, the proportion of trips by privatised motor transport has slowly
 1675 declined since the late 1990s, while levels have remained high in Vancouver and Sydney and appear
 1676 to be increasing in Santiago. Levels of cycling are generally low, but appear to be increasing in many
 1677 cities.

1678 Public transport in emerging cities is often insufficient, inefficient and in poor condition, potentially
 1679 leading to further declines in sustainable travel in many rapidly growing cities in the future. ¹⁴⁵ As
 1680 this transition occurs, ensuring the mistakes made in Organization for Economic Cooperation and
 1681 Development (OECD) countries are not repeated will be vital. In particular, it is critical to improve
 1682 walking and cycling environments, in order to both make these modes attractive choices and protect
 1683 road users from injury. Recent United Nations (UN) guidance recommends devoting 20% of
 1684 transport budgets to funding non-motorized transport at national and local levels in low- and
 1685 middle-income countries. ¹⁴⁶



1686
 1687 Figure 3.12 Trends in modal share in selected cities. Note: Data from Santiago in 1991 represents travel on a
 1688 usual day; Data from Sydney represent Weekdays only; Cycling modal share in Sydney is <1%.¹⁴⁷⁻¹⁵⁶ (Figure
 1689 created using data from the following sources: Institute for Mobility Research (2016); Transport for London
 1690 (2016); NSW Department of Transport (1996); NSW Department of Transport (2003); NSW Department of
 1691 Transport (2009); NSW Department of Transport (2017); Translink (2012); Dictuc S.A. (1992); Rode et al (2015);
 1692 and City of Berlin (2013))
 1693

1694 [Food and agriculture](#)

1695 The availability of food is central to human health. Its production, however, is also a major
1696 contributor to climate change, with the agricultural sector alone contributing 19-29% of
1697 anthropogenic GHG emissions globally.^{10,157}

1698 Dietary choices determine food energy and nutrient intake, which are essential for human health,
1699 with inadequate and unhealthy diets associated with malnutrition and health outcomes including
1700 diabetes, cardiovascular diseases, and some cancers. Globally, dietary risk factors were estimated to
1701 account for over 10% of all Disability Adjusted Life Years (DALYs) lost in 2013.¹⁵⁸ A transition to
1702 healthier diets, with reduced red and processed meat consumption, and higher consumption of
1703 locally and seasonally produced fruits and vegetables, could provide significant emissions savings.¹⁵⁹

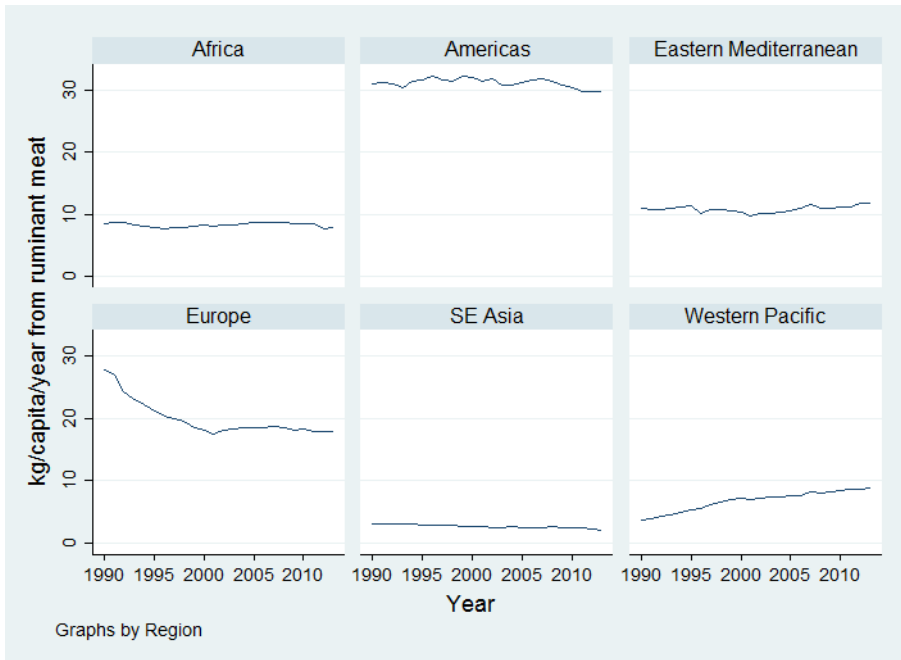
1704 Tracking progress towards more sustainable diets requires consistent and continuous data on food
1705 consumption, and related GHG emissions throughout food product life cycles. This would require
1706 annual nationally representative dietary survey data on food consumption. However, due to the
1707 complexity and cost of such data collection, dietary surveys are available for a limited number of
1708 countries and years only.¹⁶⁰ Although efforts to compile data and ensure comparability are under
1709 way, their current format is not suitable for global monitoring of progress towards optimal dietary
1710 patterns in terms of health benefits of climate change mitigation.^{161,162}

1711

1712 [Indicator 3.8: Ruminant meat for human consumption](#)

1713 **Headline Finding:** *Globally, the amount of ruminant meat available for human consumption has*
1714 *declined slightly from 12.09 kg/capita/year in 1990 to 11.23 in 2013; the proportion of energy*
1715 *(kcal/capita/day) available for human consumption from ruminant meat as opposed to other sources*
1716 *has declined marginally from 1.86% in 1990 to 1.65% in 2013.*

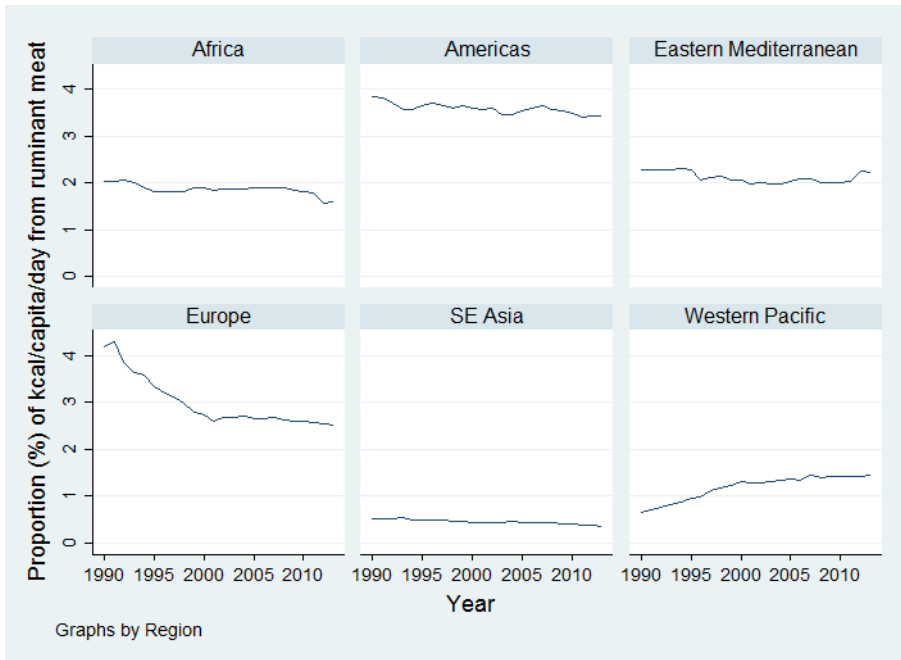
1717 This indicator focuses on ruminants because the production of ruminant meat, in particular cattle,
1718 dominates GHG emissions from the livestock sector (estimated at 5.6-7.5 GtCO₂e per year), and
1719 consumption of red meat has known associations with adverse health outcomes.¹⁶³ It measures the
1720 total amount of ruminant meat available for consumption, and the ratio of ruminant meat energy
1721 supply to total energy supply. Together, these reflect the relative amount of high GHG emission
1722 foods in the system (Figure 3.13).¹⁶⁴⁻¹⁶⁶ Assuming correlation between ruminant meat supply and
1723 consumption, the indicator therefore also provides information on variations in certain diet-related
1724 health outcomes (such as colorectal cancer and heart disease).^{167,168} This indicator should be viewed
1725 in the context of the specific setting where this trend is examined (in some populations, meat
1726 consumption is a main source of food energy and provides essential micronutrients, as well as
1727 livelihoods). Data was constructed using data from the FAO food balance sheets, which comprises
1728 national supply and utilisation accounts of primary foods and processed commodities.¹⁶⁹



1729

1730 Figure 3.13. The total amount of ruminant meat available for human consumption in kg/capita/year by WHO-
 1731 defined regions.

1732 The amount of ruminant meat available for consumption is high in the Americas and has remained
 1733 relatively stable across 1990-2013. In Europe, the amount of ruminant meat was relatively high in
 1734 1990, declined rapidly from 1990-2000 and has remained stable from 2000-2013. Amounts are more
 1735 moderate in Africa and the Eastern Mediterranean and have remained reasonably constant over
 1736 time; South East Asia and Western Pacific have low amounts but have been slowly increasing in the
 1737 Western Pacific since 1990.



1738

1739 Figure 3.14 The proportion of energy (kcal/capita/day) available for human consumption from ruminant meat
 1740 vs from all food sources by WHO-defined regions.

1741 The proportion of energy supply from ruminant meat has been markedly higher in the Americas than
 1742 other regions since the 1990s, although the trend has been decreasing over time (Figure 3.14). In
 1743 Europe, the proportion of energy from ruminant meat rapidly declined from 1990-2000 and has
 1744 continued to slowly decline. By contrast, the trend has been increasing in the Western Pacific,
 1745 possibly reflecting the increasing trend in beef consumption in China (16% annually).¹⁷⁰

1746 **Healthcare sector**

1747 The healthcare sector is a considerable contributor to GHG emissions, and has both a responsibility
 1748 and an appreciable opportunity to lead by example in reducing its carbon footprint. In 2013, the
 1749 estimated US healthcare sector emissions were 655 MtCO₂e, which exceeded emissions of the entire
 1750 UK.¹⁷¹ GHG emissions in the healthcare sector illustrate an obvious externality which contributes to
 1751 climate change, contradicting the sector's aim of improving population health.

1752 The World Bank estimates that a 25% reduction from existing healthcare emissions in Argentina,
 1753 Brazil, China, India, Nepal, Philippines, and South Africa would equate to 116-194 million metric tons
 1754 of CO₂e emission reduction, in other terms equal to decommissioning of 34-56 coal fired power
 1755 plants or removing 24-41 million passenger vehicles from the road.¹⁷¹

1756

1757 **Indicator 3.9: Healthcare sector emissions**

1758 **Headline Finding:** Whilst no systematic global standard for measuring the greenhouse gas emissions
 1759 of the healthcare sector currently exists, a number of healthcare systems in the UK, US, and around
 1760 the world are working to reduce their contribution to climate change.

1761 Several health sector emission reduction targets can be highlighted as positive examples. The
1762 National Health Service (NHS) in the UK set an ambitious target of 34% health-system wide GHG
1763 emission reduction by 2020; Kaiser Permanente in the U.S. has set 2025 as a target to become net
1764 carbon positive; the Western Cape Government health system in South Africa committed to 10%
1765 emission reduction by 2020 and 30% by 2050 in government hospitals; and Albert Einstein Hospital
1766 in Sao Paulo, Brazil, has reduced its annual emissions by 41%.¹⁷¹

1767 In the UK, comprehensive GHG emissions reporting was facilitated by the centralized structure of the
1768 NHS. The Sustainable Development Unit (SDU) of the NHS has been monitoring GHG emissions from
1769 a 1992 baseline, including major contributions from procurement of pharmaceuticals and other
1770 products. NHS emissions reduced by 11% from 2007 to 2015, despite an 18% increase in activity.¹⁷²
1771 Mitigation efforts from the healthcare sector provide remarkable examples of hospitals and health
1772 care systems leading by example, yielding impressive financial savings and health benefits for their
1773 patients. To this end, the efforts of the hospitals, governments, and civil society organisations driving
1774 this work forward must be supported and redoubled, ensuring a full transition to a healthier, more
1775 sustainable model of climate-smart, and increasingly carbon neutral healthcare.¹⁷¹

1776 Monitoring healthcare system emissions is an essential step towards accounting for the externality
1777 of these emissions. Comprehensive national GHG emissions reporting by the healthcare system is
1778 currently only routinely performed in the UK. Elsewhere, select healthcare organisations, facilities,
1779 and companies provide self-reported estimates of emissions, however this is rarely standardized
1780 across sites. The Lancet Countdown will continue to work on developing a standardised indicator on
1781 health sector emissions for subsequent reports.

1782

1783 Conclusion

1784 The indicators presented in this section have provided an overview of activities relevant to public
1785 health for the energy, transport, food and healthcare sectors' mitigation. They have been selected
1786 for their relevance to both climate change and human health and wellbeing.

1787 A number of areas show remarkable promise – each of which should yield impressive benefits for
1788 human health. However, these positive examples must not distract from the enormity of the task at
1789 hand. The indicators presented in this section serve as a reminder of the scale and scope of
1790 increased ambition required to meet commitments under the Paris Agreement. They demonstrate a
1791 world which is only just beginning to respond to climate change, and hence only just unlocking the
1792 opportunities available for better health.

1793

1794

1795 4. Finance & Economics

1796

1797 Introduction

1798 Interventions to protect human health from climate change risks have been presented above. This
1799 section focuses on the economic and financial mechanisms necessary for them to be implemented,
1800 and their implications. Some the indicators here do not have an explicit link to human health, and yet,
1801 investment in renewable energy and a declining investment in coal capacity, for instance, is essential
1802 in displacing fossil fuels and reducing their two principal externalities – the social cost of climate
1803 change and the health costs from air pollution. Other indicators, such as economic and social losses
1804 from extreme weather events, have more explicit links to human wellbeing.

1805 The 2006 Stern Review on the Economics of Climate Change estimated that the impacts of climate
1806 change would cost the equivalent of reducing annual global Gross World Product (GWP) – the sum
1807 of global economic output – by “5-20% now, and forever”, compared to a world without climate
1808 change.¹⁷³ The Intergovernmental Panel on Climate Change’s (IPCC) AR5 estimates an aggregate loss
1809 of up to 2% GWP even if the rise in global mean temperatures is limited to 2.5°C above pre-industrial
1810 levels.²² However, such estimates depend on numerous assumptions, such as the rate at which
1811 future costs and benefits are discounted. Further, existing analytical approaches are poorly suited to
1812 producing estimates of the economic impact of climate change, and hence their magnitude is likely
1813 greatly underestimated.^{174 175} In the presence of such uncertainty, with potentially catastrophic
1814 outcomes, risk minimisation through stringent emissions reduction seems the sensible course of
1815 action.

1816 The indicators in this section, which seek to track flows of finance and impacts on the economy and
1817 social welfare resulting from (in)action on climate change, fall into four broad themes: investing in a
1818 low-carbon economy; the economic benefits of tackling climate change; pricing GHG emissions from
1819 fossil fuels; and adaptation financing. The indicator presented are:

- 1820 4.1 Investments in zero-carbon energy and energy efficiency
- 1821 4.2 Investment in coal capacity
- 1822 4.3 Funds divested from fossil fuels
- 1823 4.4 Economic losses due to climate-related extreme events
- 1824 4.5 Employment in low-carbon and high-carbon industries
- 1825 4.6 Fossil fuel subsidies
- 1826 4.7 Coverage and strength of carbon pricing
- 1827 4.8 Use of carbon pricing revenues
- 1828 4.9 Spending on adaptation for health and health-related activities
- 1829 4.10 Health adaptation funding from global climate financing mechanisms
- 1830

1831 Appendix 5 provides more detailed discussion of the data and methods used.

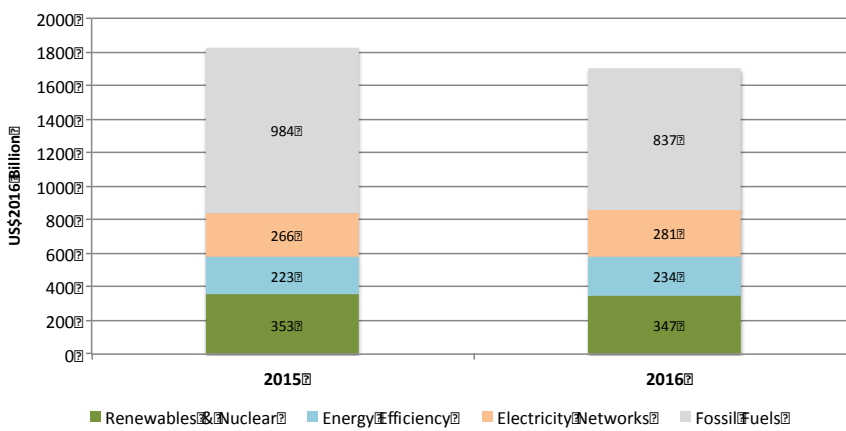
1832

1833

1834 Indicator 4.1: Investments in zero-carbon energy and energy efficiency
 1835 **Headline Finding:** Proportional investment in renewable energy and energy efficiency increased in
 1836 2016, whilst absolute and proportional investment in fossil fuels decreased, and crucially, ceased to
 1837 account for the majority of annual investments in the global energy system.

1838 This indicator tracks the level of global investment in zero-carbon energy and energy efficiency in
 1839 absolute terms, and as a proportion of total energy system investment. Figure 4.1 illustrates the data
 1840 for 2015 and 2016; the data for this indicator is sourced from the IEA.^{176,177}

1841



1842 Figure 4.1 Annual Investment in the Global Energy System.

1843

1844 In 2015, total investment in the energy system was around \$1.83 trillion (in US\$2016), accounting
 1845 for 2.4% of GWP. Renewables and nuclear comprised 19% of this investment, and energy efficiency
 1846 12%. Most investment (54%) was in fossil fuel infrastructure. Electricity networks accounted for the
 1847 remaining 15%. In 2016, total investment in the energy system reduced to around \$1.68 trillion,
 1848 accounting for 2.2% of GWP. Although the absolute value of investment in renewables and nuclear
 1849 energy reduced slightly in absolute (real) terms, its proportional contribution increased to 20%.
 1850 Investment in energy efficiency increased in both absolute and proportional terms to 14%. Fossil fuel
 1851 infrastructure suffered a significant reduction in investment, ceasing to account for the majority of
 1852 investment (at 49%). Such trends broadly represent a continuation of the trends experienced
 1853 between 2014 and 2015.¹⁷⁸

1854 Investment in renewables and nuclear is driven by renewable electricity capacity (with over 87% of
 1855 investment by value in this category in 2016). This, in turn, is largely driven by investments in solar
 1856 PV and onshore wind. Solar PV capacity additions in 2016 were 50% higher than 2015 (reaching
 1857 record levels of 73GW), driven by new capacity in China, the USA and India. However, this was
 1858 coupled with just a 20% increase in investment, resulting from a 20% reduction in the cost of solar
 1859 PV units. By contrast, investments in onshore wind reduced by around 20% between 2015 and 2016,
 1860 largely driven by changes to incentive schemes and elevated wind power curtailment rates in China.
 1861 The increase in energy efficiency investment was driven by policies that shifted markets towards
 1862 more energy efficient goods (such as appliances and lighting) and buildings (along with the

1863 expansion of the construction industry), and an increase in the sales of energy efficient (and low-
1864 carbon) vehicles. Europe accounted for the largest proportion of spending on energy efficiency
1865 (30%), followed by China (27%), driven by efficiency investments in the buildings and transport
1866 sectors.¹⁷⁷

1867 The substantial reduction in fossil fuel infrastructure investment, both upstream (such as mining,
1868 drilling and pipelines, which dominate fossil fuel investment) and downstream (such as fossil fuel
1869 power plants) is driven by a combination of low (and reducing) fossil fuel prices and cost reductions
1870 (particularly upstream, which have on average reduced by 30% since 2014).¹⁷⁷

1871

1872 In order to hold a 66% probability of remaining within 2°C of warming, it is estimated that average
1873 annual investments in the energy system between 2016 and 2050 must reach \$3.5 trillion, with
1874 renewable energy investments increasing by over 150%, and energy efficiency increasing by around
1875 a factor of ten.¹⁷⁹

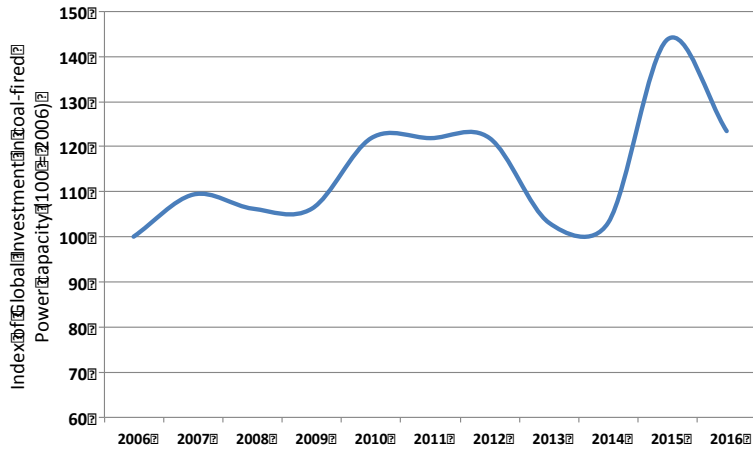
1876

1877 **Indicator 4.2: Investment in coal capacity**

1878 **Headline Finding:** *Although investment in coal capacity has increased since 2006, in 2016 this trend*
1879 *turned and declined substantially.*

1880 The combustion of coal is the most CO₂-intensive method of generating of electricity..¹⁸⁰This
1881 indicator tracks annual investment in coal-fired power capacity. Figure 4.2 presents an index of
1882 global annual investment in coal power generation capacity from 2006 to 2016, using IEA data.¹⁷⁷

1883



1884 Figure 4.2. Annual Investment in coal-fired power capacity.

1885

1886 It is clear that global investment in coal-fired electricity capacity generally increased from 2006 to
1887 2012, before returning to 2006 levels in 2013-14, and rebounding significantly to over 40% above
1888 this level in 2015. This rapid growth was driven principally by China, which increased investment in

1889 coal-fired power capacity by 60% from 2014, representing half of all new global coal capacity in 2015
1890 (with investment in India and other non-OECD Asia countries also remaining high).¹⁷⁸ The
1891 subsequent reduction in investment in 2016 was similarly driven by reduced investment in China,
1892 due to overcapacity in generation, concerns about local air pollution and new government measures
1893 to reduce new capacity additions and halt the construction of some plants already in progress.¹⁷⁷

1894

1895 [Indicator 4.3: Funds divested from fossil fuels](#)

1896 **Headline Finding:** *Global Value of Funds Committing to Divestment in 2016 was \$1.24 trillion, of*
1897 *which Health Institutions represent \$2.4 billion; this represents a cumulative sum of \$5.45 trillion*
1898 *(with health accounting for \$30.3 billion).*

1899 The fossil fuel divestment movement seeks to encourage institutions and investors to divest
1900 themselves of assets involved in the extraction of fossil fuels. ‘Divestment’ is defined relatively
1901 broadly, ranging from an organisation that has made a binding commitment to divest from coal
1902 companies only, to those who have fully divested from any investments in fossil fuel companies and
1903 have committed to avoiding such investments in future. Proponents cite divestment as embodying
1904 both a moral purpose (for example, reducing the fossil fuel industry’s ‘social licence to operate’), and
1905 an economic risk reduction strategy (for example, through reducing the investor’s exposure to the
1906 risk of ‘stranded assets’). However, others believe active engagement between investors and fossil
1907 fuel businesses is a more appropriate course of action (for instance, encouraging diversification into
1908 less carbon-intensive assets, through stakeholder resolutions).¹⁸¹

1909 This indicator tracks the global total value of funds committing to divestment in 2016, and the value
1910 of funds committed to divestment by health institutions in 2016, which was \$1.24 trillion, and \$2.4
1911 billion respectively. The values presented above are calculated from data collected and provided by
1912 350.org. They represent the total assets (or assets under management (AUM)) for institutions that
1913 have committed to divest in 2016, and thus do not directly represent the sums divested from fossil
1914 fuel companies. It also includes only those institutions for which such information is publicly
1915 available (or provided by the institution itself), with non-US\$ values converted using the market
1916 exchange rate when the commitment was made.

1917 By the end of 2016, a total of 694 organisations with cumulative assets worth at least \$5.45 trillion,
1918 including 13 health organisations with assets of at least \$30.3 billion, had committed to divestment.
1919 From the start of January 2017 to the end of March 2017, a further 12 organisations with assets
1920 worth \$46.87 billion joined this total (including Australia’s Hospitals Contribution Fund – HCF – with
1921 assets of \$1.45 billion).

1922

1923 [Indicator 4.4: Economic losses due to climate-related extreme events](#)

1924 **Headline Finding:** *In 2016, a total of 797 events resulted in \$129 billion in overall economic losses,*
1925 *with 99% of losses in low-income countries uninsured.*

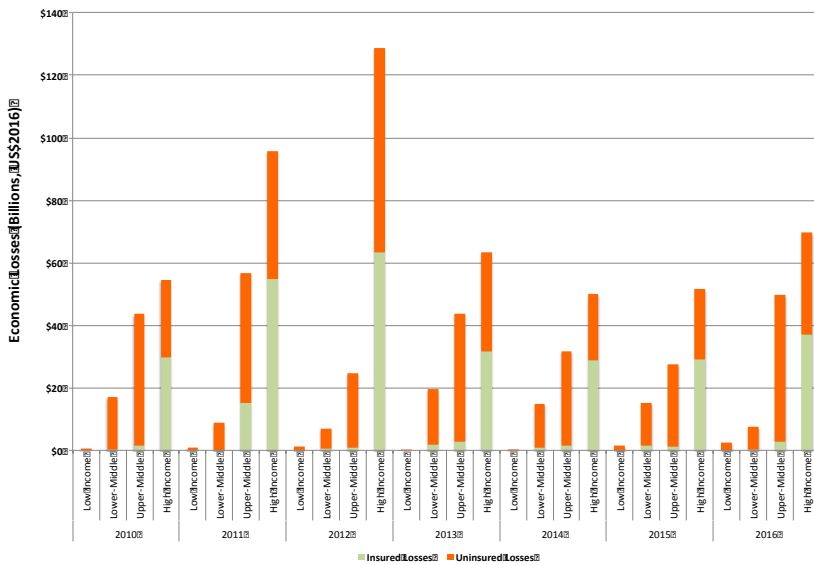
1926 Climate change will continue to increase the frequency and severity of meteorological (tropical
1927 storms), climatological (droughts) and hydrological (flooding) phenomena, across the world. As
1928 demonstrated by indicator 1.4, the number of weather-related disasters has increased in recent
1929 years. The number of people affected and the economic costs associated with this increase is
1930 expected to have risen. This indicator tracks the number of events and the total economic losses
1931 (insured and uninsured) resulting from such events. In addition to the health impacts of these

1932 events, economic losses (particularly uninsured losses) have potentially devastating impacts on
1933 wellbeing and mental health.¹⁸²

1934 The data upon which this indicator is based is sourced from Munich Re.¹⁸³ Economic losses (insured
1935 and uninsured) refer to the value of physical assets, and do not include the economic value of loss of
1936 life or ill health, or health and casualty insurance. Values are first denominated in local currency,
1937 converted to US\$ using the market exchange rate in the month the event occurred, and inflated to
1938 US\$2016 using country-specific Consumer Price Indices (CPI). This indicator and underlying data does
1939 not seek to attribute events and economic losses to climate change *per se*, but may plausibly be
1940 interpreted as showing how climate change is changing the frequency and severity of these events.

1941 Figure 4.3 presents insured and uninsured economic losses resulting from all significant
1942 meteorological, climatological and hydrological events across the world, from 2010 to 2016, by
1943 country income group. An annual average of 700 events resulted in an annual average of \$127 billion
1944 in overall economic losses per year over this timeframe. Upper-middle and high-income countries
1945 experienced around two-thirds of the recorded events and around 90% of economic losses, with
1946 <1% attributable to those of low-income. The same ratios for the number of events and economic
1947 losses between income groups is present in the data for the period 1990-2016, despite an increasing
1948 trend in the total global number of events and associated total value of economic losses over this
1949 period.

1950



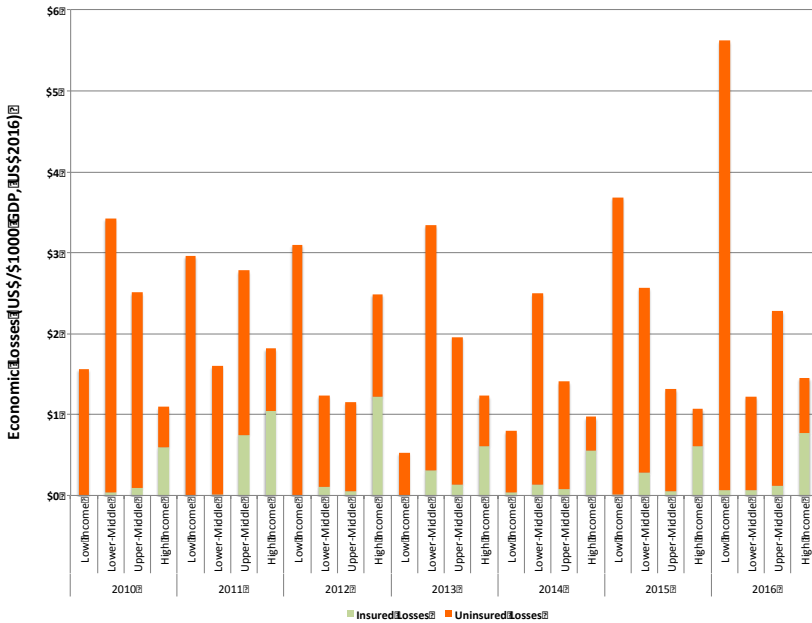
1951

1952 Figure 4.3 Economic Losses from Climate-Related Events – Absolute.

1953

1954 However, the data in Figure **Error! Reference source not found.**3 does not indicate the relative scale
1955 of impacts across different income groups. For example, although the majority of economic losses
1956 have occurred in upper-middle and high-income countries, these countries are among the most

1957 populous, with more economically valuable property and infrastructure (in absolute terms). A rather
 1958 different picture emerges in Figure 4.4, which presents the data in terms of 'intensity' – insured and
 1959 uninsured economic losses per \$1000 GDP (in US\$2016).
 1960



1961 Figure 4.4 Economic Losses from Climate-Related Events - Intensity.

1962
 1963 Between 2010 and 2016, high and upper-middle income countries experienced the least average
 1964 annual economic loss as a proportion of GDP (\$1.45/\$1000 GDP and \$1.95/\$1000 GDP, respectively),
 1965 with low and lower-middle income countries subject to somewhat higher values (\$2.65/\$1000 GDP
 1966 and \$2.3/\$1000 GDP, respectively). Economic losses in low-income countries were more than three
 1967 times as high in 2016 than in 2010. However, for 1990-2016, average annual values vary significantly
 1968 (see Appendix 5 for the full dataset). Whilst high and upper-middle income countries maintain
 1969 relatively similar values (\$1.60/\$1000 GDP and \$2.9/\$1000 GDP, respectively), average annual
 1970 economic losses experienced by (particularly) low and lower-middle income countries increase
 1971 substantially (to \$10.95/\$1000 GDP and \$4.22/\$1000 GDP, respectively).

1972 It is clear that, on average, lower income countries experience greater economic loss as a proportion
 1973 of GDP as a result of climate-related events than higher-income countries. However, a more striking
 1974 result is the difference in the proportion of economic losses that are uninsured. In high-income
 1975 countries, on average around half of economic losses experienced are insured. This share drops
 1976 rapidly to under 10% in upper-middle income countries, and to well under 1% in low-income
 1977 countries. Over the period 1990-2016, uninsured losses in low-income countries were on average
 1978 equivalent to over 1.5% of their GDP. For contrast, expenditure on healthcare in low-income
 1979 countries on average for the period 1995-2015 was equivalent to 5.3% of GDP.¹⁸⁴

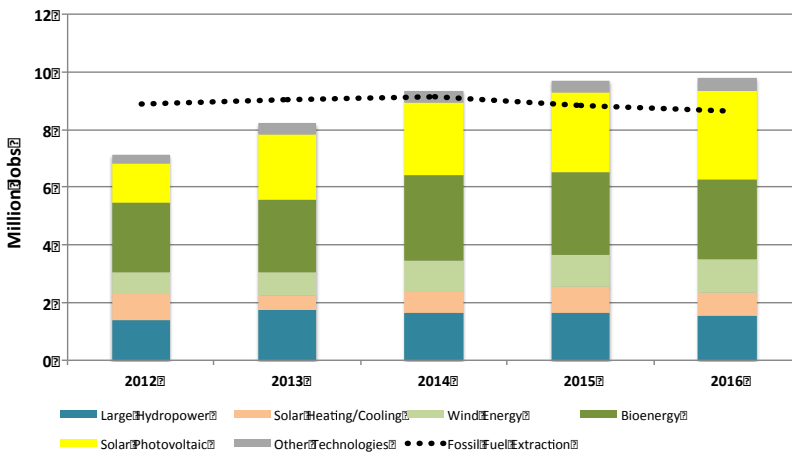
1980 Indicator 4.5: Employment in low-carbon and high-carbon industries

1981 **Headline Finding:** In 2016, global employment in renewable energy reached 9.8 million, with
 1982 employment in fossil fuel extraction trending down, to 8.6 million.

1983 The generation and presence of employment opportunities in low- and high-carbon industries have
 1984 important health implications, both in terms of the safety of the work environment itself and
 1985 financial security for individuals and communities. As the low-carbon transition gathers pace, high-
 1986 carbon industries and jobs will decline. A clear example is seen in fossil fuel extraction. Some fossil
 1987 fuel extraction activities, such as coal mining, have substantial impacts on human health. Coal mining
 1988 accidents led to over 1,000 deaths in 2008 in China alone (a rapid decline from nearly 5,000 in 2003),
 1989 with exposure to particulate matter and harmful pollutants responsible for elevated levels of
 1990 cardiovascular, respiratory and kidney disease, in coal mining areas.¹⁸⁵⁻¹⁸⁸ The low-carbon transition
 1991 is also likely to stimulate the growth of new industries and employment opportunities. With
 1992 appropriate planning and policy, the transition from employment in high-carbon to low-carbon
 1993 industries will yield positive consequences for human health.

1994 This indicator tracks global employment levels in fossil fuel extraction industries (coal mining and oil
 1995 and gas exploration and production), and in renewable energy. Figure 4.5 presents these values for
 1996 2012-2016. The data for this indicator is sourced from International Renewable Energy Agency
 1997 (IRENA) (renewables), and IBIS World (fossil fuel extraction).¹⁸⁹⁻¹⁹¹

1998



1999

2000 Figure 4.5 Employment in Renewable Energy and Fossil Fuel Extraction.

2001

2002 From a peak of 9.1 million in 2014, jobs in the global fossil fuel extraction industry reduced by
 2003 around 500,000 to 8.6 million in 2016. Reductions in the coal mining industry largely drove this
 2004 change, which was the result of a range of factors, including its substitution by lower-cost natural
 2005 gas in the power sector in many countries, reducing the demand for coal and leading to
 2006 overcapacity, industry consolidation, and the rising automation of extractive activities.¹⁹¹

2007 By contrast, employment in the renewable energy industry increased rapidly from over 7.1 million
 2008 jobs in 2012 to over 9.3 million in 2014, and reaching 9.8 million in 2016. This growth has largely
 2009 been driven by the solar PV industry, which added over 1.7 million jobs between 2012 and 2016.
 2010 Solar PV is now the largest renewable energy employer, overtaking bioenergy, which has
 2011 experienced a reduction of 250,000 jobs since 2012.

2012

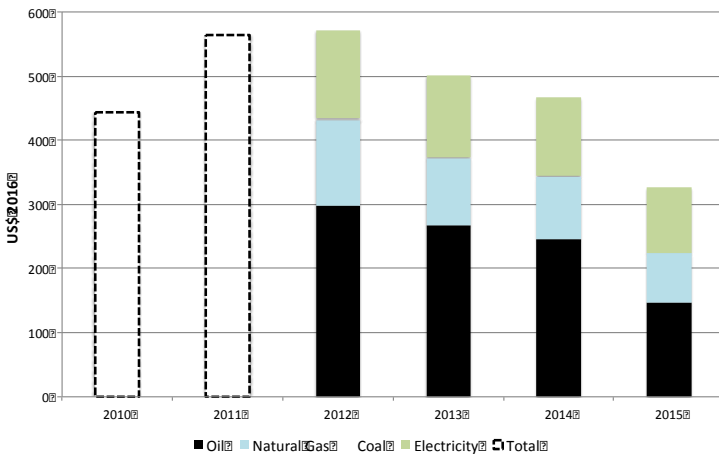
2013 **Indicator 4.6: Fossil fuel subsidies**

2014 **Headline Finding:** In 2015, fossil fuel consumption subsidies followed a trend seen since 2012,
 2015 decreasing markedly to \$327 billion, principally as a result of declining global oil prices.

2016 The combustion of fossil fuels results in a variety of harmful consequences for human health, and
 2017 the presence of subsidies for fossil fuels, either for its production (such as fossil fuel extraction) or
 2018 consumption (such as regulated gasoline prices), artificially lowers prices, promoting
 2019 overconsumption. This indicator tracks the global value of fossil fuel consumption subsidies. Figure
 2020 4.6 illustrates the value of fossil fuel consumption subsidies for 2010-2016 using IEA data.^{178,192}

2021

2022



2023 Figure 4.6 Global Fossil Fuel Consumption Subsidies - 2010-2015.

2024

2025 Despite rising from \$444 billion in 2010 to a peak of \$571 billion in 2012, fossil fuel consumption
 2026 subsidies have decreased markedly to \$327 billion in 2015 (in US\$2016). The principal driver for this
 2027 is the doubling in oil price between 2010 and 2012, after which it plateaued, before falling rapidly to
 2028 below 2010 levels from mid-2014. Fossil fuel consumption subsidies are typically applied in order to
 2029 moderate energy costs for low-income consumers (although in practice, 65% of such subsidies in
 2030 LMICs benefit the wealthiest 40% of the population).¹⁹³ As such, rising oil (and other fossil fuel)
 2031 prices tend to increase subsidy levels, as the differences between market and regulated consumer
 2032 prices increase, and governments take further action to mitigate the impact on citizens. When fossil

2033 fuel prices decrease, the gap between market and regulated prices reduces, and governments can
 2034 reform fossil fuel subsidies whilst keeping overall prices relatively constant.

2035 Between 2014 and 2015, several countries took advantage of this opportunity, particularly regarding
 2036 oil-based fuels, which accounted for over 60% of the reduction in total fossil fuel subsidies between
 2037 2012 and 2015 (followed by natural gas at around 25%). This included India, which in deregulating
 2038 diesel prices accounted for a \$19 billion subsidy reduction between 2014 and 2015 (~13% of the
 2039 global total reduction), and the major oil and natural gas producing nations (including Angola,
 2040 Algeria, Indonesia, Iran, Qatar, Saudi Arabia and Venezuela), in which reduced hydrocarbon revenue
 2041 created pressure for fiscal consolidation, and in turn for consumption subsidy reform.¹⁷⁸ To
 2042 encourage the low-carbon transition, fossil fuel subsidies should be phased out as soon as possible.
 2043 The commitment made by the G7 in 2016 to achieve this goal by 2025 should be extended to all
 2044 OECD countries, and globally by 2030.¹⁹⁴

2045

2046 **Indicator 4.7: Coverage and strength of carbon pricing**

2047 **Headline Finding:** *So far in 2017, various carbon pricing mechanisms covered 13.1% of global*
 2048 *anthropogenic CO₂ emissions, up from 12.1% in 2016. This reflects a doubling in the number of*
 2049 *national and sub-national jurisdictions with a carbon pricing mechanism over the last decade.*

2050 This indicator tracks the extent to which carbon pricing instruments are applied around the world as
 2051 a proportion of total GHG emissions, and the weighted average carbon price such instruments
 2052 provide (Table 4.1).

2053

	2016	2017
Global Emissions Coverage*	12.1%	13.1%
Weighted Average Carbon Price of Instruments (current prices, US\$)	\$7.79	\$8.81
Global Weighted Average Carbon Price (current prices, US\$)	\$0.94	\$1.12

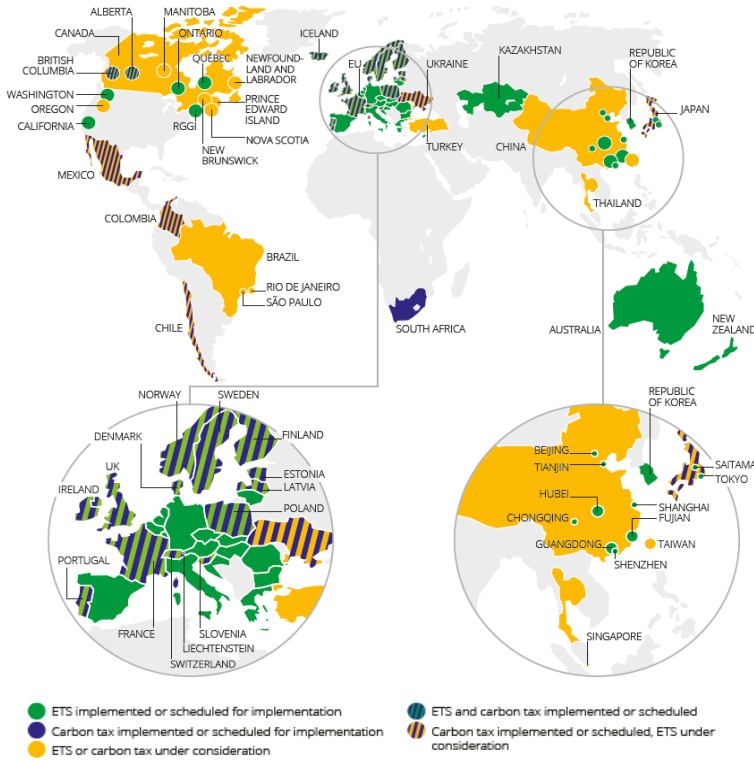
2054 Table 4.1 Carbon Pricing - Global Coverage and Weighted Average Prices per tCO₂e. *Global emissions
 2055 coverage is based on 2012 total anthropogenic GHG emissions.¹⁹⁵ (Source: World Bank, 2017)

2056

2057 Between 2016 and 2017, the proportion of global emissions covered by carbon pricing instruments,
 2058 and the weighted average price of these instruments (and thus the global weighted average price for
 2059 all anthropogenic GHG emissions), increased. This is due to the introduction of four new instruments
 2060 in 2017 (note, this data runs up to 1 April 2017) - the carbon taxes in Alberta, Chile and Colombia,
 2061 and an Emissions Trading System (ETS) in Ontario. As such, over 40 national and 25 sub-national
 2062 jurisdictions now put a price on at least some of their GHG emissions (with substantially varying
 2063 prices, from less than \$1/tCO₂e in Chongqing, to over \$126/tCO₂e in Sweden). The last decade has
 2064 seen a rapid increase in the number of carbon pricing instruments around the world, with the
 2065 number of jurisdictions introducing them doubling.¹⁹⁶ Over 75% of the GHG emissions covered by
 2066 carbon pricing instruments are in HICs, with the majority of the remainder covered by the 8 pilot
 2067 pricing instruments in China (Figure 4.7).

2068 The World Bank provides the data for this indicator.^{195,196} Prices for 2016 and 2017 are those as of 1
 2069 August 2016 and 1 April 2017, respectively. For 2017, the indicator includes only instruments that
 2070 had been introduced by 1 April 2017. Instruments without price data are excluded.

2071



2072
 2073 Figure 4.7 Carbon Pricing Instruments implemented, scheduled for implementation and
 2074 under consideration.¹⁹⁶ (Source: World Bank, 2017)

2075
 2076 In total, a further 21 carbon pricing instruments are either scheduled for implementation, or are
 2077 under consideration. This includes the commencement of a national ETS in China expected in the
 2078 second half of 2017. Although this would replace the 8 pilot schemes currently in place in China, it
 2079 could expand their emissions coverage fourfold, surpassing the European ETS to become the largest
 2080 carbon pricing instrument in the world.¹⁹⁶

2081
 2082 Indicator 4.8: Use of carbon pricing revenues
 2083 **Headline Finding:** 40% of government revenues generated from carbon pricing are spent on climate
 2084 change mitigation, totalling US\$9 billion.

2085 Carbon pricing instruments require those responsible for producing the emissions concerned to pay
 2086 for their emissions, in one form or another. In most cases this generates revenue for the
 2087 governments or authorities responsible for introducing the instrument. Such revenue may be put to
 2088 a range of uses, including investment in climate change mitigation or adaptation or environmental
 2089 tax reform (ETR), which involves shifting the burden of tax from negative activities, such as the
 2090 generation of pollution, to positive activities, such as labour or environmentally beneficial products
 2091 or activities. Such options may produce a 'double dividend' of environmental improvement with
 2092 social and economic benefits.¹⁹⁷ This indicator tracks the total government revenue from carbon
 2093 pricing instruments, and how such income is allocated.

	Mitigation	Adaptation	Environmental Tax Reform (ETR)	General Funds	Total Revenue (US\$2016)
Proportion (%)	40.4%	4%	19.5%	36.1%	\$22.31 Billion
Value (US\$2016)	\$9.01 Billion	\$0.9 Billion	\$4.34 Billion	\$8.06 Billion	

2094

2095 Table 4.2. Carbon Pricing revenues and allocation in 2016.¹⁹⁵ (Source: World Bank, 2017)

2096

2097 Table 4.2 presents total government revenue generated by carbon pricing instruments in 2016, and
 2098 four categories of expenditure for this revenue. The largest expenditure category is climate change
 2099 mitigation, which is in receipt of over \$9 billion annually in funds. Despite this, less than half of
 2100 revenue-generating instruments allocate revenue for mitigation.

2101 ETR policies accounted for around 20% of revenue allocation in 2016. Just two instruments (the
 2102 Portuguese and British Columbia Carbon Taxes) allocate all their revenue to allowing revenue-neutral
 2103 reduction in other (for example, income) taxes, with another four allocating part of their revenue to
 2104 this purpose. By contrast, only four instruments do not have any revenue allocated to general
 2105 government funds (The British Colombian, Swiss, Japanese and Portuguese carbon taxes), with 11
 2106 instruments allocating all revenues to this category (reaching €8 billion – or more than a third – of
 2107 revenues generated in 2016). Data for individual carbon pricing instruments may be found in Appendix
 2108 5.

2109 Data on revenue generated is provided by the World Bank, with revenue allocation information
 2110 obtained from various sources (see Appendix 5).¹⁹⁵ Only instruments with revenue estimates, and only
 2111 revenue received by the administering authority before redistribution, are considered. Revenue must
 2112 be explicitly allocated to climate change mitigation or adaptation, or for ETR, to be considered in these
 2113 categories. If such explicit earmarking is not present, or no data is available, then revenue is assumed
 2114 to be allocated to general funds.

2115

2116 [Indicator 4.9: Spending on adaptation for health and health-related activities](#)

2117 **Headline finding:** Out of the world's total adaptation spend just 4.63% (\$16.46 billion USD) is on
 2118 health and 13.3% (\$47.29 billion USD) on health-related adaptation.

2119 This indicator reports estimates of spending on health and health-related climate change adaptation
 2120 and resilience. Many adaptation activities within and beyond the formal health sector yield health

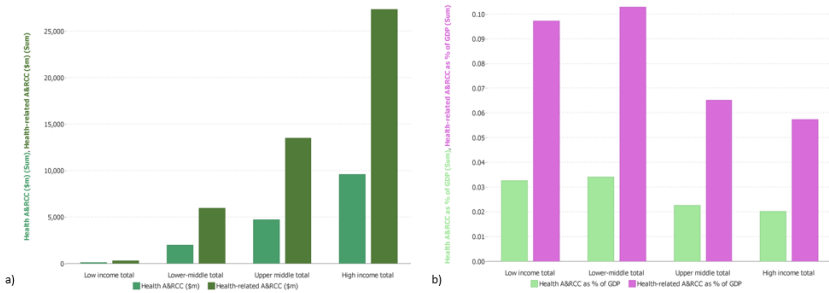
2121 co-benefits, which are important to understand and capture. Here, estimates of the total health and
 2122 health-related adaptation spending were derived from the Adaptation & Resilience to Climate
 2123 Change (A&RCC) dataset produced by kMatrix. This global dataset, covering financial transactions
 2124 relevant to climate change adaptation, was compiled from a relevant subset of over 27,000
 2125 independent databases and sources (such as public disclosures and reports from insurance
 2126 companies, the financial sector, and governments).¹⁹⁸ In this case, entries were triangulated
 2127 between at least seven independent sources before being included.

2128 Examples of transactions captured here range from the procurement of goods or services (for
 2129 example, purchasing sandbags for flood levees) through to spending on research and development
 2130 (for example, for vulnerability and adaptation assessments) or staff training.¹⁹⁸ Each of these
 2131 ‘adaptation activities’ are grouped in to eleven sectors: Agriculture and Forestry, Built Environment,
 2132 Disaster-Preparedness, Energy, Health, ICT, Natural Environment, Professional Services, Transport,
 2133 Waste, and Water. Whilst adaptation spending relevant directly to the formal health sector is clearly
 2134 important (the ‘health’ category), interventions outside of the healthcare system will also yield
 2135 important benefits for health and wellbeing. ‘Health-related adaptation spending’ was defined as
 2136 that which additionally included adaptation spending from the agricultural sector (due to the
 2137 centrality of food and nutrition to health) and disaster preparedness sector (due to the direct public
 2138 health benefits that often result from these efforts).

2139 This data from the A&RCC dataset is reported here, showing health and health-related adaptation
 2140 spending for 180 countries for the 2015-2016 financial year. Global health adaptation spending for
 2141 the financial year 2015-2016, calculated in this way, totalled 16.46 billion USD, representing 4.63% of
 2142 the global aggregate adaptation spend. Health-related adaptation spending totalled 47.29 billion
 2143 USD, or 13.3% of the global total adaptation spend (Figure 4.8).

2144 Health-related adaptation and resilience spending, both national totals and per capita levels, is
 2145 extremely low in low-income countries, and increase across the continuum towards high-income
 2146 countries. Interestingly, health and health-related adaptation spending as a proportion of total
 2147 adaptation spending is relatively constant across income groups.

2148



2149
 2150 Figure 4.8 For the financial year 2015-2016. 4.8a) Total health and health-related adaptation spending and
 2151 4.8b) health and health-related adaptation and resilience to climate change (A&RCC) spending as a proportion
 2152 of GDP. All plots are disaggregated by World Bank Income Grouping.

2153
2154
2155 It is important to note that further work is required to more completely determine what should be
2156 considered as ‘health-related adaptation spending’. Spending for agriculture and disaster
2157 preparedness were included here, however other forms of adaptation spending clearly have
2158 important health implications. Second, only economic data relating to the financial year 2015-2016
2159 was available, precluding time trend analysis. Third, since public sector transactions may not leave a
2160 sufficient ‘footprint’ to be picked up by this methodology, adaptation spending data here may
2161 exclude some public-sector spending.

2162

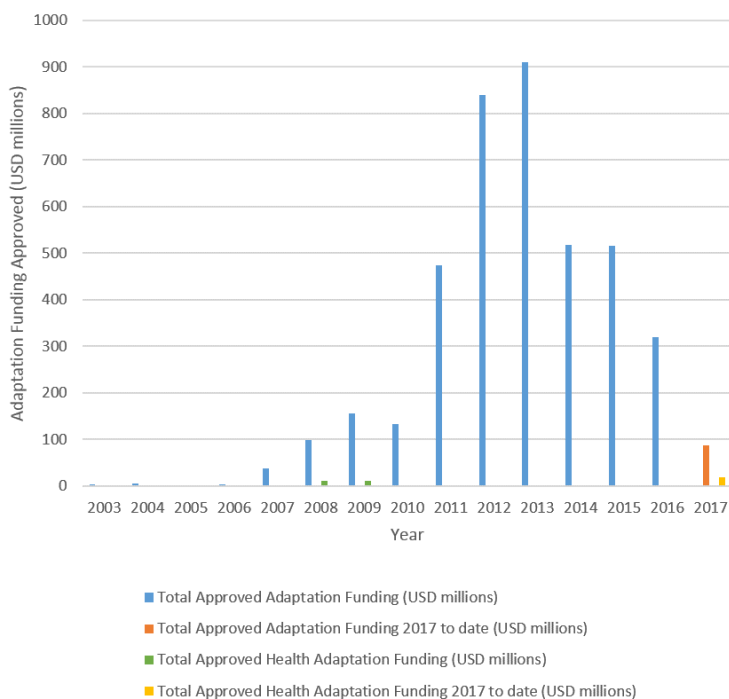
2163 [Indicator 4.10: Health adaptation funding from global climate financing mechanisms](#)

2164 **Headline Finding:** *Between 2003 and 2017, 0.96% of total adaptation funding for development,*
2165 *flowing through global climate change financing mechanisms, was dedicated to health adaptation.*

2166 The final indicator in this section is designed in parallel with indicator 4.9, and aims to capture
2167 development funds available for climate change adaptation. It reports global financial flows
2168 dedicated to health adaptation to climate change, moving through established global climate
2169 financing mechanisms. Data was drawn from the Climate Funds Update (CFU), an independent
2170 source which aggregates funding data from multilateral and bilateral development agencies since
2171 2003.^{16,199} CFU data is presented in four categories (pledged, deposited, approved, and disbursed);
2172 this indicator uses data designated as ‘approved’.

2173 Between 2003 and 2017, only 0.96% of approved adaptation funding was allocated to health
2174 adaptation, corresponding with a cumulative total of 39.55 million USD (Figure 4.9). Total global
2175 adaptation funding peaked in 2013 at 910.36 million USD and declined thereafter. However, health-
2176 related adaptation funding reached its highest level in early 2017, resulting in the near-doubling in
2177 the proportion of adaptation funding allocated to health. Panel 4.1 provides a brief overview of
2178 growing interest in health and climate change from the international donor community.

2179



2180 Figure 4.9 Year on year multilateral and bilateral funding for all adaptation projects and health adaptation
 2181 projects (2003 through May 2017).
 2182

2183

2184 **Panel 4.1 International Donor Action on Climate Change and Health.**

2185 In 2017, the World Bank released three independent reports on climate change and health,
 2186 articulating (i) a new action plan for climate change and health, (ii) geographic focus areas, and (iii)
 2187 new strategy for climate-smart healthcare. In addition to training staff and increasing government
 2188 capacity, the World Bank outlines an approach to ensuring that at least 20% of new World Bank
 2189 health investments are climate-smart by 2020, corresponding to as much as \$1bn in new climate-
 2190 smart health finance for countries. Other development institutions and foundations are also getting
 2191 involved. Two separate, major gatherings of public and private funders occurred in 2016 (May,
 2192 Helsinki) and 2017 (May, Chicago) toward establishing new channels for health and climate finance,
 2193 and a third is planned for late 2017 (October, Washington, DC).

2194 **Conclusion**

2195 The indicators presented in this section seek to highlight the status of the economics and finance
 2196 associated with climate change and health across four themes; investing in a low-carbon economy,
 2197 economic benefits of tackling climate change, pricing the GHG emissions from fossil fuels, and
 2198 adaptation financing.

2199 Many of the trends show positive change over time, notably global investment in zero-carbon energy
 2200 supply, energy efficiency, new coal-fired electricity capacity, employment in renewable energy, and

2201 divestment in fossil fuels. However, the rate of change is relatively slow, and must accelerate rapidly
2202 to meet the objectives of the Paris Agreement.

2203 **5. Public and Political Engagement**

2204

2205 **Introduction**

2206 So far, this report has presented indicators on the health impacts of climate hazards; resilience and
2207 adaptation to climate change; health co-benefits of climate change mitigation; and economics and
2208 finance mechanisms that facilitate a transition to a low-carbon economy.

2209 Policy change requires public support and government action. This is particularly true of policies with
2210 the reach and impact to enable societies to transition to a low-carbon future.²⁰⁰ The overarching
2211 theme of this section is therefore the importance of public and political engagement in addressing
2212 health and climate change, and the consequent need for indicators that track engagement in the
2213 public and political domains.

2214 The aim is to track engagement with health and climate change in the public and political domains
2215 and identify trends since 2007. In selecting indicators, priority has been given to high-level
2216 indicators, which can be measured globally, tracked over time and provide a platform for more
2217 detailed analysis in future Lancet Countdown reports. The indicators relate to coverage of health and
2218 climate change in the media, science, and government. Search terms for the indicators are aligned
2219 and a common time-period was selected for all indicators (2007-2016). The period runs from before
2220 the resolution on health and climate change by the 2008 World Health Assembly, which marked a
2221 watershed in global engagement in health and climate change; for the first time, member states of
2222 the UN made a multilateral commitment to protect human health from climate change.²⁰¹

2223 The indicators presented are:

- 2224 5.1. Media coverage of health and climate change
- 2225 5.2. Health and climate change in scientific journals
- 2226 5.3. Health and climate change in the United Nations General Assembly

2227

2228 Corresponding Appendix 6 provide more detailed discussion of the data and methods used.

2229

2230 **Indicator 5.1: Media coverage of health and climate change**

2231 **Headline Finding:** *Global newspaper coverage of health and climate change has increased 78% since*
2232 *2007, with marked spikes in 2009 and 2015, coinciding with the 15th and 21st Conference of the*
2233 *Parties (COP).*

2234 Media plays a crucial role in communicating risks associated with climate change.²⁰² Knowledge
2235 about climate change is related to perceptions of risk and intentions to act.^{203,204} Public perceptions
2236 of a nation's values and identity are also an important influence on public support for national
2237 action.²⁰⁵ Indicator 5.1 therefore tracks media coverage of health and climate change, with a global
2238 indicator on newspaper coverage on health and climate change (5.1.1), complemented by an in-
2239 depth analysis of newspaper coverage on health and climate change for two national newspapers
2240 (5.1.2).

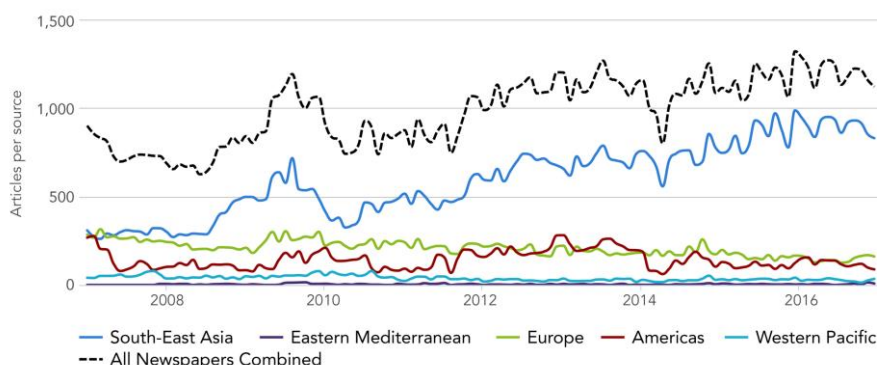
2241

2242 5.1.1: Global newspaper reporting on health and climate change

2243 Focusing on English-language and Spanish-language newspapers, this indicator tracks global
2244 coverage of health and climate change in high-circulation national newspapers from 2007 to 2016.
2245 Using 18 high-circulation 'tracker' newspapers, global trends are shown and disaggregated regionally
2246 to provide a global indicator of public exposure to news coverage of health and climate change.

2247 Since 2007, newspaper coverage of health and climate change has risen globally by 78% (Figure 5.1).
2248 However, this trend is largely driven by South-East Asian newspapers. Although mostly due to the
2249 higher number of South-East Asian newspapers included in this analysis, the South-East Asian
2250 newspapers here did have a higher than average coverage of health and climate change than other
2251 regions, particularly among Indian sources (see Appendix 6). This generally high volume of coverage
2252 in the Indian press can be attributed to the centrality of newspapers as communication channels for
2253 elite-level discourse in India and to relatively high levels of climate change coverage throughout
2254 Asia.²⁰⁶⁻²⁰⁸ For the Eastern Mediterranean, Americas, and Western Pacific, there is not a strong trend
2255 in the media reporting. Some spikes are notable in 2009 in Europe, which is largely maintained for
2256 the rest of the time series, and in the Americas, which drops until a secondary spike between 2012
2257 and 2014. The first major spike globally was in 2009, coinciding with COP15 (Conference of the
2258 Parties) in Copenhagen, for which there was high expectation. Newspaper reporting then dropped
2259 around 2010, but since 2011 has been rising overall globally.

2260



2261

2262 Figure 5.1 Newspaper reporting on health and climate change (for 18 newspapers) from 2007 to 2016, broken
2263 down by WHO region.

2264

2265 Data was assembled by accessing archives through the Lexis Nexis, Proquest and Factiva databases.
2266 These sources were selected through the weighting of four main factors: geographical diversity
2267 (favouring a greater geographical range), circulation (favouring higher circulating publications),
2268 national sources (rather than local/regional), and reliable access to archives over time (favouring
2269 those accessible consistently for longer periods). Search terms were aligned to those used for the
2270 indicators of scientific and political engagement and searches, with Boolean searches done in English
2271 and Spanish.

2272

2273 5.1.2: In-depth analysis of newspaper coverage on health and climate change
2274 The second part of this indicator provides an analysis of two national newspapers; Le Monde
2275 (France) and Frankfurter Allgemeine Zeitung (FAZ) (Germany). Le Monde and FAZ were chosen for
2276 this analysis, as these are leading newspapers in France and Germany; two countries with political
2277 weight in Europe. Both newspapers continue to set the tone of public debates in France and
2278 Germany.^{209,210}

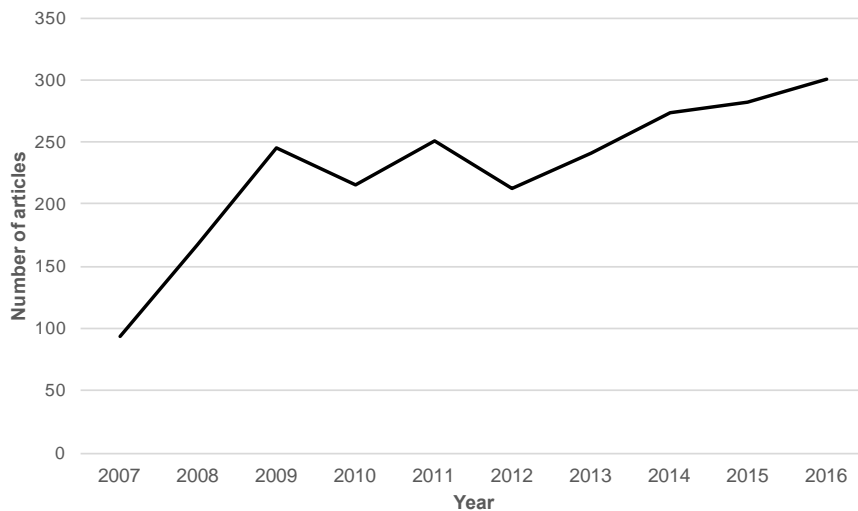
2279 Only a small proportion of articles on climate change mentioned the links between health and
2280 climate change: 5% in Le Monde and 2% in FAZ. The analysis also pointed to important national
2281 differences in reporting on health and climate change. For example, in France, 70% of articles
2282 referring to health and climate change represented the health-climate change nexus as an
2283 environmental issue, whereas in Germany articles had a broader range of references: the economy
2284 (23%), local news (20%) and politics (17%). The recommended policy responses also differed; in Le
2285 Monde, the emphasis was on adaptation (41% of articles), while FAZ put more emphasis on
2286 mitigation (40% of articles). The co-benefits that public health policies can represent for mitigation
2287 were mentioned by 17% of Le Monde articles and 9% of FAZ articles. Overall, the analysis points to
2288 the marked differences in media reporting of health and climate change, and therefore in the
2289 information and perspectives to which the public is exposed (see Appendix 6 for details).

2290

2291 **Indicator 5.2: Health and climate change in scientific journals**

2292 **Headline Finding:** *Since 2007, the number of scientific papers on health and climate change has more*
2293 *than trebled.*

2294 Science is critical to increasing public and political understanding of the links between climate
2295 change and health; informing mitigation strategies; and accelerating the transition to low-carbon
2296 societies.^{211,212} This indicator, showing scientific engagement with health and climate change, tracks
2297 the volume of peer-reviewed publications in English-language journals from PubMed and Web of
2298 Science (see Appendix 6 for details). The results show there has been a marked increase in published
2299 research on health and climate change in the last decade, from 94 papers in 2007 to over 275
2300 published in both 2015 and 2016. Within this overall upward trend, the volume of scientific papers
2301 increased particularly rapidly from 2007-2009 and from 2012, with a plateauing between these
2302 periods (Figure 5.2).



2303

2304 Figure 5.2 Number of scientific publications on climate change and health per year (2007-2016) from PubMed
2305 and Web of Science journals.

2306

2307 The two periods of growth in scientific outputs coincided with the run-up to the UNFCCC COPs held
2308 in Copenhagen in 2009 (COP15) and in Paris in 2015 (COP21). This pattern suggests that scientific
2309 and political engagement in health and climate change are closely linked, with the scientific
2310 community responding quickly to the global climate change agenda and the need for evidence.

2311 Most publications focus on the impacts of climate change and health in Europe and North America.
2312 Overall, more than 2000 scientific articles were identified, of which 30% of papers focussed on
2313 Europe, followed by 29% on the Americas. Within the Americas, the large majority (72%) of the
2314 papers related to health and climate change in North America (see Figure S5.1 in Appendix 6). By
2315 contrast, only 10% of published articles had a focus on Africa or the Eastern Mediterranean Region,
2316 demonstrating a marked global inequality in the science of health and climate change (see Figures
2317 S5.1 and S5.2 in Appendix 6).

2318 Among the journals in the analysis, infectious diseases, particularly dengue fever and other
2319 mosquito-transmitted infections, are the most frequently investigated health outcomes;
2320 approximately 30% of selected papers covered these health-related issues. Important gaps in the
2321 scientific evidence base were identified, including migration and mental ill-health.

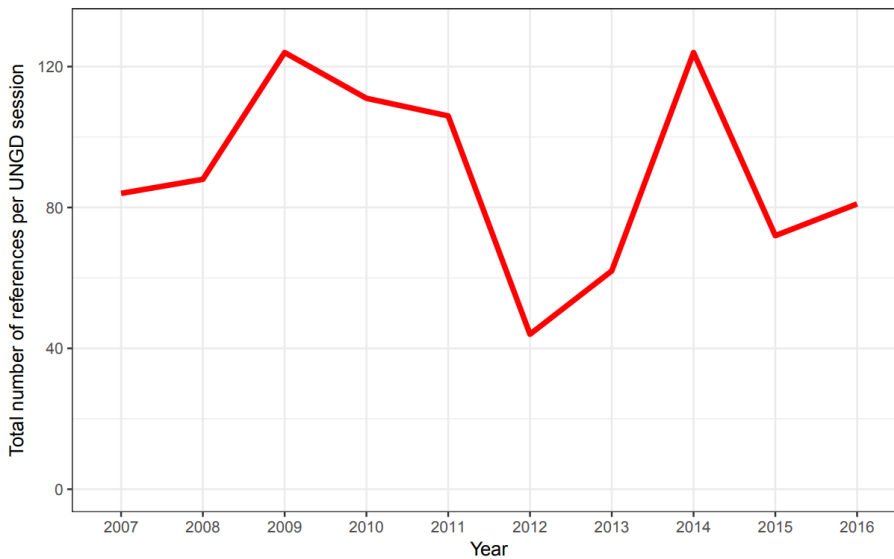
2322 For this indicator, a scoping review of peer-reviewed articles on health and climate change,
2323 published in English between 2007 and 2016, was conducted; an appropriate approach for broad
2324 and inter-disciplinary research fields.²¹³ Two databases were used, PubMed and Web of Science, to
2325 identify papers through a bibliometric analysis using keyword searches (see Appendix 6 for
2326 details).²¹⁴ Inclusion and exclusion criteria were applied to capture the most relevant literature on
2327 the human health impacts of climate change within the chosen timeframe and papers were
2328 independently reviewed and screened three times to identify relevant publications.²¹⁵

2329

2330 **Indicator 5.3: Health and climate change in the United Nations General Assembly**
2331 **Headline Finding:** *There is no overall trend in United Nations General Debate (UNGD) references to*
2332 *health and climate change, but two significant peaks occurred in 2009 and 2014.*

2333 The General Debate (GD) takes place every September at the start of each new session of the United
2334 Nations General Assembly (UNGA). Governments use their annual statements to present their
2335 perspective on events and issues they consider the most important in global politics, and to call for
2336 greater action from the international community. All UN Member States can address the UNGA, free
2337 from external constraints. Therefore, GD statements provide an ideal data source on political
2338 engagement with health and climate change, which is comparable spatially and temporally. This
2339 indicator focuses on the extent to which governments refer to linkages between health and climate
2340 change issues in their annual statements in the GD, with one reference representing one ‘hit’.

2341 Health and climate change are issues frequently raised in UNGD statements (see Figures S5.3-S5.5 in
2342 Appendix 6). However, statements less frequently link health and climate change together. Between
2343 2007 and 2016, linked references to health and climate change in the annual UNGD ranged from 44
2344 to 124 (Figure 5.3). The comparable figures for references to climate change alone were 378 and
2345 989. It was found that there is no overall trend in conjoint references to health and climate change
2346 across the period.

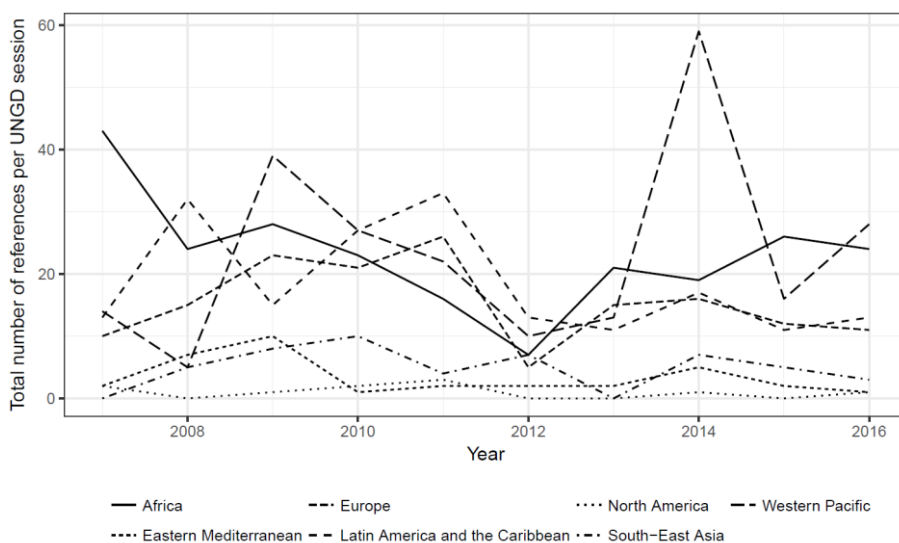


2347
2348 **Figure 5.3** Political engagement with the intersection of health and climate change, represented by joint
2349 references to health and climate change in the UNGD.

2350
2351 While no overall trend is apparent, there are two distinct peaks between 2009 and 2011 and in
2352 2014. In both 2009 and 2014, there were 124 references linking health and climate change in the GD
2353 statements. The 2009 peak occurred after the 2008 World Health Day, which focussed on health and
2354 climate change, and in the build-up to COP15 in Copenhagen in 2009. The 2014 peak is indicative of
2355 the influence of the large UNGA on climate change in 2014 and the lead up to COP21 in Paris in
2356 2015.

2357 The 2015 UNGA, which focused on the Sustainable Development Goals, made relatively limited
 2358 reference to climate change, and, after the 2014 peak, conjoint references to health and climate
 2359 change declined. This irregular pattern points to the importance of key events in the global
 2360 governance of health and climate change in driving high-level political engagement.

2361 There are country-level differences in the attention given to health and climate change in UNGD
 2362 statements (Figure 5.4). More frequent reference is made to the issue by countries in the Western
 2363 Pacific, particularly by the SIDS in these regions. In contrast, governments in the East Mediterranean,
 2364 the Americas and South-East Asia tend to make fewer references to health and climate change.



2365
 2366 Figure 5.4 Regional political engagement with the intersection of health and climate change, represented by
 2367 joint references to health and climate change in the UNGD, broken down by WHO region.

2368
 2369 This indicator is based on the application of keyword searches in the text corpus of debates. A new
 2370 dataset of GD statements was used (UNGD corpus), in which the annual UNGD statements have
 2371 been pre-processed and prepared for use in quantitative text analysis (see Appendix 6 for details).²¹⁶

2372
 2373 **Conclusion**
 2374 The indicators in this section have demonstrated the importance of global governance in mobilising
 2375 public and political engagement in health and climate change. The UN (and particularly the annual
 2376 COPs) have a significant role here, clearly influencing media, scientific and political engagement with
 2377 health and climate change.

2378 To further improve understanding of public and political engagement, indicators relating to national
 2379 governments' health and climate change legislation, private sector engagement, the inclusion of
 2380 climate change in professional health education, and the prominence given to health in UNFCCC
 2381 negotiations are proposed for future analysis. The previous sections in this report have presented
 2382 findings on the impacts of climate hazards, adaptation and resilience, co-benefits of mitigation, and

2383 finance and economics. All of these hinge upon policy, which in turn is dependent upon public and
2384 political engagement.

2385 **Conclusion - the Lancet Countdown in 2017**

2386 In June 2015, the Lancet Commission laid the groundwork for its global monitoring platform,
2387 designed to systematically track progress on health and climate change, and hold governments to
2388 account for their commitments under the then to-be-finalised Paris Agreement.⁴ The Lancet
2389 Countdown will continue this work, reporting annually on the indicators presented in this report and
2390 on new indicators in future.

2391

2392 **The direction of travel is set**

2393 The data and analysis presented in this 2017 report cover a wide range of topics and themes from
2394 the lethality of weather-related disasters, to the phase-out of coal-fired power. The report begins
2395 with an indicator set dedicated to tracking the health effects of climate change and climate hazards.
2396 The analysis here demonstrates that the symptoms of climate change have been clear for a number
2397 of years, with the health impacts far worse than previously understood. These effects have been
2398 spread unequally, with a 9.4% increase in vectorial capacity of the dengue fever carrying *Aedes*
2399 *aegypti* predominantly spreading to low- and middle-income countries since 1950; and India
2400 disproportionately affected by the additional 75 million exposure events to potentially fatal
2401 heatwaves since 2000.

2402 These indicators also suggest that populations are beginning to adapt, with improvements in the
2403 world's overall health profile strengthening its resilient capacity, and national governments
2404 beginning to invest in health adaptation planning for climate change. This is supported by some
2405 \$47.29 billion USD spent annually on health-related adaptation (some 13.3% of global total
2406 adaptation spend). However, the academic literature and past experience make it clear that there
2407 are very real and immediate technological, financial, and political barriers to adaptation.¹⁰

2408 The indicators in the third section track health-relevant mitigation trends across four sectors, with an
2409 ultimate focus of keeping temperature rise "well below 2°C" and meeting the Paris Agreement. At an
2410 aggregate level, the past two decades have seen limited progress here, with many of the trends and
2411 indicators remaining flat or moving strongly in the opposite direction. More recently, trends in the
2412 electricity generation (deployment of renewable energy and a dramatic slow-down in coal-fired
2413 power) and transport sectors (soon-to-be cost parity of electric vehicles with their petrol-based
2414 equivalents) provide cause for optimism, which, if sustained, could reflect the beginning of system-
2415 wide transformation.

2416 Indicators in the fourth and fifth sections underpin and drive forward this transition. Again, trends
2417 across the last two decades reflect concerning levels of inaction, with accelerated investment and
2418 intervention seen in more recent years. They reflect record levels of employment in the renewable
2419 energy sector to overtake those in fossil fuel extraction, and a global reduction in fossil fuel
2420 consumption subsidies. Carbon pricing mechanisms are slowly widening and now cover some 13.1%
2421 of global CO₂ emissions. The final section considers the degree to which the public, political and
2422 academic communities have engaged with the links between climate change and health. It points to
2423 uneven patterns of engagement and the vital role of global institutions, and the UN particularly, in
2424 driving forward public, political and scientific support for enhanced mitigation and adaptation
2425 policies.

2426 Overall, the trends elucidated in the Lancet Countdown's 2017 report provide cause for deep
2427 concern, highlighting the immediate health threats from climate change and the relative inaction
2428 seen across the world over the past two decades. However, they also point to more recent trends

2429 over the last five years demonstrating a rapid increase in action, which was solidified in the Paris
2430 Agreement. These ‘glimmers of progress’ are encouraging, and reflect a growing political consensus
2431 and ambition, which was seen in full-force in response to the US’s departure from the 2015 climate
2432 change treaty. Whilst action needs to increase rapidly, taken together, this provides the clearest
2433 signal to-date that the world is beginning to transition to a low-carbon world, that no one country or
2434 head of state can halt this progress, and that from today until 2030, the direction of travel is set.

2435

2436

2437 **Contributors**

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2461

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2475

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2511 [References](#)

2512

- 2513 1. Kang Y, Khan S, Ma X. Climate change impacts on crop yield, crop water productivity
2514 and food security – A review. *Progress in Natural Science* 2009; **19**(12): 1665–74.
- 2515 2. Lindgren E, Andersson, Y, Suk, J.E, Sudre, B. and Semenza, J.C. Monitoring EU
2516 Emerging Infectious Disease Risk Due to Climate Change. *Science* 2012; **336**(6080): 418-9.
- 2517 3. Reuveny R. Climate change-induced migration and violent conflict. *Political*
2518 *Geography* 2007; **26**(6): 656–73.
- 2519 4. Watts N, et al. Health and climate change: policy responses to protect public health.
2520 *The Lancet* 2015; **386**(10006): 1861–914.
- 2521 5. Watts N, et al. The Lancet Countdown: tracking progress on health and climate
2522 change. *The Lancet* 2016; **389**(10074): 1151–64.
- 2523 6. World Health Organization. Second Global Conference: Health and Climate (Paris 7-8
2524 July 2016), 2016.
- 2525 7. United Nations Framework Convention on Change. Paris Agreement. In: United
2526 Nations, editor. Paris, France; 2015.
- 2527 8. United Nations Environment Program. The Emissions Gap Report 2016. In: United
2528 Nations, editor. Nairobi, Kenya; 2016.
- 2529 9. Intergovernmental Panel on Climate Change. Climate Change 2014: Impacts,
2530 Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working
2531 Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
2532 Cambridge, United Kingdom and New York, NY, USA, 2014.
- 2533 10. Smith KR, Woodward A, Campbell-Lendrum D, et al. Human health: Impacts,
2534 adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, et al., eds. Climate Change
2535 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects
2536 Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental
2537 Panel of Climate Change. Cambridge and New York: Cambridge University Press; 2014: 709-
2538 54.
- 2539 11. Berry HL, Bowen K, Kjellstrom T. Climate change and mental health: a causal
2540 pathways framework. *International Journal of Public Health* 2010; **55**(2): 123-32.
- 2541 12. Reinmuth-Selzle K, et al. Air Pollution and Climate Change Effects on Allergies in the
2542 Anthropocene: Abundance, Interaction, and Modification of Allergens and Adjuvants.
2543 *Environmental Science and Technology* 2017; **51**(8): 4119-41.
- 2544 13. Glaser J, et al. Climate Change and the Emergent Epidemic of CKD from Heat Stress
2545 in Rural Communities: The Case for Heat Stress Nephropathy. *Clinical Journal of the*
2546 *American Society of Nephrology* 2016; **11**(8): 1472–83.
- 2547 14. McMichael AJ. Globalization, Climate Change, and Human Health. *The New England*
2548 *Journal of Medicine* 2013; **368**: 1335-43.

- 2549 15. European Centre for Medium-Range Weather Forecasts (ECMWF). 2017.
2550 <https://www.ecmwf.int/>.
- 2551 16. European Centre for Medium-Range Weather Forecasts (ECMWF). Climate
2552 Reanalysis. 2017. <https://www.ecmwf.int/en/research/climate-reanalysis>.
- 2553 17. NASA. Gridded Population of the World (GPW), v4. 2017.
- 2554 18. Jacob D, Petersen J, Eggert B, et al. EURO-CORDEX: new high-resolution climate
2555 change projections for European impact research. *Regional Environmental Change* 2014;
2556 **14**(2): 563-78.
- 2557 19. HEAT-SHIELD. 2017. <https://www.heat-shield.eu/>.
- 2558 20. Kjellstrom T, Briggs D, Freyberg C, Lemke B, Otto M, Hyatt O. Heat, Human
2559 Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate
2560 Change Impacts. *Annual Review of Public Health* 2016; **37**: 97–112.
- 2561 21. Ijaz K, Kasowski E, Arthur RR, Angulo FJ, Dowell SF. International Health
2562 Regulations—What Gets Measured Gets Done. *Emerging Infectious Diseases* 2012; **18**(7):
2563 1054-7.
- 2564 22. Intergovernmental Panel on Climate Change. Climate Change 2014: Synthesis
2565 Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the
2566 Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A.
2567 Meyer (eds.)]. Geneva, Switzerland: IPCC, 2014.
- 2568 23. Emergency Events Database. The Human Cost of Weather-Related Disasters 1995-
2569 2015: Centre for Research on the Epidemiology of Disasters (CRED), 2015
- 2570 24. Emergency Events Database. The International Disaster Database - Centre for
2571 Research on the Epidemiology of Disasters. 2017.
- 2572 25. International Federation of Red Cross and Red Crescent Societies. World Disasters
2573 Report 2014: Focus on Culture and Risks, 2014.
- 2574 26. Centre for Research on the Epidemiology of Disasters. The Human Cost of Natural
2575 Disasters: A Global Perspective. Brussels: CRED (Centre for Research on the Epidemiology of
2576 Disasters), 2015.
- 2577 27. Global Burden of Disease. Global Burden of Disease Study 2015. Global Burden of
2578 Disease Study 2015 (GBD 2015) Results. In: Institute for Health Metrics and Evaluation
2579 (IHME), editor. Seattle, United States; 2016.
- 2580 28. Liyanage P, Tissera H, Sewe M, et al. A Spatial Hierarchical Analysis of the Temporal
2581 Influences of the El Nino-Southern Oscillation and Weather on Dengue in Kalutara District,
2582 Sri Lanka. *International journal of environmental research and public health* 2016; **13**(11).
- 2583 29. Wilder-Smith A, Byass P. The elusive global burden of dengue. *The Lancet Infectious
2584 diseases* 2016; **16**(6): 629-31.

- 2585 30. Mitchell D, Heaviside C, Vardoulakis S, et al. Attributing human mortality during
 2586 extreme heat waves to anthropogenic climate change. *Environmental Research Letters*
 2587 2016; **11**(7): 074006.
- 2588 31. Zanobetti A, Schwartz J. Temperature and mortality in nine US cities. *Epidemiology*
 2589 (*Cambridge, Mass*) 2008; **19**(4): 563-70.
- 2590 32. Gasparrini A, Guo Y, Hashizume M, et al. Temporal Variation in Heat-Mortality
 2591 Associations: A Multicountry Study. *Environmental health perspectives* 2015; **123**(11): 1200-
 2592 7.
- 2593 33. Shi L, Kloog I, Zanobetti A, Liu P, Schwartz JD. Impacts of Temperature and its
 2594 Variability on Mortality in New England. *Nature climate change* 2015; **5**: 988-91.
- 2595 34. Guo Y, Gasparrini A, Armstrong BG, et al. Temperature Variability and Mortality: A
 2596 Multi-Country Study. *Environmental health perspectives* 2016.
- 2597 35. Wang Y, Shi L, Zanobetti A, Schwartz JD. Estimating and projecting the effect of cold
 2598 waves on mortality in 209 US cities. *Environment international* 2016; **94**: 141-9.
- 2599 36. Murray CJL, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries
 2600 in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study
 2601 2010. *The Lancet* 2013; **380**(9859): 2197–223.
- 2602 37. Dye C. After 2015: infectious diseases in a new era of health and development. *Royal*
 2603 *Philosophical Transactions of The Royal Society B* 2014; **369**(1645).
- 2604 38. World Health Organization. Using climate to predict infectious disease epidemics.
 2605 Geneva, Switzerland, 2005.
- 2606 39. World Health Organization. The Health and Environment Lexicon: Multi-Language
 2607 Glossary of Health and Environment Terminology. 2017.
 2608 <http://apps.who.int/thelexicon/entry.php>.
- 2609 40. Stanaway JD, et al. The global burden of dengue: an analysis from the Global Burden
 2610 of Disease Study 2013. *The Lancet: Infectious Diseases* 2016; **16**(6): 712–23.
- 2611 41. Hales S, de Wet, N, Maindonald, J. and Woodward, A. Potential effect of population
 2612 and climate changes on global distribution of dengue fever: an empirical model. *The Lancet*
 2613 2002; **360**(9336): 830-4.
- 2614 42. Krishnamurthy PK, et al. A methodological framework for rapidly assessing the
 2615 impacts of climate risk on national-level food security through a vulnerability index. *Global*
 2616 *Environmental Change* 2014; **24**: 121–32.
- 2617 43. Nelson GC, Rosegrant MW, Palazzo A, et al. Food Security Farming and Climate
 2618 Change to 2050: scenarios, results, policy options: International Food Policy Research
 2619 Institute, 2010.

- 2620 44. Schmidhuber J, Tubiello FN. Global food security under climate change. *Proceedings*
2621 *of the National Academy of Sciences of the United States of America* 2007; **104**(50): 19703-8.
- 2622 45. Campbell-Lendrum D, Woodruff R. Comparative risk assessment of the burden of
2623 disease from climate change. *Environmental health perspectives* 2006; **114**: 1935-41.
- 2624 46. Campbell-Lendrum DH, Corvalán CF, Prüss-Ustün A. How Much Disease Could
2625 Climate Change Cause? Geneva: The World Health Organization, 2003.
- 2626 47. Naylor RL, Falcon WP. Food security in an era of economic volatility. *Population and*
2627 *development review* 2010; **36**(4): 693-723.
- 2628 48. Headey D, Fan S. Reflections on the global food crisis: how did it happen? how has it
2629 hurt? and how can we prevent the next one?, 2010.
- 2630 49. Asseng S, Ewert F, Martre P, et al. Rising temperatures reduce global wheat
2631 production. *Nature climate change* 2015; **5**(2): 143-7.
- 2632 50. Peng S, Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S.,
2633 Khush, G.S. and Cassman, K.G. Rice yields decline with higher night temperature from global
2634 warming. *Proceedings of the National academy of Sciences of the United States of America*
2635 2004; **101**(27): 9971-5.
- 2636 51. Lobell DB, Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylor, R.L.
2637 Prioritizing climate change adaptation needs for food security in 2030. *Science* 2007;
2638 **319**(5863): 607-10.
- 2639 52. Lobell DB, Schlenker, W. and Costa-Roberts, J. Climate trends and global crop
2640 production since 1980. *Science* 2011; **333**(6042): 616-20.
- 2641 53. Gornall J, et al. Implications of climate change for agricultural productivity in the
2642 early twenty-first century. *Philosophical Transactions of the Royal Society B Biological*
2643 *Sciences* 2010; **365**(1554).
- 2644 54. FAO. The FAO Hunger Map 2015. In: Food and Agriculture Organization of the United
2645 Nations, editor.; 2015.
- 2646 55. Jones PG, Thornton PK. The potential impacts of climate change on maize production
2647 in Africa and Latin America in 2055. *Global Environmental Change* 2003; **13**(1): 51-9.
- 2648 56. Lobell DB, Bänziger M, Magorokosho C, Vivek B. Nonlinear heat effects on African
2649 maize as evidenced by historical yield trials. *Nature climate change* 2011; **1**(1): 42-5.
- 2650 57. High Level Panel of Experts on Food Security and Nutrition of the Committee on
2651 World Food Security. Sustainable Fisheries and Aquaculture for Food Security and Nutrition.
2652 Rome, Italy, 2014.
- 2653 58. World Health Organization. Availability and consumption of fish. 2017.
2654 http://www.who.int/nutrition/topics/3_foodconsumption/en/index5.html (accessed July
2655 2017.

- 2656 59. Djouse L, et al. Fish consumption, omega-3 fatty acids and risk of heart failure: a
2657 meta-analysis. *Clinical Nutrition* 2012; **31**(6): 846-53.
- 2658 60. Golden Cea. Fall in fish catch threatens human health. *Nature* 2016; **534**(317).
- 2659 61. Bushaw-Newton KL, Sellner KG. Harmful Algal Blooms: National Oceanic and
2660 Atmospheric Administration, 1999.
- 2661 62. Armstrong EM, Vazquez-Cuervo J. A New Global Satellite-Based Sea Surface
2662 Temperature Climatology. *Geophysical Research Letters* 2001; **28**(22): 4199-202.
- 2663 63. International Organization for Migration. Migration and Climate Change, 2008.
- 2664 64. Gleick PH. Water, Drought, Climate Change, and Conflict in Syria. *American
2665 Meteorological Society* 2014.
- 2666 65. Kelley CP, Mohtadib S, Canec MA, Seagerc R, Kushnirc Y. Climate change in the
2667 Fertile Crescent and implications of the recent Syrian drought. *Proceedings of the National
2668 Academy of Sciences of the United States of America* 2015; **112**(11): 3241–6.
- 2669 66. McMichael C, Barnett J, McMichael AJ. An Ill Wind? Climate Change, Migration, and
2670 Health. *Environmental health perspectives* 2012; **120**(5): 646-54.
- 2671 67. Green M. Contested territory. *Nature climate change* 2016; **6**: 817–20.
- 2672 68. United Nations Office for the Coordination of Humanitarian Affairs. Fiji: Building
2673 resilience in the face of climate change, 2014.
- 2674 69. EU-GIZ Adapting to Climate Change and Sustainable Energy Programme. Planned
2675 Relocation Project. 2017.
- 2676 70. Connell J. Last days in the Carteret Islands? Climate change, livelihoods and
2677 migration on coral atolls. *Asia Pacific Viewpoint* 2016; **57**(1): 3-15.
- 2678 71. Strauss S. Are cultures endangered by climate change? Yes, but ... *WIREs Climate
2679 Change* 2012; **3**(4): 371-7.
- 2680 72. Bronen R, Chapin I. Adaptive governance and institutional strategies for climate-
2681 induced community relocations in Alaska. *PNAS, Proceedings of the National Academy of
2682 Sciences* 2013; **110**(23): 9320-5.
- 2683 73. Shearer C. The political ecology of climate adaptation assistance: Alaska Natives,
2684 displacement, and relocation. *Journal of Political Ecology* 2012; **19**: 174-83.
- 2685 74. Small C, Nicholls RJ. A Global Analysis of Human Settlement in Coastal Zones.
2686 *Journal of Coastal Research* 2003; **19**(3): 584-99.
- 2687 75. McGranahan G, Balk, D. and Anderson, B. The rising tide: assessing the risks of
2688 climate change and human settlements in low elevation coastal zones. *Environment &
2689 Urbanization* 2007; **19**(1): 17-37.

- 2690 76. Merkens JL, Reimann, L, Hinkel, J. and Vafeidis, A.T. Gridded population projections
2691 for the coastal zone under the Shared Socioeconomic Pathways. *Global and Planetary*
2692 *Change* 2016; **145**: 57-66.
- 2693 77. Gregory J. Projections of sea level rise: Working Group I contribution to the IPCC
2694 Fifth Assessment Report - Climate Change 2013: The Physical Science Basis, 2013.
- 2695 78. Collins PY, et al. Grand challenges in global mental health: A consortium of
2696 researchers, advocates and clinicians announces here research priorities for improving the
2697 lives of people with mental illness around the world, and calls for urgent action and
2698 investment. *Nature* 2011; **475**: 27-30.
- 2699 79. Vins H, Bell J, Saha S, Hess J. The mental health outcomes of drought: A systematic
2700 review and causal process diagram. *International journal of environmental research and*
2701 *public health* 2015; **12**: 13251.
- 2702 80. Intergovernmental Panel on Climate Change. Climate Change 2007: Working Group
2703 II: Impacts, Adaptation and Vulnerability, 2001.
- 2704 81. Rockefeller Foundation. Resilience. 2017.
2705 <https://www.rockefellerfoundation.org/our-work/topics/resilience/> (accessed 02 Jul 2017).
- 2706 82. United Nations Framework Convention on Change. National Adaptation Plans. 2017.
- 2707 83. World Health Organization. WHO guidance to protect health from climate change
2708 through health adaptation planning. Switzerland, 2014.
- 2709 84. World Health Organization. Operational framework for building climate resilient
2710 health systems. Geneva, Switzerland, 2015.
- 2711 85. United Nations. The World's Cities in 2016, 2016.
- 2712 86. Doherty M, Klima K, Hellmann JJ. Climate change in the urban environment:
2713 Advancing, measuring and achieving resiliency. *Environmental Science & Policy* 2016; **66**:
2714 310-3.
- 2715 87. Compact of Mayors. 2017. <https://www.compactofmayors.org/>.
- 2716 88. Carbon Disclosure Project. Carbon Disclosure Project Data. 2017.
- 2717 89. Carbon Disclosure Project. CDP Cities 2016 Information Request, 2016.
- 2718 90. Sustainable Development Knowledge Platform. Sustainable Development Goal 3 -
2719 Ensure healthy lives and promote well-being for all at all ages. 2017.
2720 <https://sustainabledevelopment.un.org/sdg3>.
- 2721 91. World Health Organization. International Health Regulations (2005) Second Edition,
2722 2008.
- 2723 92. World Health Assembly. World Health Assembly resolution WHA 62.1 2008.

- 2724 93. International Health Regulations. IHR Core Capacity Monitoring Framework:
2725 Questionnaire for monitoring progress in the implementation of IHR core capacities in states
2726 parties: World Health Organization, 2005.
- 2727 94. World Health Organization. International Health Regulations (2005). IHR Core
2728 Capacity Monitoring Framework: Questionnaire for Monitoring Progress in the
2729 Implementation of IHR Core Capacities in States Parties, 2017.
- 2730 95. World Meteorological Organization. Monitoring and Evaluation. 2017.
- 2731 96. World Health Organization. Protecting Health from Climate Change: Vulnerability
2732 and Adaptation Assessment, 2013.
- 2733 97. Lim SS, Allen K, Bhutta ZA, et al. Measuring the health-related Sustainable
2734 Development Goals in 188 countries: a baseline analysis from the Global Burden of Disease
2735 Study 2015. *The Lancet* 2016; **16**: 31467-2.
- 2736 98. Ministry of Economic Affairs and Employment. National Energy and Climate Strategy.
2737 In: Government of Finland, editor.; 2016.
- 2738 99. Department for Business Energy and Industrial Strategy. Coal Generation in Great
2739 Britain. The pathway to a low-carbon future: consultation document In: HM Government,
2740 editor.; 2016.
- 2741 100. Mason J. In latest move, China halts over 100 coal power projects. 2017.
2742 <http://uk.reuters.com/article/us-china-coal-idUKKBN151090> (accessed July 2017).
- 2743 101. UBS. UBS Evidence Lab Electric Car Teardown – Disruption Ahead?, 2017.
- 2744 102. International Energy Agency. Medium-Term Renewable Energy Market Report 2016,
2745 2016.
- 2746 103. Dezem V. Solar Sold in Chile at Lowest Ever, Half Price of Coal. 2016.
2747 [https://www.bloomberg.com/news/articles/2016-08-19/solar-sells-in-chile-for-cheapest-](https://www.bloomberg.com/news/articles/2016-08-19/solar-sells-in-chile-for-cheapest-ever-at-half-the-price-of-coal)
2748 [ever-at-half-the-price-of-coal.](https://www.bloomberg.com/news/articles/2016-08-19/solar-sells-in-chile-for-cheapest-ever-at-half-the-price-of-coal)
- 2749 104. Le Quéré C, Andrew, R.M, Canadell, J.G, et al. Global Carbon Budget 2016. *Earth*
2750 *System Science Data* 2016; **8**: 605-49.
- 2751 105. Schirnding YV. Framework for Linkages between Health, Environment and
2752 Development, 2002.
- 2753 106. Intergovernmental Panel on Climate Change. Climate Change 2014: Mitigation of
2754 Climate Change. Contribution of Working Group III to the Fifth Assessment
2755 Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and
2756 New York, NY, USA, 2014.
- 2757 107. International Energy Agency. Energy and Climate Change, 2015.

- 2758 108. Rogelj J, Schaeffer, M, Meinshausen, M, et al. Zero emission targets as long-term
2759 global goals for climate protection. *Environmental Research Letters* 2015; **10**(105007).
- 2760 109. Pye S, Li FGN, Price J, Fais B. Achieving net-zero emissions through the reframing of
2761 UK national targets in the post-Paris Agreement era. *Nature Energy* 2017; **2**.
- 2762 110. Rockström J, Gaffney, O, Rogelj, J, Meinshausen, M, Nakicenovic, N. and
2763 Schellnhuber, H.J. A roadmap for rapid decarbonization. *Science* 2017; **80**(355): 1269–71.
- 2764 111. International Energy Agency. World Energy Outlook. Paris, France, 2016.
- 2765 112. International Energy Agency. Energy and Air Pollution: World Energy Outlook Special
2766 Report. Paris, France, 2016.
- 2767 113. Green F, Stern N. China’s changing economy: implications for its carbon dioxide
2768 emissions. *Climate Policy* 2017; **17**: 423–42.
- 2769 114. Shearer C, Ghio, N, Myllyvirta, L, Yu, A. and Nace, T. Boom and Bust 2017 - Tracking
2770 the global coal plant pipeline, 2017.
- 2771 115. IRENA. Conference on the establishment of the international renewable energy
2772 agency. Bonn, Germany, 2009.
- 2773 116. World Health Organization. The European health report 2015: Targets and beyond –
2774 reaching new frontiers in evidence, 2015.
- 2775 117. World Health Organization. Proportion of population with primary reliance on clean
2776 fuels and technology. Geneva, Switzerland, 2017.
- 2777 118. International Energy Agency, World Bank. Sustainable Energy for All 2017—Progress
2778 toward Sustainable Energy. Washington, D.C., 2017.
- 2779 119. World Energy Outlook. WEO 2016 Biomass Database. 2016.
- 2780 120. World Energy Outlook. WEO 2016 Electricity Access Database. 2016.
- 2781 121. World Health Organization. Household Fuel Combustion: WHO guidelines for indoor
2782 air quality, 2014.
- 2783 122. Bonjour S, Adair-Rohani, H, Wolf, J. et al. Solid Fuel Use for Household Cooking:
2784 Country and Regional Estimates for 1980–2010. *Environmental health perspectives* 2013;
2785 **121**: 784–90.
- 2786 123. West JJ, Smith, S.J, Silva, R.A. et al. Co-benefits of Global Greenhouse Gas Mitigation
2787 for Future Air Quality and Human Health. *Nature climate change* 2013; **3**: 885–9.
- 2788 124. Institute for Health Metrics and Global Burden of Disease. State of Global Air - 2017:
2789 A special report on global exposure to air pollution and its disease burden, 2017.

- 2790 125. World Health Organization. WHO's Urban Ambient Air Pollution database – Update
2791 2016. Geneva, Switzerland, 2017.
- 2792 126. Milner J, Taylor, J, Barreto, M.L. et al. Environmental risks of cities in the European
2793 region: analyses of the Sustainable Healthy Urban Environments (SHUE) database. *Public*
2794 *Health Panorama* 2017; **3**: 300-9.
- 2795 127. World Health Organization. Air pollution levels rising in many of the world's poorest
2796 cities, 2016.
- 2797 128. European Commission. Europe, Latin America and The Caribbean: sharing
2798 experiences in regional development policies, 2015.
- 2799 129. Instituto Nacional de Estadística e Informática. 2017.
- 2800 130. Fondo De Inclusion Social Energetico. Memoria Anual De Gestion Fise 2015, 2015.
- 2801 131. Fondo De Inclusion Social Energetico. Memoria Anual De Gestion Fise 2014, 2014.
- 2802 132. European Commission. Directive 2001/80/EC of the European Parliament and of the
2803 Council on the limitation of emissions of certain pollutants into the air from large
2804 combustion plants. OJEC L 309/1. 2001.
- 2805 133. EU Parliament and Council. Directive 2010/75/EU of the European Parliament and of
2806 the Council of 24 November 2010 on industrial emissions (integrated pollution prevention
2807 and control). OJEC L 334/17. 2010.
- 2808 134. Pope CAea. Lung Cancer, Cardiopulmonary Mortality and Long-Term Exposure to
2809 Fine Particulate Air Pollution. *Journal of the American Medical Association* 2002; **287** (9):
2810 1132–41.
- 2811 135. Lim SSea. A Comparative Risk Assessment of Burden of Disease and Injury
2812 Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990–2010: A
2813 Systematic Analysis for the Global Burden of Disease Study 2010. *The Lancet* 2012;
2814 **380**(9859): 2224–60.
- 2815 136. Forouzanfar MHea. Global, Regional, and National Comparative Risk Assessment of
2816 79 Behavioural, Environmental and Occupational, and Metabolic Risks or Clusters of Risks in
2817 188 Countries, 1990–2013: A Systematic Analysis for the Global Burden of Disease Study
2818 2013. *The Lancet* 2015; **386**(10010): 2287–323.
- 2819 137. World Health Organization. Ambient Air Pollution: A Global Assessment of Exposure
2820 and Burden of Disease. Geneva, Switzerland, 2016.
- 2821 138. Amann M, I. Bertok, J. Borcken-Kleefeld, J. Cofala, C. Heyes, L. Höglund-Isaksson, Z.
2822 Klimont, et al. Cost-Effective Control of Air Quality and Greenhouse Gases in Europe:
2823 Modeling and Policy Applications. *Environmental Modelling & Software* 2011; **26**(2): 1489–
2824 501.
- 2825 139. International Energy Agency. Energy Technology Perspectives. Paris, France, 2016.

- 2826 140. International Energy Agency. Global EV Outlook 2016: Beyond on million electric
2827 cars. Paris, France, 2016.
- 2828 141. International Energy Agency. Global EV Outlook 2017: Two Million and Counting,
2829 2017.
- 2830 142. Electric Vehicle Initiative. Global Electric Vehicle Outlook. 2016.
- 2831 143. Land Transport Authority. Passenger Transport Mode Shares in World Cities, 2014.
- 2832 144. Salon D, Gulyani S. Mobility, Poverty, and Gender: Travel 'Choices' of Slum Residents
2833 in Nairobi, Kenya. *Transport Reviews* 2010; **30**: 641–57.
- 2834 145. Sims R. RS, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M.J. Figueroa Meza,
2835 L. Fulton, S., Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J.J. Schauer, D.
2836 Sperling, and G. Tiwari. Transport, 2014.
- 2837 146. United Nations Environment Program. Global Outlook on Walking and Cycling:
2838 United Nations, 2016.
- 2839 147. Institute for Mobility Research. Mobility trends in cutting edge cities, 2016.
- 2840 148. Transport for London. Travel in London Report 9, 2016.
- 2841 149. NSW Department of Transport. Public transport travel patterns in the greater Sydney
2842 Metropolitan area 1981-1991. 1996.
- 2843 150. NSW Department of Transport. Household Travel Survey Summary Report 2002.
2844 2003.
- 2845 151. NSW Department of Transport. Household Travel Survey Summary Report 2007.
2846 2009.
- 2847 152. NSW Department of Transport. Key Transport Indicators- How do people travel.
2848 2017.
- 2849 153. Translink. Metro Vancouver Regional Trip Diary Survey Briefing Paper #1. 2012.
- 2850 154. S.A. D. Estudio Encuesta origen destino de viajes del Gran Santiago, 1991, 1992.
- 2851 155. Rode P, Hoffmann C, Kandt J, Smith D, Graff A. Toward New Urban. Mobility: The
2852 case of London and Berlin. London: London School of Economics and Political Science, 2015.
- 2853 156. City of Berlin. Mobility in the City: Berlin Traffic in Figures, 2013.
- 2854 157. Vermeulen SJ, Campbell BM, Ingram JSI. Climate change and food systems. *Annual
2855 Review of Environment and Resources* 2012; **37**: 195-222.
- 2856 158. Lim SS, Vos, T, Flaxman, A.D. et al. Global, regional, and national comparative risk
2857 assessment of 79 behavioural, environmental and occupational, and metabolic risks or

- 2858 clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of
2859 Disease Study 2013. *The Lancet* 2016; **380**: 2224–60.
- 2860 159. Springmann Mea. Analysis and valuation of the health and climate change cobenefits
2861 of dietary change. *PNAS, Proceedings of the National Academy of Sciences* 2016; **15**: 4146-
2862 51.
- 2863 160. Hawkesworth S, Dangour, A.D, Johnston, D. et al. Feeding the world healthily: the
2864 challenge of measuring the effects of agriculture on health. *Philosophical Transactions of the*
2865 *Royal Society B Biological Sciences* 2010; **365**: 3083–97.
- 2866 161. Smith MR, Micha, R, Golden, C.D. et al. Global Expanded Nutrient Supply (GENuS)
2867 Model: A New Method for Estimating the Global Dietary Supply of Nutrients. *PLoS One*
2868 2016; **11**.
- 2869 162. Gobbo LCD, Khatibzadeh, S, Imamura, F. et al. Assessing global dietary habits : a
2870 comparison of national estimates from the FAO and the Global Dietary Database 1 – 4,
2871 2015.
- 2872 163. Herrero Mea. Greenhouse gas mitigation potentials in the livestock sector. *Nature*
2873 *climate change* 2016; **6**: 452–61.
- 2874 164. O’Mara FP. The significance of livestock as a contributor to global greenhouse gas
2875 emissions today and in the near future. *Animal Feed Science and Technology* 2011; **166–167**:
2876 7–15.
- 2877 165. Herrero M, Havlík P, Valin H, et al. Biomass use, production, feed efficiencies, and
2878 greenhouse gas emissions from global livestock systems. *Proceedings of the National*
2879 *Academy of Sciences of the United States of America* 2013; **110**: 20888–93.
- 2880 166. Carlsson-Kanyama A, González AD. Potential contributions of food consumption
2881 patterns to climate change. *American Journal of Clinical Nutrition* 2009; **89**: 1704S–9S.
- 2882 167. Larsson SC, Wolk A. Meat consumption and risk of colorectal cancer: A meta-analysis
2883 of prospective studies. *International Journal of Cancer* 2006; **119**: 2657–64.
- 2884 168. Norat T, Lukanova, A, Ferrari, P. and Riboli, E. Meat consumption and colorectal
2885 cancer risk: Dose-response meta-analysis of epidemiological studies. *International Journal of*
2886 *Cancer*; **98**: 241–56.
- 2887 169. FAOSTAT. Food Balance Sheets, 2017.
- 2888 170. Ng M, Fleming T, Robinson M, al. e. Global, regional, and national prevalence of
2889 overweight and obesity in children and adults during 1980-2013: A systematic analysis for
2890 the Global Burden of Disease Study 2013. *The Lancet* 2013; **384**: 766–81.
- 2891 171. World Bank. Climate-Smart Healthcare: Low-Carbon and Resilience Strategies for the
2892 Health Sector. Washington DC, 2017.
- 2893 172. NHS Sustainable Development Unit. NHS carbon footprint, 2016.

- 2894 173. Stern N. Stern Review on the Economics of Climate Change. In: Kingdom GotU,
2895 editor. London: Blackwell Publishing; 2006. p. 5.
- 2896 174. Weitzmann. M. Fat-Tailed Uncertainty in the Economics of Catastrophic Climate
2897 Change. *Review of Environmental Economics and Policy* 2011; **5**(2): 17.
- 2898 175. Stern N. The Structure of Economic Modeling of the Potential Impacts of Climate
2899 Change: Grafting Gross Underestimation of Risk onto Already Narrow Science Models.
2900 *Journal of Economic Literature* 2013; **51**(3): 21.
- 2901 176. International Energy Agency. World Energy Investment 2016. Paris, 2016.
- 2902 177. International Energy Agency. World Energy Investment 2017. Paris, 2017.
- 2903 178. International Energy Agency. World Energy Outlook 2016. Paris, France, 2016.
- 2904 179. International Energy Agency, International Renewable Energy Agency. Perspectives
2905 for the energy transition: Investment needs for a low-carbon energy system. Berlin,
2906 Germany, 2017.
- 2907 180. Olivier JGJ, Janssens-Maenhout G, Muntean M, Peters JAHW. Trends in Global CO2
2908 Emissions: 2016 Report: PBL Netherlands Environmental Assessment Agency, The Hague,
2909 2016.
- 2910 181. Ansar A, Caldecott B, Tilbury J. Stranded assets and the fossil fuel divestment
2911 campaign: what does divestment mean for the valuation of fossil fuel assets?: Smith School
2912 of Enterprise and the Environment, 2013.
- 2913 182. North CS. Disaster Mental Health Epidemiology: Methodological Review and
2914 Interpretation of Research Findings. *Psychiatry* 2016; **79**(2): 16.
- 2915 183. Munich Re. NatCatSERVICE. In: Re M, editor.; 2017.
- 2916 184. World Health Organization. Global Health Observatory (GHO) data. In: World Health
2917 Organization, editor. Geneva; 2017.
- 2918 185. Ming-Xiao. W, Tao. Z, Miao-Rong. X, Bin. Z, Ming-Qiu. J. Analysis Of National Coal-
2919 mining Accident data In China, 2001–2008. *Public Health Rep* 2011; **126**(2): 5.
- 2920 186. Hendryx M, Ahern MM. Relations Between Health Indicators and Residential
2921 Proximity to Coal Mining in West Virginia. *American Journal of Public Health* 2008; **98**(4): 2.
- 2922 187. Zullig. KJ, Hendryx. M. A Comparative Analysis of Health-Related Quality of Life for
2923 Residents of U.S. Counties with and without Coal Mining. *Public Health Reports* 2010;
2924 **125**(4): 7.
- 2925 188. Hendryx M. Mortality from heart, respiratory, and kidney disease in coal mining
2926 areas of Appalachia. *International Archives of Occupational and Environmental Health* 2009;
2927 **82**(2): 6.

- 2928 189. IBIS World. Global Coal Mining: Market Research Report, 2016.
- 2929 190. IBIS World. Global Oil & Gas Exploration & Production: Market Research Report,
2930 2017.
- 2931 191. IRENA. Renewable Energy and Jobs: Annual Review 2017. Abu Dhabi: International
2932 Renewable Energy Agency, 2017.
- 2933 192. International Energy Agency. World Energy Outlook 2012. Paris, France, 2012.
- 2934 193. Granado JA, Coady D, Gillingham R. The Unequal Benefits of Fuel Subsidies: A Review
2935 of Evidence for Developing Countries, 2010.
- 2936 194. General Secretariat of the Council. G7 Ise-Shima Leaders' Declaration. Brussels,
2937 Belgium; 2016. p. 1.
- 2938 195. World Bank. Carbon Pricing Dashboard. 2017.
2939 <http://carbonpricingdashboard.worldbank.org> (accessed 06.06.2017 2017).
- 2940 196. World Bank, Ecofys. Carbon Pricing Watch 2017. Washington DC, USA, 2017.
- 2941 197. Patuelli R, Nijkamp P, Pels E. Environmental tax reform and the double dividend: a
2942 meta-analytical performance assessment. *Ecological Economics* 2005; **55**: 564-83.
- 2943 198. Georgeson L, al. e. Global Disparity in the Supply of Commercial Weather and
2944 Climate Information Services. *Science Advances* 2017; **3**(5).
- 2945 199. Climate Funds Update. Climate Funds Update: The Data. 2017.
2946 <http://www.climatefundsupdate.org/>.
- 2947 200. Crompton T. Common Values: The Case for Working with our Cultural Values: WWF,
2948 2010.
- 2949 201. World Health Assembly. Sixty-first World Health Assembly WHA61.19. 2008.
- 2950 202. Boykoff MT, Goodman MK, Curtis I. Cultural Politics of Climate Change: Interactions
2951 in Everyday Spaces, 2009.
- 2952 203. Lee TM, Markowitz EM, Howe PD, al e. Predictors of public climate change
2953 awareness and risk perception around the world *Nature climate change* 2015; **5**: 1014–20.
- 2954 204. Boykoff MT. Media and scientific communication: a case of climate change
2955 *Geological Society* 2008; **305**: 11-8.
- 2956 205. Steentjes K, al e. European Perceptions of Climate Change: Topline findings of a
2957 survey conducted in four European countries in 2016, 2017.
- 2958 206. Billett S. Dividing climate change: global warming in the Indian mass media. *Climatic
2959 Change* 2010; **99**(1/2): 525-37.

- 2960 207. Bhatta SNA. Coverage of Climate Change Issues in Indian Newspapers and Policy
2961 Implications. *Current Science* 2015; **108**(11): 1972-3.
- 2962 208. Andrews K, Boykoff, M., Daly, M., Gifford, L., Luedecke, G., McAllister, L., and Nacu-
2963 Schmidt, A. . World Newspaper Coverage of Climate Change or Global Warming, 2004-2017:
2964 Center for Science and Technology Policy Research, Cooperative Institute for Research in
2965 Environmental Sciences, University of Colorado, 2017.
- 2966 209. Schütte S, Depoux A, Vigil S, al. e. The influence of health concerns in scientific and
2967 policy debates on climate change. 2015; **Journal of Epidemiology and Community Health**.
- 2968 210. Depoux A, Hémono M, Puig-Malet S, Pédrón R, Flahault A. Communicating climate
2969 change and health in the media. *Public Health Reviews* 2017; **38**(1): 7.
- 2970 211. Hosking J, Campbell-Lendrum D. How well does climate change and human health
2971 research match the demands of policymakers? A scoping review. *Environmental health*
2972 *perspectives* 2012; **120**(8): 1076-82.
- 2973 212. Campbell-Lendrum D, Bertollini R, Neira M, Ebi K, McMichael A. Health and climate
2974 change: a roadmap for applied research. *The Lancet* 2009; **373**(9676): 1663-5.
- 2975 213. Arksey H, O'Malley L. Scoping studies: towards a methodological framework.
2976 *International Journal of Social Research Methodology* 2005; **8**(1): 19-32.
- 2977 214. Janssen MA, Schoon, M.L, Ke, W, and Börner, K. Scholarly networks on resilience,
2978 vulnerability and adaptation within the human dimensions of global environmental change.
2979 *Global Environmental Change* 2006; **16**(3): 240-52.
- 2980 215. Herlihy N, Bar-Hen A, Verner G, et al. Climate change and human health: what are
2981 the research trends? A scoping review protocol. *British Medical Journal* 2016; **6**.
- 2982 216. Baturo A, Dasandi N, Mikhaylov S. Understanding State Preferences with Text as
2983 Data: Introducing the UN General Debate Corpus. *Research and Politics* 2017; **4**(2).
2984