Court of Appeal File No.: C65807

COURT OF APPEAL FOR ONTARIO

IN THE MATTER OF A REFERENCE to the Court of Appeal pursuant to section 8 of the *Courts of Justice Act,* RSO 1990, c. C34, by Order-in-Council 1014/2018 respecting the constitutionality of the *Greenhouse Gas Pollution Pricing Act,* Part 5 of the *Budget Implementation Act, 2018, No. 1,* SC 2018, c. 12

RECORD OF THE INTERVENER, CANADIAN PUBLIC HEALTH ASSOCIATION (Reference Returnable April 15-18, 2019)

February 26, 2019

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AFFIDAVIT OF IAN CULBERT
(Affirmed December 19, 2018)

I, Ian Culbert, of the City of Ottawa, in the Province of Ontario, AFFIRM AND SAY:

1. I am the Executive Director of the Canadian Public Health Association ("CPHA"), an applicant for intervener status. Accordingly, I have knowledge of the matters to which I depose in this affidavit. Where my knowledge is based on information and belief from a source other than my direct personal knowledge, I have indicated the source of my information or belief and I believe such information to be true.

2. I have worked at CPHA since 1990. I have assumed various roles including Secretary of the Community Health Secretariat and HIV Prevention Program Officer and Coordinator. In 2002, I became a Director of the Association managing the day-to-day operational and programmatic functions. I was promoted to Director of Communications and Business Development in 2008 and was appointed Executive Director in 2013.

3. CPHA seeks leave to intervene before the Court of Appeal for Ontario in the matter of Ontario's Lieutenant Governor in Council's reference to the Court of Appeal respecting the constitutionality of the *Greenhouse Gas Pollution Pricing Act,* Part 5 of the *Budget*

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Implementation Act, 2018, No. 1, SC 2018, c. 12 (the "Act"). CPHA supports the position that the Act is constitutional.

4. In this affidavit, I address the following matters:

(a) A description of CPHA – a well-recognized organization with a unique expertise in public health and a broad and identifiable membership base;

(b) The basis of CPHA's interest in the issues raised by this reference; and

(c) An explanation of what CPHA's public health expertise will contribute to the resolution of this reference.

I. BACKGROUND – CPHA AND PUBLIC HEALTH

(a) About CPHA

5. Founded in 1910 through an Act of Parliament and registered as a charitable organization since 1975, CPHA is a national, independent, non-partisan, non-governmental organization ("NGO") representing the interests of public health in Canada, with links to the international public health community. As the only national NGO in Canada focussed exclusively on public health, CPHA is uniquely positioned to advise decision-makers about healthy public policy and to guide initiatives to help safeguard the personal and community health of Canadians. A copy of the Certificate of Continuance of CPHA under the *Canada Not-for Profit Corporations Act* is attached as **Exhibit "A".**

6. CPHA's primary purpose is to enhance the health and health equity of populations in Canada by facilitating development and exchange of public health knowledge and by advocating for evidence-informed, healthy public policies. In this regard, it encourages and contributes to the development of sound, evidence-based public policy, legislation,

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regulations, strategies, programs and practices that protect and promote health and prevent illness and injury at a population level (as opposed to at the individual patient level).

7. Membership in CPHA is voluntary and CPHA's members are primarily front-line professionals, academics and researchers representing over 25 different health-related disciplines across the country. Though its members are vital to supporting the activities of CPHA, CPHA is not a professional association and is not primarily focussed on the provision of health or medical services at an individual level. CPHA is a unique organization that brings the public health conceptual framework to bear on issues of vital importance to the health and well-being of Canadians at a population level. *Public Health: A Conceptual Framework* ("CPHA Conceptual Framework") describes CPHA's public health approach and is attached as **Exhibit "B"**.

8. CPHA provides a forum, drawing on the expertise of its members, to share knowledge that informs program development and implementation, and policy-making processes. When public health evidence supports particular policy measures, CPHA may engage in an advocacy role by disseminating important findings directly to decision-makers in government, practitioners in the workforce, and the Canadian public. When CPHA performs this function, it does so in an assiduously non-partisan manner, unencumbered by constraints that many public health professionals face as employees of government or government-funded organizations or agencies.

9. Select examples of CPHA's initiatives to advance public health education, research, policy and practice in Canada and around the world in the past century include:

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(a) *Publishing the Canadian Journal of Public Health ("CJPH"):* CPHA has published this independent, peer-reviewed journal, since 1910. The Journal is dedicated to fostering excellence in public health research, scholarship, policy and practice. The aim of the Journal is to advance public health research and practice in Canada and around the world.

(b) *Advocating for the creation of a federal department of health (now Health Canada):* CPHA played a key role in advocating for the creation of a federal department of health in 1919.

(c) *The National Seminar on Smoking and Health*: CPHA co-sponsored this conference with the Department of National Health and Welfare in 1972. The conference initiated stronger, sustained leadership in tobacco education initiatives.

(d) *Alma Ata Conference:* CPHA presented the position of the NGO community at the World Health Organization ("WHO") / United Nations International Children's Emergency Fund ("UNICEF") International Conference on Primary Health Care in Alma Ata, Kazakhstan in 1978 (the "Alma Ata Conference"). The Alma Ata Declaration adopted at the Alma Ata Conference emerged as a major milestone of the 20th century in the field of public health.

(e) *First International Conference on Health Promotion:* In November 1986, CPHA, Health and Welfare Canada and WHO organized the first International Conference on Health Promotion held in Ottawa, leading to the

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publication of *The Ottawa Charter for Health Promotion*, a seminal document in the practice of public health around the world.

(f) *Implementation of the Canadian International Development Agency's ("CIDA") International Immunization Program:* CIDA chose CPHA to implement its international immunization program against all vaccine-preventable diseases in developing Commonwealth and Francophone nations, which CIDA launched in partnership with WHO, UNICEF and a consortium of Canadian NGOs in 1986.

(g) *Publishing position statements, discussion documents and other resources:* CPHA regularly publishes timely, evidence-informed public health guidance and perspectives to public health professionals and policy makers.[1]

10. CPHA has advocated for environment-specific health policies since the 1930s when it examined standards for water, sewage and dairy products. I prepared a selected list of CPHA activities related to ecological determinants of health, attached as **Exhibit "C"**.

11. Since the early 1990s, CPHA has recognized the threat of excessive greenhouse gas ("GHG") emissions to public health and the need to address climate change through

[1] Policy and position statements published by CPHA since 2011 include: The Winnable Battle: Ending Tobacco Use in Canada (2011), Managing Illegal Psychoactive Substances in Canada (2014), Statement of Support for a National Inquiry Concerning Missing and Murdered Aboriginal Women (2014), Discussion Paper on the Ecological Determinants of Health (2015), Medical Assistance in Dying (2016), The Opioid Crisis in Canada (2016), A Public Health Approach to the Legalization, Regulation and Restriction of Access to Cannabis (2017), A Public Health Approach to Nicotine-Containing Vaping Devices (2018), and Racism and Public Health (2018).

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policy action. Some of CPHA's initiatives related to public health and climate change include:

(a) 1991 Task Force Report – *Human & Ecosystem Health: Canadian Perspectives, Canadian Action:* This was a major working document researched and written by an expert task force commissioned by CPHA that details the expected future human health impacts of climate change;

(b) 1999 Survey – *Supporting Public Awareness Initiatives on the Health Effects of Climate Change & Air Pollution: Survey Report:* CPHA commissioned a survey of public awareness of the health effects of climate change in four sectors (health, education, advocacy and the private sector), with support contributed by the Federal government. The majority of organizations surveyed regarded the health effects of climate change and air pollution as major areas of concern;

(c) 2000 Roundtable – *Roundtable on Health and Climate Change*: In partnership with Health Canada, Environment Canada and Natural Resources Canada, CPHA organized and co-chaired a roundtable attracting the participation of over forty organizations. Participants agreed on the need for strong public outreach and engagement on climate change and air pollution;

(d) 2001 Plan – *Strategic Plan on Health and Climate Change: A Framework for Collaborative Action*: Building on the findings of the Roundtable on Health and Climate Change, CPHA published a plan emphasizing the need for policy development, research and knowledge, public outreach and

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engagement, adaptation and response capability and promotion of personal action;

(e) 2002 Workshop – *Clean Air Day*: CPHA developed and disseminated resource materials and public awareness activities for Clean Air Day and beyond. CPHA also designed and implemented a pilot workshop for health professionals;

(f) 2006 Interviews – *Snapshot of Adaptation and Response Capacity in Public Health:* CPHA questioned key public health community members in Canada on the degree to which they considered climate change risks in policies and planning;

(g) 2007 Policy Assessment – *Climate Change and Health Vulnerability Assessment*: CPHA reviewed the draft technical and synthesis report of the Government of Canada's Climate Change and Health Vulnerability Assessment 2007 and selected key issues on which to report to public health professionals in Canada;

(h) 2015 Paper– *Discussion Paper on the Ecological Determinants of Health:* This CPHA expert publication discussed climate change as a key determinant of human health;

(i) 2016 Article – *Public Health supports the Government of Canada's push to accelerate phase-out of coal power*: CPHA published online an article explaining how the Government of Canada's efforts to eliminate coal plant emissions would improve human health and help to stabilize the climate;

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(j) 2017 Article – *Climate Change and Vector-borne Illness*: A contributing public health scientist described how climate change may be increasing the range of ticks and mosquitos which are vectors for Lyme Disease and West Nile virus, both of which pose increasing threats to Canadian public health;

(k) 2017 Report – *Lancet Countdown Report: Briefing for Canadian Policymakers*: A brief summarizing Canadian issues based on the 2017 report, entitled *Lancet Countdown on health and climate change*. The brief is directed towards Canadian policy-makers and was written by a team of medical doctors and researchers. CPHA edited and distributed the Report in partnership with *The Lancet*, one of the world's oldest and most reputable peer-reviewed medical journals.

(l) 2018 Report – *Lancet Countdown Report: Briefing for Canadian Policymakers*: This report is described in more detail below, and is attached as **Exhibit "D"**.

12. In 1992, CPHA was the first NGO to receive the Sasakawa Health Prize from the WHO. The Sasakawa Health Prize is awarded for outstanding, innovative work in health development, such as the promotion of health programs or notable advances in primary health care, in order to encourage the further development of such work.

(b) What is Public Health?

13. The concept of public health is central to the work of CPHA and to the issues raised in this Reference. Public health is by definition a domain with inter-jurisdictional accountability where all levels of government are responsible for different aspects of

public health, requiring collaboration, cooperation and mutual accountability among the various levels of government in order to be efficacious.

14. Public health is not the same thing as publicly funded health care. Public health was defined in Canada's first Chief Public Health Officer's 2008 Report as "the organized efforts of society to keep people healthy and prevent injury, illness and premature death. It is a combination of programs, services and policies that protect and promote the health of all Canadians." While health care focusses on the provision of health services to individuals who are ill or injured, public health works to prevent people from becoming sick or sicker, and to address primordial[2] and primary prevention.[3] For example, medical services treat an individual's lung cancer, but public health services promote abstention from tobacco to prevent cancer. Excerpts from the Chief Public Health Officer's 2008 Report on the State of Public Health in Canada is attached as **Exhibit "E"**. The Chief Public Health Officer at that time was Dr. David Butler-Jones; a former President of CPHA.

15. Public health's primary focus is protecting and improving the collective health of the broader community. This "population health approach", targets entire populations by identifying and reducing health threats. For example, policies addressing issues such as poverty, housing, sanitation, food and drugs, and the environment directly and indirectly influence the health of populations.

16. Public health experts have long recognized an inexorable link between the environment and human health. Throughout the 20th and 21st centuries, public health

[2] Primordial prevention means preventing the emergence or development of risk factors by addressing the social and environmental conditions in which these factors are observed to develop. For example, encouraging children to adopt healthy lifestyles to prevent the emergence of health risks later in life.
[3] Primary prevention is concerned with preventing the onset of disease by treating risk factors. Examples include changes to behaviours such as cigarette smoking or diet.

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evidence has demonstrated that human health outcomes are inseparable from environmental conditions and policies. For more information about the environmental dimensions of public health, see CPHA's 2015 discussion document, *Global Change and Public Health: Addressing the Ecological Determinants of Health*, attached as **Exhibit "F"** ("CPHA Global Change and Public Health").

17. Core among public health principles for the purposes of this Reference is reliance on sound, scientific evidence. Such an approach focusses policy initiatives on evidence of what works or shows promise of working. This approach is key to understanding the hazards that GHG emissions and climate change pose to public health, and in developing effective policy responses.

18. The evidence-based public health approach has revolutionized human well-being in Canada and around the world. Population-focussed public health policies and practices have eradicated or controlled various sexually-transmitted (*syphilis*), nutritional (*scurvy*), occupational (*asbestosis*), and environmental (*lead and mercury poisoning*) diseases. For further detail, see the CPHA Conceptual Framework, attached at Exhibit "B". For more detail on the history of public health in Canada, see the Chief Public Health Officer's 2008 report attached at Exhibit "E".

19. Public health is ultimately a constitutional responsibility of government. The responsibility is shared by different jurisdictional levels including federal, provincial, territorial, municipal, and Indigenous governments. The obligations on governments are captured in a core principle of public health – stewardship. Stewardship places a duty on governments to act in ways that enhance the health of communities. The measures the

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governments adopt with a public health dimension must further the objectives of public health or, at minimum, not act as a detriment to public health.

20. CPHA believes that government policies including the *Greenhouse Gas Pollution Pricing Act* should be examined from a population health perspective.

II. CPHA'S INTEREST IN THIS REFERENCE

21. CPHA seeks leave to intervene in this Reference as it raises national public health issues of critical importance. These issues engage CPHA's primary purpose to advocate for the improvement and maintenance of community health in Canada according to public health principles, including by advocating for evidence-informed responses to broad-based harms such as climate change. As described in more detail below:

(a) Substantial and irrefutable scientific evidence has established that anthropogenic climate change is a critical public health issue. It is causing measurable impacts on the health of populations on a national and international scale, demonstrating an unacceptably high level of risk for the current and future health of populations across the world; and

(b) The public health approach supports federal authority to coordinate an effective and consistent inter-jurisdictional response to climate change as a public health issue of national and international concern.

22. CPHA is deeply concerned with these issues as climate change is a critical public health issue that threatens to undermine the past century of gains in public health in Canada and internationally, achieved, in part, through CPHA's efforts since 1910.

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(a) Specific Climate Change Impacts on Public Health

23. The causal link between GHG emissions, climate change, and negative public health impacts is incontrovertible.

24. The state of climate change science and its impacts is established by the work of the Intergovernmental Panel on Climate Change ("IPCC"). The IPCC was created in 1988 to regularly review and report on the state of knowledge on climate change. Its reports, including the 2014 and 2018 Summaries for Policymakers (attached as **Exhibits "G"** and **"H"** to this affidavit)[4] are based on the contributions of thousands of scientists around the world. The reports are endorsed by all 195 member governments after multiple rounds of expert drafting and review. Information on the IPCC's rigorous reporting process is attached to this affidavit as **Exhibit "I"**. IPCC reports provide a uniquely rigorous and balanced perspective that reflects both scientific and political consensus on the state of climate science and its impacts.

25. The independent findings of Environment Canada in its comprehensive *7th National Communication to the United Nations Framework Convention on Climate Change* ("UN Communication"), are consistent with the findings of the IPCC. Excerpts of the UN Communication is attached as **Exhibit "J"** to this affidavit.[5]

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[4] IPCC, *Climate Change 2014 Synthesis Report Summary for Policy Makers* (2014) [*2014 IPCC Report*] and IPCC, *Special Report on Global Warming: Summary for Policymakers* (October 6, 2018) [*2018 IPCC Report*]. Both the 2014 and 2018 IPCC Reports are included in Canada's Record in the Saskatchewan climate change reference, *Attorney General of Saskatchewan v Attorney General of Canada* (Court File No. CACV3239), at Vol. 1, Tabs 1C and 1D respectively.

[5] The UN Communication is included in Canada's Record in the Saskatchewan climate change reference, *Attorney General of Saskatchewan v Attorney General of Canada* (Court File No. CACV3239), at Vol. 1, Tab 1G.

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26. Climate change is widely recognized in the public health community as the biggest global health threat of the 21st century. The *"Lancet Countdown: Tracking Progress on Health and Climate Change"* (the *"Lancet Countdown"*) is a global, interdisciplinary research collaboration between 27 academic institutions and inter-governmental organization that monitors the progress on the relationships between health and climate, and their implications for national governments. The central finding of the *Lancet Countdown* is that "the human symptoms of climate change are unequivocal and potentially irreversible – affecting the health of populations around the world today. While these effects will disproportionately impact the most vulnerable in society, every community will be affected."

27. The *Lancet Countdown 2018 Report*: *Briefing for Canadian Policy-Makers* ("*Canadian Briefing 2018*") attached at Exhibit "D" was released November 29, 2018, in parallel with the 2018 International *Lancet Countdown.* Authored by physicians and public health experts, the *Canadian Briefing 2018* was developed in conjunction with Canadian Medical Association and draws on data provided by the *Lancet Countdown* to make evidence-informed recommendations. The *Canadian Briefing 2018* focuses on the links between climate change and health and their implications for Canadian policymakers.

28. The scientific record on the impacts of climate change on public health is extensive and establish with scientific certainty that climate change will have severely negative impacts on human health in North America and around the world.[6] In Canada, public health impacts are expected to be particularly intense as warming is occurring at double

[6] *2018 IPCC Report*, Exhibit "H" to this affidavit at B5.2; *2014 IPCC Report*, Canada's Record, Exhibit "G" to this affidavit at 7.

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the global rate.[7] The Arctic, where the rate is triple the global rate, is considered by the IPCC to be one of the world's most vulnerable areas to the impacts of climate change.[8]

29. Some of these impacts are direct, immediate consequences of air pollution and higher temperatures. Others are indirect, but nonetheless causal, consequences of climate change. Some impacts are already being experienced throughout Canada, while others are not occurring now, but are highly likely to emerge in the future.

30. Direct and immediate public health impacts of climate change include:

(a) *Heat-related illnesses:* Increased morbidity and mortality from illnesses exacerbated by heat, such as heat stroke, heat edema, heat rash, heat stress, acute cardiovascular disease such as heart attacks, and renal disease;[9] and

(b) *Air pollution-related illness:* Increased morbidity and mortality from illnesses exacerbated by higher GHG concentrations and ground-level ozone, including asthma, ischemic heart disease, stroke, acute lower respiratory infections, lung cancer, and chronic obstructive pulmonary disease ("COPD").[10]

31. Indirect causally-linked public health impacts of climate change are scientifically established to include:

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[7] *UN Communication*, Exhibit "J" to this affidavit at 178.
[8] *2018 IPCC Report*, Exhibit "H" to this affidavit at B5.1.
[9] *Lancet Countdown 2018 Report*: *Briefing for Canadian Policy-Makers* [*Canada Briefing 2018*], Exhibit "D" to this affidavit at 8; *2018 IPCC Report*, Exhibit "H" to this affidavit at B5.2; *UN Communication*, Exhibit "J" to this affidavit at 187.
[10] *Canada Briefing 2018*, Exhibit "D" to this affidavit at 11; *UN Communication*, Exhibit "J" to this affidavit at 187.

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(a) *Vector-borne diseases:* Increased prevalence of mosquito- and tick-borne diseases, due to expanded geographic range of disease-bearing insects due to warmer temperatures. This includes disease such as West Nile and Lyme disease;[11]

(b) *Extreme weather events:* Increase in frequency and intensity of extreme weather events such as flooding, wildfires, heat waves, droughts and hurricanes;[12]

(c) *Water-borne illness and contamination:* Increase in water-borne illnesses and contamination due to increased precipitation and flooding;[13]

(d) *Additional respiratory diseases:* Further increase in respiratory illnesses mentioned above due to increased production of pollens and other allergens and regional incidents of wildfire smoke;

(e) *Strains on food security:* Food security risks, such as crop yield uncertainty,[14] ecological impacts on Indigenous hunting traditions,[15] and impacts on fisheries due to ocean warming and acidification[16] are expected; and

[11] *UN Communication*, Exhibit "J" to this affidavit 178.
[12] *UN Communication*, Exhibit "J" to this affidavit at 184–185; *2014 IPCC Report*, Exhibit "G" to this affidavit 1C at 8.
[13] *UN Communication*, Exhibit "J" to this affidavit at 186.
[14] *2014 IPCC Report*, Exhibit "G" to this affidavit at 6, 13.
[15] *UN Communication*, Exhibit "J" to this affidavit at 184.
[16] *2014 IPCC Report*, Exhibit "G" to this affidavit at 6.

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(f) *Coastal population displacement:* Coastal communities are expected to be affected by rising sea levels, which in turn is expected to lead to human displacement, unstable shorelines, and flooding.[17]

32. Specific public health impacts of climate change that are already underway in Canada include:

(a) *Lyme disease and West Nile virus:* Due to rising temperatures, the geographic spread of Lyme-disease-bearing ticks has led to a spike in diagnoses of Lyme disease in Canada. Similarly, the expanded range of West-Nile-bearing mosquitos has brought Canada the annual threat of West Nile disease;[18]

(b) *Wildfires:* The historic 2016 Fort McMurray wildfire displaced 94,000 people and destroyed 2,400 homes and buildings with insured losses exceeding $3.5 billion;[19]

(c) *Floods:* Flooding in 2017 in Quebec and Ontario caused thousands to evacuate their homes and required military intervention;[20]

(d) *Heat waves:* An extreme heatwave in Quebec in 2018 has been linked to climate change and caused at least 90 deaths;[21] and

(e) *Destruction of northern infrastructure and livelihoods:* With the Arctic warming at triple the global rate, the Canadian North is already experiencing

[17] *2014 IPCC Report*, Exhibit "G" to this affidavit at 13, 16.
[18] *UN Communication*, Exhibit "J" to this affidavit at 178.
[19] *UN Communication*, Exhibit "J" to this affidavit at 184.
[20] *UN Communication*, Exhibit "J" to this affidavit at 184.
[21] *Canada Briefing 2018*, Exhibit "D" to this affidavit at 8.

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unique and dramatic impacts such as destruction of property and infrastructure due to permafrost melt, melting of glacial sea ice that provides traditional hunting routes, and thawing of winter ice roads that provide connectivity to and between remote communities.[22]

(b) Public Health and Federal Role in Responding to Climate Change

33. Federal authority is essential to address the borderless impacts of climate change and is supported by the public health approach. As with other national public health issues, addressing climate change will require co-ordination between many levels of government. The federal government has a necessary leadership role to coordinate Canada's approach to this global issue, provide minimum standards and fill in gaps to reduce GHG emissions to ensure public health is protected across Canada. The IPCC concludes that co-operative, multi-level governance is required to overcome regional constraints and achieve target emissions mitigation.[23]

34. As an advocate of public health and healthy public policy, CPHA is interested in action at all levels of government to mitigate climate change. Similar to other national and global health issues, such as communicable disease prevention,[24] hazardous material standards,[25] or tobacco control initiatives,[26] reducing GHG emissions to avoid dangerous levels of climate change demands a federal role to co-ordinate and implement carbon

[22] *UN Communication*, Exhibit "J" to this affidavit at 184 -185.
[23] *2014 IPCC Report*, Exhibit "G" to this affidavit at 4.1.
[24] *Quarantine Act*, S.C. 2005, c. 20; *Human Pathogens and Toxins Act*, S.C. 2009, c. 24.
[25] *Canadian Environmental Protection Act, 1999*, S.C. 1999, c. 33.
[26] WHO Framework Convention on Tobacco Control; *Tobacco and Vaping Products Act*, S.C. 1997, c. 13; *Non-smokers' Health Act*, R.S.C. 1985, c. 15 (4th Supp.).

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pricing policy as soon and as broadly as possible, enhancing ambition gradually in a predictable manner.

35. Climate change is a multi-sectoral problem. As the Countdown Report describes, GHG emissions can be attributed to land-based transportation, households, agriculture, marine shipping, electricity generation, and a variety of other sources.[27] The public health approach does not limit action to particular sectors. The IPCC has been clear with a high degree of scientific certainty, that rapid and far-reaching action is required across sectors to avert the impacts of climate change.[28]

36. CPHA is interested in evidence-based healthy public policy, including systemic and behavioral change as a solution to public health problems. Carbon pricing is well-established as an effective and efficient regulatory mechanism to reduce GHG emissions through behavioural change, and thereby mitigate public health risks. Based on the best available evidence, the *Canadian Briefing 2018* report at Exhibit "D" recommends the application of carbon pricing instruments to address climate change and protect human health. Other authoritative health organizations such as the Canadian Medical Association have expressed support for carbon pricing in strong terms.[29]

III. CPHA WILL CONTRIBUTE TO THE PROCEEDINGS

37. CPHA will contribute its distinct public health perspective and expertise, described above, to the constitutional issues raised in this Reference.

---

[27] *Canada Briefing 2018*, Exhibit "D" to this affidavit at 11.
[28] *2014 IPCC Report*, Exhibit "G" to this affidavit at 3.3; *2018 IPCC Report*, Exhibit "H" to this affidavit at C2.
[29] See Exhibit "L" to this affidavit, Letter of Support of Dr. Owen Adams, Chief Policy Advisor, Canadian Medical Association.

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38. CPHA has experience contributing a public health perspective as an intervener in constitutional cases. CPHA sought and was granted leave to appeal by the Supreme Court of Canada in *Canada (Attorney General) v PHS Community Services Society,* 2011 SCC 44 ("*PHS*") and by the Ontario Superior Court of Justice in *Simons v Canada (Attorney General)*, 2018 ONSC 3741("*Simons*"). Both were constitutional cases regarding access to harm reduction for people addicted to intravenous drugs. In both of these interventions, CPHA assisted the Courts with its unique public health perspective on the constitutional issues raised.

39. The Court of Appeal for Saskatchewan has already granted CPHA leave to intervene in the Saskatchewan climate change reference, *Attorney General of Saskatchewan v Attorney General of Canada* (Court File No. CACV3239). A copy of the Court of Appeal for Saskatchewan's Second Order concerning interventions, dated December 10, 2018 is attached as **Exhibit "K"**.

40. CPHA believes that a focus on the public health impacts are necessary for this Honourable Court to appreciate the full extent of the national concern posed by climate change.

41. CPHA's application for intervention is supported by the CMA. A letter of support from Dr. Owen Adams, Chief Policy Advisor, Canadian Medical Association, is attached as **Exhibit "L".**

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IV. CONCLUSION

42. CPHA seeks leave to intervene in this Reference due to the critical public health implications of the issues raised by this Reference, with the intention of providing this Honourable Court with helpful and distinct submissions on the issues to be determined.

43. CPHA will abide by all Court Orders, including any limits on the materials to be used at the hearing of the merits, the length of interveners' factum and time limits for oral argument. CPHA undertakes to consult with the parties and other interveners in an effort to avoid duplication of arguments.

44. CPHA is a not-for-profit public interest association and is working with pro-bono counsel. CPHA requests that no costs be awarded for or against it in its proposed intervention.

SWORN BEFORE ME in the City of Ottawa, in the Province of Ontario, this 19th day of December, 2018.

Commissioner for Taking Affidavits
(or as may be)

IAN CULBERT

**Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.**

IN THE MATTER OF A REFERENCE to the Court of Appeal pursuant to section 8 of the *Courts of Justice Act,* RSO 1990, c. C34, by Order-in-Council 1014/2018 respecting the constitutionality of the *Greenhouse Gas Pollution Pricing Act,* Part 5 of the *Budget Implementation Act, 2018, No. 1,* SC 2018, c. 12

Court of Appeal File No.: C65807

COURT OF APPEAL FOR ONTARIO

PROCEEDING COMMENCED AT
TORONTO

AFFIDAVIT OF IAN CULBERT

GOWLING WLG (CANADA) LLP
Barristers & Solicitors
1 First Canadian Place
100 King Street West, Suite 1600
Toronto ON M5X 1G5
Tel: 416-862-7525
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Jennifer L. King (#54325R)
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Michael Finley (#65496C)
Tel: 416-369-6990
michael.finley@gowlingwlg.com
Liane Langstaff (#70947W)
Tel: 416-814-5637
liane.langstaff@gowlingwlg.com

Lawyers for the proposed Intervener, Canadian Public Health Association

This is Exhibit "A" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat, a Commissioner, etc., Province of Ontario, while a Student-at-Law. Expires May 1, 2020.

KELLY SANTINI LLP/SRL
lawyers · avocats

August 15, 2013

Canadian Public Health Association
404 – 1525 Carling Avenue
Ottawa, ON K1Z 8R9

Attention: Debra Lynkowski

Dear Ms. Lynkowski:

Re: Continuance under the new Canada Not-For-Profit Corporations Act

We are pleased to write that Industry Canada has granted a Certificate of Continuance to The Canadian Public Health Association, in accordance with the new *Canada Not-for-Profit Corporations Act*.

Please find attached your Certificate of Continuance and corresponding documents to be kept with your organization records.

At this time, we ask that you kindly provide us a final and formatted copy of your new by-laws, so that we may submit to Industry Canada. Industry Canada will not review or comment on the by-laws, but will simply keep them on record.

It was a pleasure working with your organization through this transition and we look forward to working with you again in the future.

Yours very truly,

KELLY SANTINI LLP

Michael Leaver

2013-08-08

Corporations Canada
9th floor, Jean Edmonds Towers South
365 Laurier Avenue West
Ottawa, Ontario K1A 0C8

Corporations Canada
9e étage, Tour Jean-Edmonds sud
365, avenue Laurier ouest
Ottawa (Ontario) K1A 0C8

KELLY SANTINI LLP
MICHAEL LEAVER
160 ELGIN ST
SUITE 2401
OTTAWA ON K2P 2P7
Canada

Corporation Number:
Numéro de l'organisation : **095942-1**

Request Received:
Date de réception de la demande : **2013-08-01**

Request ID:
Numéro de la demande : **6132127**

Your Reference:
Votre référence :

Please find enclosed the **Certificate of Continuance** issued under the *Canada Not-for-profit Corporations Act* (NFP Act) and related documents for **THE CANADIAN PUBLIC HEALTH ASSOCIATION**. Please ensure that these documents are kept with the corporate records.

Vous trouverez ci-joint le **certificat de prorogation** émis en vertu de la *Loi canadienne sur les organisations à but non lucratif* (Loi BNL) ainsi que les documents connexes relativement à **THE CANADIAN PUBLIC HEALTH ASSOCIATION**. Veuillez vous assurer de les conserver avec les livres de l'organisation.

The issuance of this certificate will be listed in the next Corporations Canada online Monthly Transactions report. The corporation will also be included in our online database of federal corporations. You can access both the report and the database on the Corporations Canada website.

L'émission de ce certificat sera publiée dans le prochain rapport électronique des transactions mensuelles de Corporations Canada. L'organisation sera également ajoutée dans notre base de données de sociétés de régime fédérales. Vous pouvez consulter le rapport ainsi que la base de données dans le site Web de Corporations Canada.

Please ensure that the corporation is aware of its ongoing reporting obligations by referring to the pamphlet, "Your Reporting Obligations under the *Canada Not-for-profit Corporations Act*" enclosed or available on our website.

Veuillez vous assurer que l'organisation est informée de ses obligations de déclaration. Vous pouvez consulter la brochure « Vos obligations de déclaration en vertu de la *Loi canadienne sur les organisations à but non lucratif* » incluse ou disponible dans notre site Web.

Additional information about protecting a corporate name is enclosed or available on our website.

Vous trouverez ci-joint ou dans notre site Web, des renseignements concernant la protection de la dénomination.

For further information, please visit our website or contact Corporations Canada.

Pour de plus amples renseignements, veuillez visiter notre site Web ou communiquer avec Corporations Canada.

2013-08-08

Corporation Information Sheet

Canada Not-for-profit Corporations Act (NFP Act)

Fiche de renseignements concernant l'organisation

Loi canadienne sur les organisations à but non lucratif (Loi BNL)

THE CANADIAN PUBLIC HEALTH ASSOCIATION

Corporation Number	095942-1	Numéro d'organisation
Corporation Key Required for changes online	55214563	Clé de société Requise pour mettre les renseignements à jour en ligne
Anniversary Date Required to file annual return	08-01 (mm-dd/mm-jj)	Date anniversaire Requise pour le dépôt du rapport annuel
Annual Return Filing Period Starting in 2014	08-01 to/au 09-30 (mm-dd/mm-jj)	Période pour déposer le rapport annuel Débutant en 2014

Reporting Obligations

A corporation can be dissolved if it defaults in filing a document required by the NFP Act. To understand the corporation's reporting obligations, consult the pamphlet "Your Reporting Obligations under the *Canada Not-for-profit Corporations Act*" enclosed or available on our website.

Corporate Name

Where a name has been approved, be aware that the corporation assumes full responsibility for any risk of confusion with trade names and trademarks (including those set out in the NUANS Name Search Report). The corporation may be required to change its name in the event that representations are made to Corporations Canada and it is established that confusion is likely to occur. Also note that any name granted is subject to the laws of the jurisdiction where the corporation carries on its activities. For additional information about protecting corporate names, consult our website.

Obligations de déclaration

Une organisation peut être dissoute si elle omet de déposer un document requis par la Loi BNL. Pour connaître les obligations de déclaration de l'organisation, veuillez consulter « Vos obligations de déclaration en vertu de la *Loi canadienne sur les organisations à but non lucratif* » ci-joint ou disponible dans notre site Web.

Dénomination

Dans les cas où Corporations Canada a approuvé une dénomination, il faut savoir que l'organisation assume toute responsabilité de risque de confusion avec toutes dénominations commerciales, marques de commerce existantes (y compris celles qui sont citées dans le Rapport NUANS de recherche de dénominations). L'organisation devra peut-être changer sa dénomination advenant le cas où des représentations soient faites auprès de Corporations Canada établissant qu'il existe une probabilité de confusion. Il faut aussi noter que toute dénomination octroyée est assujettie aux lois de la province ou du territoire où l' organisation mène ses activités. Pour obtenir des renseignements supplémentaires concernant la protection d'une dénomination, consulter notre site Web.

Industry Canada Industrie Canada

Certificate of Continuance

Canada Not-for-profit Corporations Act

Certificat de prorogation

Loi canadienne sur les organisations à but non lucratif

THE CANADIAN PUBLIC HEALTH ASSOCIATION

Corporate name / Dénomination de l'organisation

095942-1

Corporation number / Numéro de l'organisation

I HEREBY CERTIFY that the above-named corporation, the articles of continuance of which are attached, is continued under section 211 of the *Canada Not-for-profit Corporations Act*.

JE CERTIFIE que l'organisation susmentionnée, dont les statuts de prorogation sont joints, a été prorogée en vertu de l'article 211 de la *Loi canadienne sur les organisations à but non lucratif*.

Marcie Girouard

Director / Directeur

2013-08-01

Date of Continuance (YYYY-MM-DD)
Date de prorogation (AAAA-MM-JJ)

Canada

Industry Canada Industrie Canada

Canada Not-for-profit Corporations Act **(NFP Act)**
Form 4011
Articles of Continuance (import)
Not to be used for a continuance from the *Canada Corporations Act* (CCA).

1 - Corporate name on continuance

THE CANADIAN PUBLIC HEALTH ASSOCIATION

2 - The province or territory in Canada where the registered office is situated

Ontario

3 - Minimum and maximum number of directors *(for a fixed number, indicate the same number in both boxes)*

Minimum number 8 **Maximum number** 10

4 - Statement of the purpose of the corporation

The purpose of the Corporation shall be the development and diffusion throughout Canada of the knowledge of public health and preventive medicine and all other matters and things appertaining thereto or connected therewith.

5 - Restrictions on the activities that the corporation may carry on, if any

None.

6 - The classes, or regional or other groups, of members that the corporation is authorized to establish

The Corporation is authorized to establish Active Members, Honorary Members, Student Members, Retired Members and International Members.

Each Active Member, Honorary Member, Student Member, Retired Member and International Member shall be entitled to receive notice of and to attend all meetings of the members of the Corporation and each Active Member, Honorary Member, Student Member, Retired Member and International Member shall have one (1) vote at each such meeting, except for meetings at which only members of another class are entitled to vote separately as a class.

Canada

Industry Canada Industrie Canada

Canada Not-for-profit Corporations Act (NFP Act)
Form 4011
Articles of Continuance (import)

7 - Statement regarding the distribution of property remaining on liquidation

Any property remaining on liquidation of the Corporation, after discharge of liabilities, shall be distributed to one or more qualified donees within the meaning of subsection 248(1) of the Income Tax Act.

8 - Additional provisions, if any

None.

9 - Previous name *(if there is a change of name on continuance)*

10 - Details of incorporation *(see instructions)*

Special Act of Parliament - 1912-04-01

11 - Declaration

I hereby certify that I am a director or an authorized officer of the incorporated body continuing into the NFP Act.

Signature:

Print name: Ian Culbert, Executive Director *Phone Number:* 613-725-3769 Ext 142

Note: A person who makes, or assists in making, a false or misleading statement is guilty of an offence and liable on summary conviction to a fine of not more than $5,000 or to imprisonment for a term of not more than six months or to both (subsection 262(2) of the NFP Act).

Canada

Industry Canada Industrie Canada

Canada Not-for-profit Corporations Act (NFP Act)

FORM 4002

INITIAL REGISTERED OFFICE ADDRESS AND FIRST BOARD OF DIRECTORS

(To be filed with articles of incorporation, continuance (transition), amalgamation, or continuance (import))

1 - Corporate name

THE CANADIAN PUBLIC HEALTH ASSOCIATION

2 - Complete address of the registered office *(cannot be a post office box)*

Number and street name

404-1525 Carling Avenue

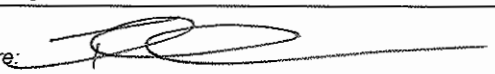
City	Province or Territory	Postal code
Ottawa	ONTARIO	K1Z 8R9

3 - Directors of the corporation *(if space available is insufficient, complete attached schedule)*

First and last name	Address *(cannot be a post office box)*
Lynn McIntyre	20 Arbour Estates Landing NW Calgary, AB T3G 3Z9
Ardene Robinson Vollman	19 Evergreen Rise SW Calgary AB T2Y 3H6
Alycia Fridkin	205-1763 Nelson Street Vancouver, BC V6G 1M6
Paul Gully	503-1625 Manitoba Street Vancouver, BC V5Y 0B8
Joel Kettner	20 Ruskin Row Winnipeg, MB R3M 2R7

4 - Declaration

I hereby certify that I am an incorporator of the new corporation, or that I am a director or an authorized officer of the corporation continuing into or amalgamating under the NFP Act.

Signature: 

01 AUG '13 11:13

Print name: Ian Culbert, Executive Director *Phone Number:* 613-725-3769, ext. 142

Note: A person who makes, or assists in making, a false or misleading statement is guilty of an offence and liable on summary conviction to a fine of not more than $5,000 or to imprisonment for a term of not more than six months or to both (subsection 262(2) of the NFP Act).

Canada

Industry Canada Industrie Canada

Schedule
(Item 3 of Form 4002)
Directors of the corporation
To be used if space on form is insufficient

1 - Corporate Name

CANADIAN PUBLIC HEALTH ASSOCIATION

3 - Directors of the corporation

First and last name	Address *(cannot be a post office box)*
Katie Lafferty	301-600 Peter Morand Crescent Ottawa, ON K1G 5Z3
Madonna MacDonald	25 Bay Street Antigonish, NS B2G 2G5
Mary Martin-Smith	19 Marquis Crescent Regina, SK S4S 6J8
Isaac Sobol	406-1138 Melville Street Vancouver, BC V6E 4S3
Ian Culbert	1590 County Road 18 Oxford Mills, ON K0G 1S0

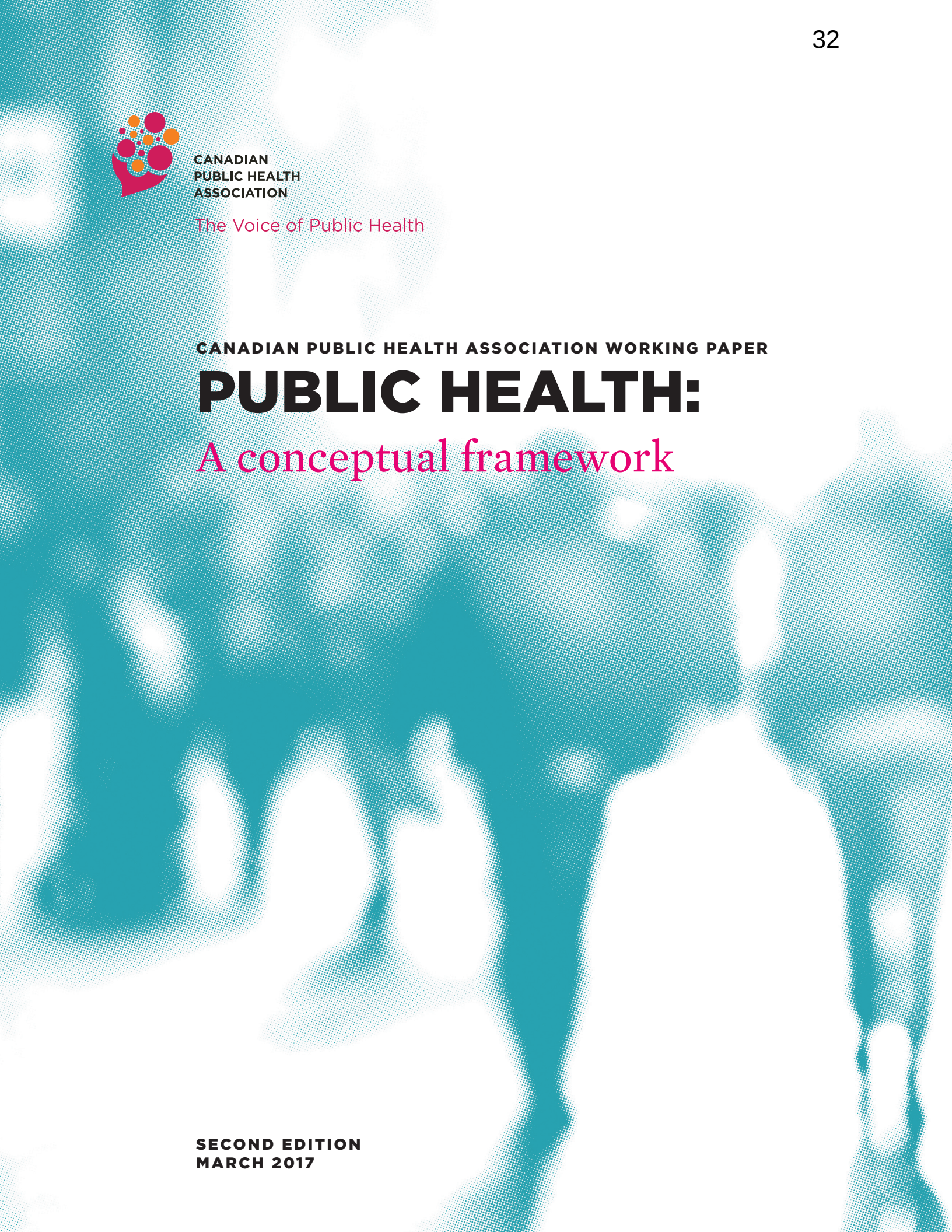
M 1 AUG '13 9:26

Canada

This is Exhibit "B" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

**Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.**



CANADIAN
PUBLIC HEALTH
ASSOCIATION

The Voice of Public Health

CANADIAN PUBLIC HEALTH ASSOCIATION WORKING PAPER

PUBLIC HEALTH:

A conceptual framework

SECOND EDITION
MARCH 2017

THE VOICE OF PUBLIC HEALTH

The Canadian Public Health Association is the independent national voice and trusted advocate for public health, speaking up for people and populations to all levels of government.

We champion health equity, social justice and evidence-informed decision-making. We leverage knowledge, identify and address emerging public health issues, and connect diverse communities of practice. We promote the public health perspective and evidence to government leaders and policy-makers. We are a catalyst for change that improves health and well-being for all.

We support the passion, knowledge and perspectives of our diverse membership through collaboration, wide-ranging discussions and information sharing.

We inspire organizations and governments to implement a range of public health policies and programs that improve health outcomes for populations in need.

OUR VISION
A healthy and just world

OUR MISSION
To enhance the health of people in Canada and to contribute to a healthier and more equitable world.

For more information, contact:
Canadian Public Health Association
404-1525 Carling Avenue, Ottawa, ON K1Z 8R9
T: 613-725-3769 | F: 613-725-9826 | info@cpha.ca

www.cpha.ca

PREFACE

Health professionals often refer to looking at an issue from a "public health perspective" or "through a public health lens" and yet this concept has not been clearly defined. The following is a first effort at defining such a perspective, lens or approach. It is presented for consideration, and feedback is welcomed. All comments will be considered and may be incorporated into future iterations of what we hope will be an 'evergreen' document. Comments should be directed by e-mail to: policy@cpha.ca.

The development of this working paper began with our attempts to define a "public health approach" during the development of the Association's discussion paper *A New Approach to Managing Illegal Psychoactive Substances in Canada*. CPHA's Board of Directors subsequently directed that a more substantive effort be undertaken to provide a summary document that would describe the principles and practices that underlie public health activities. As a result, practicum students working at CPHA developed an initial manuscript followed by an extensive internal review process. It was then reviewed by public health professionals who voluntarily support CPHA activities. The result of those efforts was ultimately reviewed, edited and approved as an evergreen document by our Board. The Board of Directors and staff of CPHA thank all those who participated in developing *Public Health: A Conceptual Framework*.

PURPOSE

This working paper is meant to provide a **quick reference guide** to and portrait of the underlying principles that support current public health practice; **it is not intended to be the definitive treatise** on this topic. It defines the perspective that CPHA will use to develop its policy options.

PUBLIC HEALTH: A HISTORY OF CHANGE

The practice of public health can perhaps find its roots with the development of aqueducts during the Roman/Byzantine era for the transportation of clean water into populated areas, and the management of human waste. Its true beginnings, based on a causal relationship to the prevention of infectious disease, might be better traced back to actions that were taken in Europe during the fourteenth century to limit the spread of plague. One of the first documented actions was in Venice around 1348, with the appointment of three guardians of public health to detect and exclude ships with passengers infected with that disease. Similarly, the first quarantine actions seemed to be taken in Marseille (1377) and Venice (1403), where travellers from plague-infected countries were

detained for 40 days to protect against transmission of the infection. The first surveillance systems can be dated to the "bill of mortality" established in London, England in 1532 and subsequently John Graunt's publication of his "Natural and Political Observations" (1662) that was based on findings from the Bills of Mortality. John Snow, the father of epidemiology, published "On the Mode of Communication of Cholera" in 1849. The first consideration of the importance of the social determinants of health and the inclusion of social justice as a pillar of public health was described in 1790 when Dr. Johan Peter Frank argued "... curative and preventive measures had little impact on populations where people lived in abject poverty and squalor."[1]

In the Canadian context, the first Board of Health was established in Lower Canada in 1832, with Upper Canada following suit in 1833. As these boards developed, they provided the infrastructure necessary for inspection and regulation that addressed issues as varied as pasteurization of milk, management of tuberculosis in humans, quarantine activities for various illnesses, and the control of sexually transmitted diseases. The early 20th century brought an increasing emphasis on maternal and child health and the immunization of children and youth.[2] In a parallel fashion, during the 18th and 19th centuries, public health practitioners investigated and advocated against nutritional (scurvy), occupational (mesothelioma - cancer of the scrotum) and environmental (lead poisoning) disease, and urged measures to overcome inequities of health.[1]

Through the 20th century, an expansion of focus from a principally communicable disease perspective to one combining communicable and non-communicable illnesses broadened public health practice. Similarly, there is an ongoing movement from an agentic* approach based on behaviour modification, to a population-based approach that focuses more on adjustment of societal structures, with an emphasis on support for populations at risk. The goal of these changes and this expansion has always been to foster the health of people and to develop a strong, resilient and just society. In striving for this goal, our actions have not always been correct, or may at times have been clouded by the beliefs of the day. These efforts continue, yet there are basic principles that have underlain public health practice since the beginning.

* The term *agentic* denotes self-directed actions aimed at personal development or personally chosen goals (The Free Dictionary by Farlex. Available at: www.medical-dictionary.thefreedictionary.com). This concept is based on a social cognition theory perspective in which people are producers as well as products of social systems (definition from: www.wordnik.com/words/agentic).

DEFINING PUBLIC HEALTH PRACTICE

Public health practice can be viewed as an approach to maintaining and improving the health of populations that is based on the principles of social justice, attention to human rights and equity, evidence-informed policy and practice, and addressing the underlying determinants of health. Such an approach places health promotion, health protection, population health surveillance, and the prevention of death, disease, injury and disability as the central tenets of all related initiatives. It also means basing those initiatives on evidence of what works or shows promise of working. It is an organized, comprehensive, and multi-sectoral effort.[3-5]

This definition and the practice of public health have developed over time, and will continue to develop to meet the evolving health requirements of the population. As these demands grow, there will be debates concerning the role and purpose of public health practice and the scope of practitioners' activities. Underlying these debates and developments, however, are an amalgam of concepts and practices that are the foundation and building blocks of public health.

FOUNDATION OF PUBLIC HEALTH

The foundation of, and lenses through which to view, all public health activities are the concepts of social justice[6] and health equity,[7] which relate to the social determinants of health. These lenses continually influence and inform each building block. All public health practice is built on the interconnectivity of five main building blocks (evidence base, risk assessment, policy, program and evaluation) that have been widely described in the literature, continue to evolve, and are the subject of the next section of this paper. Each component has many sub-components, and all the parts must function in a complex adaptive system[*] (see Figure 1) to meet the goals of public health.

Social Justice

The goal of social justice is to develop the ability of people to realize their potential in the society in which they live. Classically, "justice" refers to ensuring that individuals both fulfil their societal roles and receive their due from society,[8] while "social justice" generally refers to a set of institutions that enable people to lead fulfilling lives and be active contributors to their community. These institutions, among others, include education, health care, and social security.[9]

In Canada, social justice finds its root in Section 7 of the *Canadian Charter of Rights and Freedoms*, which provides for "...the right to life, liberty and security of the person and the right not to be deprived thereof except in accordance with the principles of fundamental justice."[10] This clause was used as the legal argument for the Supreme Court decision concerning *Insite*, the supervised consumption facility in Vancouver,[11] and for the decision that struck down three federal prostitution laws.[12] The *Canadian Charter of Rights and Freedoms* is further supported by various United Nations Conventions[†] that provide the social foundation on which to build a public health approach. In this context, social justice ensures that the population as a whole has equitable access to all public health initiatives implemented to minimize preventable death and disability.[3]

Health Equity

Health equity is defined as "... the absence of avoidable or remediable differences in health among groups of people, whether those groups are defined socially, economically, demographically, or geographically."[13] It is based on the principle of social justice and refers to the absence of disparities in controllable or remediable aspects of health. Underpinning this notion is the concept of the *social gradient* that notes

> *"...the poorest of the poor throughout the world have the worst health. Within countries, the evidence shows that in general the lower an individual's socioeconomic position the worse their health. There is a social gradient in health that runs from top to bottom of the socioeconomic spectrum".*[14]

In general, those who are healthier are at the top of the socioeconomic spectrum. The concept applies to every country. This notion is further shaped when the influences of *structural violence* and *intersectionality* are integrated into this consideration.[‡]

---

* Complex adaptive systems are systems composed of many interacting parts that evolve and adapt over time. Organized behaviour emerges from the simultaneous interaction of parts without a global plan (www.cognitern.psych.indiana.edu/rgoldsto/complex/intro.pdf). This approach has been applied to many complex issues, including economic, scientific and organizational design thinking.

† These include: the *International Convention on Civil and Political Rights*, the *International Convention on Economic, Social and Cultural Rights*, the *Convention Against Torture and Other Cruel, Inhuman and Degrading Treatment or Punishment*, the *Declaration of the Rights of Indigenous Peoples*, and the *International Convention on the Protection and Promotion of the Rights and Dignity of Persons with Disabilities*.

‡ *Structural violence* refers to the physical and psychological harms that can be caused by society's social, political and economic systems. As such, it is avoidable and preventable. The theory is described in Ho K. Structural violence as a human rights violation. *Essex Human Rights Review* 2007;4(2):1-17. *Intersectionality* refers to "... a tool for analysis, advocacy and policy that addresses multiple discriminations and helps us understand how different sets of identities affect access to rights and opportunities." Association for Women's Rights in Development. Intersectionality: A tool for gender and economic justice. *Women's Rights and Economic Change*. 2004;9(August):1-8.

One challenge is that the concepts of "equity" and "equality" are sometimes used interchangeably. They are related; however, there are important distinctions where:

> *Equity … involves trying to understand and give people what they need to enjoy full, healthy lives. Equality, in contrast, aims to ensure that everyone gets the same things in order to enjoy full, healthy lives. Like equity, equality aims to promote fairness and justice but it can only work if everyone starts from the same place.*[15]

As such, consideration must be given to the **equitable** distribution of health services and the creation of culturally competent programming and policy to meet the requirements of the population that is at risk. Attention to that population is required such that the proposed change is supported through group empowerment and ownership.

Social Determinants of Health

The social determinants of health are defined as "the conditions in which people are born, grow, live, work and age".[16] They are shaped by the distribution of money, power and resources, which causes health inequities within populations. Although the list of social determinants of health may vary depending on the source of the information, there are some that are common to all sources and are generally viewed as having the greatest effect on population health. These include income, education, gender, physical environment, social environment, access to health services, and healthy childhood development. The intermingling of these factors creates the health situation specific to an individual or population.

Ecological Determinants of Health

There are many ecological processes and natural resources essential for health and well-being and that constitute Earth's life-support systems. These ecological determinants of health include adequate amounts of oxygen, water, and food. Other important ecological processes and natural resources include the ozone layer, nitrogen and phosphorus cycles, systems to detoxify wastes, and abundant fertile soil, fresh water and marine aquatic systems to grow food and other plants. For humans, three further requirements include materials to construct our shelters and tools, energy, and a stable global climate with temperatures conducive to human and other life forms.

THE BUILDING BLOCKS OF PUBLIC HEALTH

Public health, at its root, is the amalgamation of those activities that are taken to improve population-based health issues within the general domains of communicable and non-communicable disease. There is an internal tension between the domains; however, there are several activities (see Figure 1) that form the building blocks of all public health practice.

Evidence Base

Public health relies on the robustness, accuracy and validity of its evidence base. That base is composed of scientific research, population characteristics, needs, values and preferences, and professional expertise.[17] Research, surveillance and epidemiology, and community consultation are the vehicles through which that evidence is provided (see Figure 2). There is a strong connection between each component, such that research can be used to focus and strengthen surveillance activities. Surveillance can be conducted to inform research, while both surveillance and research can support or be directed by community consultation.

Research

Research is defined as those processes and activities that contribute to generalizable knowledge.[18] In this case, these activities inform public health practice

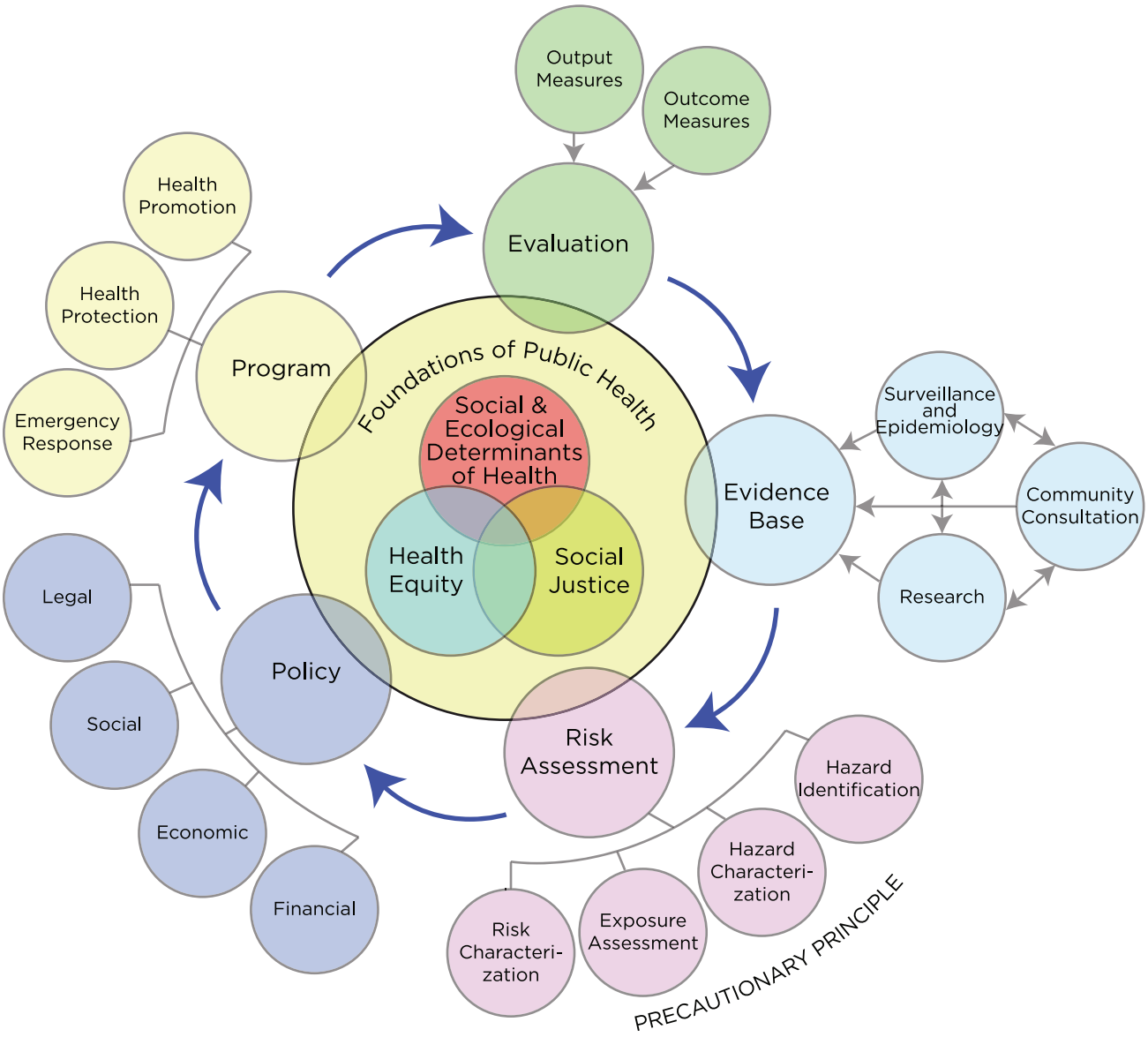


Figure 1: A conceptual framework for public health

and policy, and are targeted to develop, implement, and evaluate improved and more efficient ways of protecting and promoting health and preventing disease.[19] It can be divided into:

- *Quantitative research:* The use of data that can be counted or converted into numerical form.[20] It is primarily used to find statistical associations between variables, or when attempting to find variances in patterns of health between two populations, with an aim to minimize human bias.
- *Qualitative research:* The use of non-numerical observations to interpret phenomena.[20] It is used to gather insight as to how particular situations are interpreted by the study population. These results may come from clinical case studies,

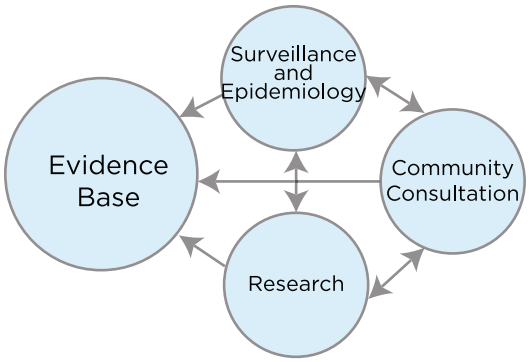


Figure 2: Interrelationship of the components of the evidence base

narratives of behaviour, ethnographies, and organizational or social studies, and can be used to develop theoretical pieces that are based on observable reality. Methods that may be used to gather this data include surveys, interviews, or focus groups to connect with the study population.

Both approaches can be combined to perform mixed methods or pragmatic research studies when seeking answers to complex research questions,[21] but there has to be a clear and strategic relationship between the methods used such that the data provides greater insight than can be obtained by using a single approach. Examples of mixed methods research are studies that link the social determinants of health with epidemiological data.

Surveillance and Epidemiology

Public health surveillance is defined as "the continuous, systematic collection, analysis, and interpretation of health-related data needed for planning, implementing, and evaluating public health practice." It can:

- serve as an early warning system for impending public health emergencies;
- document the impact of interventions, or track progress to specified goals; and
- monitor and clarify the epidemiology of health problems to allow priorities to be set and inform public health policies and strategies."[22]

Long-term or passive surveillance involves the monitoring of general health trends and health determinants[20] and provides information on, for example, current obesity or cancer trends in the population. Short-term, active or ongoing surveillance involves searching for emergent diseases or outbreaks, such as the surveillance conducted during the SARS or H1N1 outbreaks. Both types of surveillance target a specific health state, disease, or agent.

The distinction between surveillance and epidemiology should be noted. Epidemiology is defined as:

> *...the study of the distribution and determinants of health-related states or events (including diseases), and the application of this study to the control of diseases and other health problems. Various methods can be used to carry out epidemiological investigations: surveillance and descriptive studies can be used to study distribution; analytical studies are used to study determinants.*[23]

A fundamental concept for the application of epidemiological findings to preventive medicine is the distinction that separates the notion of a *high risk strategy*,* which is based on conventional medical approaches for resolving a health issue, from that of a *population strategy* that defines the public health approach for addressing preventive medicine.[24] Both concepts are developed from the *Rose Hypothesis*.†

* A *High Risk Strategy* focuses its efforts on individuals with the highest level of a risk factor and uses the established framework of medical practice to reduce that risk, while a *Population Strategy* predicts that shifting the population distribution of a risk factor prevents more burden of disease than targeting the people at high risk by providing a lower likelihood of an illness to the entire population.[22]

† The *Rose Hypothesis* notes that disease is a rare occurrence and that most people who adopt behaviour to lower a risk of disease will not benefit directly, but a few may benefit enormously. The challenge is that often a population-based approach must be applied so that those few who are at risk receive the benefits of preventive actions, or the necessary treatment. (Health Knowledge. Epidemiological basis for preventive strategies.

Research and surveillance/epidemiology may require the use of patient information, and could be subject to patient confidentiality requirements or review by organizational research ethics committees.

Community Consultation

Community consultation is a well-known methodology that can be viewed as a best practice for informed decision-making on complex issues within communities.[25] It is based on the following principles:

- Recognize the community as a unit of identity, with a shared sense of identification and emotional connection that influences common values, norms, and needs;
- Build on the strength and resources within a community to address local health concerns. Community consultation methodologies recognize and seek to expand social structures and processes that contribute to the ability of community members to work together to improve health; and
- Integrate knowledge and action for the mutual benefit of partners and stakeholders, as well as the reciprocal transfer of knowledge, skills, capacity and power.

This process enables community members to be active contributors, through collaboration and involvement, in an initiative that seeks to establish positive social change within the community.[26] The topic chosen must be of practical relevance to the community, and community members should be actively involved in the project's design, implementation, and dissemination. The design may involve aspects of quantitative and qualitative data collection methods, as well as information gathered through surveillance activities. At the completion of this process, results are transferable to community members to support positive social change. An example of where this process would prove, and has proven, useful is the development and implementation of a supervised consumption facility for illegal psychoactive substances.

Risk Assessment

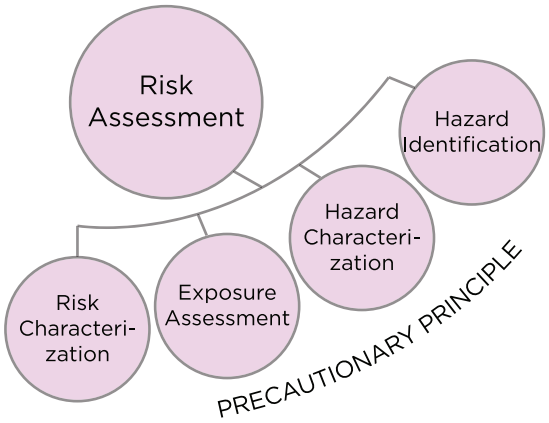


Figure 3: Components of risk assessment

The evidence base in public health is constantly expanding as new information is uncovered through research, surveillance, and community consultation. Issues recurring within that base become priorities for public health attention. Prior to taking action on a specific issue, a risk assessment is necessary to estimate the nature and likelihood of negative health outcomes in individuals.[27] It can be applied to conventional public health issues as well as occupational, environmental, social and behavioural risks. A four-step process (see Figure 3) is used, and includes:

- *Hazard identification:* Identification of specific health effects or hazards. Information from surveillance and epidemiology activities can be used to identify them.
- *Hazard characterization:* Evaluation of the nature of the effects associated with a particular hazard. Qualitative and quantitative research may be

Available at: http://www.healthknowledge.org.uk/public-health-textbook/research-methods/1c-health-care-evaluation-health-care-assessment/epidemiological-basis-pstrategies.)

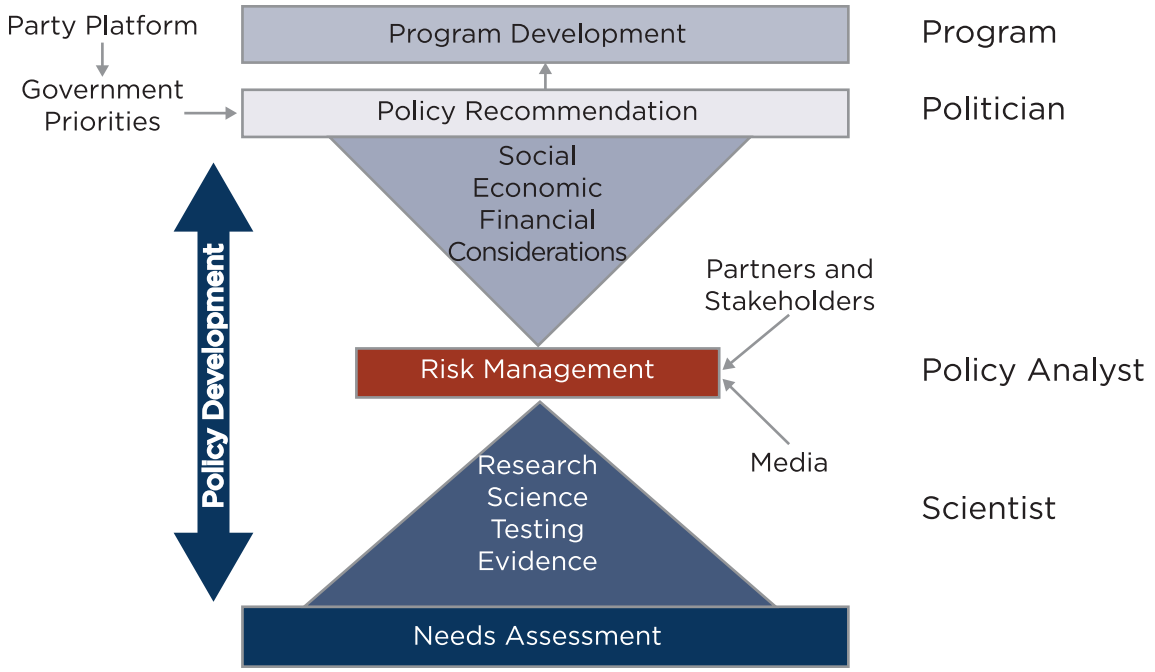


Figure 4: Simplified model of a public health policy development process

used to characterize biological, physical, and chemical hazards.

- *Exposure assessment:* Evaluation of the possible effect of the hazard.
- *Risk characterization:* Integration of hazard identification, hazard characterization, and exposure assessment into a holistic estimate of adverse effect at the population level.

Following completion of the risk assessment, response options are identified and a risk management plan developed. Managers with the appropriate level of authority must decide on actions and take steps to implement them. The desired action could be undertaken directly when immediate action is required, for example during a response to an infectious disease outbreak, or through policy and program development processes.

Underlying this decision process is the *Precautionary Principle*, an approach to managing risk that has been developed to address circumstances of scientific uncertainty. It reflects the need to take prudent action without having to wait for completion of scientific research. This principle was applied by Krever during the inquiry into the Canadian tainted blood scandal,[28] and was enshrined in the 1992 *Declaration of the Rio Conference on Environment and Development*.

Policy

Policy is defined as the principles or protocols adopted or proposed by a government, party, business or individual that provide a definitive course or method of action, and guide or determine present or future decisions. Policies are generally not time limited, and provide the supportive environment, framework and anticipated outcomes to focus program activities and enable future decision-making. Policies are usually developed through a flexible, iterative process that

encompasses issue identification, policy instrument development, consultation, coordination, decision-making, implementation and evaluation. Partner and stakeholder collaboration is required. Within the Canadian context, federal policy development can find its starting point either in the political platform of the ruling party, or through a process that originates within the bureaucracy.

Within the public health domain, an ongoing challenge is to balance the role of science in policy-making, as the evidence base and risk assessment should inform and support policy development, while the policy decision could modify scientific activities. Complicating the process is the inclusion of economic, financial and social policy, and legal and jurisdictional considerations within the decision-making process.

It is essential to engage in the process those partners and stakeholders affected by a decision. The goal is to support development of a final approach that will be acceptable to the affected groups. Those engaged in the consultation must be at a level and have the authority necessary to speak for the organization. The role of a non-governmental organization such as CPHA is to participate in the policy development process through advocacy at the political and bureaucratic levels with the expressed positions reflecting the interests of Association members and based on the best available evidence.

A simplified model of these relationships is presented in Figure 4.

Intervention

As policy development provides the framework and anticipated outcomes for public health activities, programs or interventions are the specific actions that respond to the policy direction. They address health protection, health promotion and emergency response activities. The goal of any intervention is to limit the onset and progression of disease, injury or infection,[20]

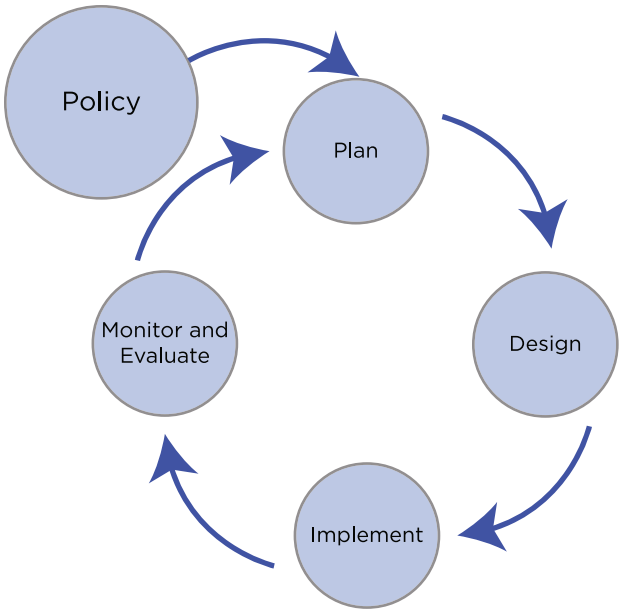


Figure 5: A generalized intervention development process

and may be implemented through collaboration with all levels of government, other government departments, non-governmental organizations, not-for-profit organizations, and private sector partners, as appropriate. In addition, all interventions must be evaluated to measure success in terms of the expected outputs (the desired product of the intervention), as well as the desired outcomes (improvement in the health of the population). Effective intervention development requires that those affected by the health issue addressed by the intervention be included in its development and implementation to improve its likelihood of success. A generalized program development process is presented in Figure 5.

Intervention activities generally address three broad categories of work and are listed below.

Health Protection

Health protection activities address the negative influences on health, and include interventions

as diverse as testing of food and water supplies, environmental testing, and surveillance to identify and track infectious disease outbreaks.[20] These activities rely on surveillance information to direct intervention activities, for example annual influenza vaccination programs, and can provide evidence for epidemiological investigations (food and water testing).

Health Promotion

Health promotion is the mix of activities that assist individuals and communities in taking charge of their personal health. It assists in developing healthy public policy, healthy environments, and personal resiliency, and "... involves any combination of health education and related organizational, economic, and political interventions designed to facilitate behavioural and environmental changes conducive to health."[20] This concept was first described as an entity in the *Ottawa Charter for Health Promotion*.[29]

Emergency Preparedness

Emergency preparedness interventions are those activities that provide the capacity to respond to acute harmful events that range from natural disasters to infectious disease outbreaks and chemical spills. They are founded on four building blocks:

- *Prevention:* those activities that reduce the likelihood of an event occurring
- *Preparedness:* planning, training and organizing to respond to harmful events and situations
- *Response:* the capacity to respond to acute, harmful events
- *Recovery:* the processes required to return to a "normal" state of existence

Evaluation

Each policy and program must be evaluated to determine whether it meets its agreed-to deliverables (output measures) and its desired effect in mediating the issue it was established to address (outcome measures). These can be described as implementation or process, and effectiveness or outcome evaluations.[30] Implementation evaluations assess whether a program is reaching its intended potential, and occur while the program is active. Qualitative and quantitative data are used to make informed judgements. Outcome evaluations measure progress in addressing the program's targeted public health challenge, and may include short-, intermediate-, and long-term results, that are also based on quantitative and qualitative data. The information gathered through evaluation can allow for further development of the program within the affected area of public health.

SUMMARY

Public health is a complex adaptive system which has evolved from providing clean water and managing human waste, to managing a broader cadre of communicable and non-communicable diseases, and continues to change as we address the influence of social determinants and the environment on health. Contributing to this challenge is the notion that the populations we serve are continually evolving, as are the related public health issues. Each public health practitioner must continually adjust his or her practise, but each adjustment must be based on the building blocks of evidence, risk assessment, policy, intervention and evaluation, which are supported by a foundation of health equity, social justice, and the social determinants of health. As such, this document should be considered a first attempt to define the basics of public health, and will continue to develop as the practice evolves.

REFERENCES

1. National Advisory Committee on SARS. Learning from SARS – Renewal of Public Health in Canada. Chapter 3A. What is Public Health? Ottawa, ON: Public Health Agency of Canada, 2003;43-68.
2. Canadian Public Health Association. This is Public Health: A Canadian History. CPHA, Ottawa: 2010.
3. Last J. *A Dictionary of Public Health.* Oxford University Press, 2007.
4. Frank J, Di Ruggiero E, Moloughney B. Proceedings of the "Think Tank on the future of public health in Canada" Calgary May 10, 2003. *Can J Public Health* 2003;95(1):6-11.
5. Canadian Public Health Association. Enhancing the Public Health Human Resource Infrastructure in Canada. Ottawa: CPHA, 2010.
6. Canadian Charter of Rights and Freedoms, s 7, Part I of the Constitution Act, c 11. Ottawa: Government of Canada, 1982.
7. Commission on Social Determinants of Health. Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health. Geneva, Switzerland: World Health Organization, 2008.
8. Rawls J. *A Theory of Justice.* Harvard University Press, 1971.
9. Swift A. *Political Philosophy,* 3rd ed. Cambridge, UK: Cambridge University Press, 2013.
10. Canadian Charter of Rights and Freedoms, s 2, Part I of the Constitution Act, c 11. Ottawa: Government of Canada, 1982.
11. Canada (Attorney General) v. PHS Community Services Society. Supreme Court Judgements 2011 SCC44 (2011) 3 SCR 134, September 30, 2011.
12. Canada (attorney General) v. Bedford. Supreme Court Judgements 2013 SCC72, 3SCR1101, December 20, 2013.
13. World Health Organization. Health systems: Equity. Geneva, Switzerland: WHO, 2014.
14. World Health Organization. Social Determinants of Health. Key Concepts. Geneva, Switzerland: WHO, 2008.
15. Atlantic Centre of Excellence for Women's Health, British Columbia Centre of Excellence for Women's Health, and Prairie Women's Health Centre of Excellence. SGBA e-Learning Centre: Rising to the Challenge.
16. World Health Organization. What are social determinants of health? Geneva, Switzerland: WHO, 2013
17. Brownson RC, Fielding JE, Maylahn CM. Evidence-based public health: A fundamental concept for public health practice. *Annu Rev Public Health* 2009;30:17-201.
18. Center for Disease Control and Prevention. Distinguishing public health research and public health non-research. Washington, DC: Department of Human and Health Services, 1999.
19. IJsselmuiden C, Matlin S 2006. Why health research? Geneva: Council on Health Research for Development and the Global Forum for Health Research, 2007.
20. The Association of Faculties of Medicine in Canada. AFMC primer on population health. Ottawa: AFMC, 2017.
21. Lingard L, Albert M, Levinson W. Grounded theory, mixed methods, and action research. The BMJ 2008:337.
22. World Health Organization, 2014. Public health surveillance. Geneva, Switzerland. 2014.
23. World Health Organization, 2014. Epidemiology. Geneva, Switzerland: WHO, 2014.
24. Rose G. *The Strategy of Preventive Medicine.* Oxford: Oxford University Press. 1992.
25. Israel BA, Schulz AJ, and Parker EA. A review of community-based research: Assessing partnership approaches to improve public health. *Ann Rev Public Health* 1998;19:173-202.
26. Centre for Community Based Research. What is community based research? Waterloo, ON: Centre for Community Based Research, 2017.
27. United States Environmental Protection Agency. Human health risk assessment. Washington: EPA, 2012.
28. Picard A. The Krever Inquiry. Toronto, ON: Historica Canada, 2014.
29. World Health Organization. The Ottawa Charter for Health Promotion. First International Conference on Health Promotion, Ottawa, 17-21 November 1986. Geneva: WHO, 1986.
30. Centers for Disease Control and Prevention. Introduction to program evaluation for public health programs: A self-study guide. Atlanta, GA: CDC, 2012.

CANADIAN
PUBLIC HEALTH
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This is Exhibit "C" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of Ontario, while a Student-at-Law.
Expires May 1, 2020.

CANADIAN PUBLIC HEALTH ASSOCIATION
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Selection of CPHA Activities Related to the Ecological Determinants of Health

The Canadian Public Health Association (CPHA) has been involved for many years in environmental health programs and activities and has worked in partnership with federal/provincial/territorial governments and the private sector to respond to the concerns of environmental health concerns throughout Canada.

In 1988, the Association conducted a national membership survey to determine what the priorities for CPHA should be over the next five years and environmental health was identified by the Association's membership as the number one issue and has remained in the top three positions since then. The following briefly outlines the Association's historical participation and involvement through an advocacy role (resolutions and position papers), the management of national health research programs and activities, the conducting of workshops and conferences and representation on external committees.

CPHA Action and Policies

The Association undertakes its advocacy role in a number of ways. One of the key processes is the development by the membership of resolutions/position papers, discussion documents and position statement. Following is brief list of policies approved by the Association that deal either directly with environmental health issues or are indirectly linked to environmental health concerns:

1936 Examination of Water, Sewage, Milk and Dairy Products (Standards)
1939 Housing
1942 Housing
1944 Housing
Disposal of Waste Products
1952 Sewage Treatment and Disposal
1953 Pollution (Water)
1959 Radiation
1969 National Environmental Health Training Centre
1970 Pesticides
Pollution (General)
Housing
1972 Environmental Health (Position Statement)
1973 Environmental Health (Position Statement)
1976 Environmental Health (Position Statement)
1977 Test Protocols and Standards for Water Treatment Devices
Environmental Health Hazards
1978 Nuclear Fuel Wastes
1981 Acid Rain Pollution
Transportation of Dangerous Goods
Use of 2,4D for Aquatic Weed Control
Promotion of National Sanitation Foundation

1982 Nuclear Power
Hazardous Waste
Nuclear Weapons
Testing of U.S. Cruise Missiles in Canada
1984 Monitoring Disposal of Antineoplastic Drugs
Nuclear Disarmament
Quality of Public Drinking Water
1985 Federal Wildlife and Toxicology Programs
1986 Removal of Lead from Gasoline
Cost of Low Lead Fuels
1988 CFC and Halon Production Cuts Beyond the Requirements of the Montreal Protocol
Extension of Ban on Aerosol Sprays using CFCs
Labelling of Products Containing CFCs
Control of Freon Emissions from Cooling Systems
Use of CFC Products by CPHA Members
Risk to Farm Families
1989 Transportation of Hydro Carbons through the Beaufort Sea
1990 Public Inquiry into Uranium and other Mining
1990 Implications for Human Health of Global Ecological Changes
1991 Human Health Effects Associated with the Pulp and Paper Industry
1992 Pollution of the Mackenzie River
Support for Newfoundland Northern Cod Fishers and Fishplan Workers
"Waste to Energy" Incineration Plants in Canada
Human and Ecosystem Health: Canadian Perspectives, Canadian Action
2015 Published Global Change and Public Health: Addressing the Ecological Determinants of Health

Advocacy Efforts

2015 Supported calls for accelerated phase-out of coal-fired power plants in Alberta
2015- Supported calls for nation-wide accelerated phase-out of coal-fired power plants
2015- Supported the Ecological Determinants Group on Education (EDGE)
2015 Supported the Paris Platform for Healthy Energy
2016 Supported the launch of the Pembina Institute Report, Out with the Coal, In with the New
2016 Supported a submission from health organizations and health professionals calling for health impact assessments to be integrated into all federal environmental assessment processes to the Expert Panel established by the Minister of Environment and Climate Change to review federal environmental assessment processes
2017 Together with a group of national organizations, issued an open letter to the Canadian government championing the swift and uncompromising implementation of the Pan-Canadian Framework on Climate Change and Clean Growth.
2017 Co-published the *Lancet Countdown Policy Brief: Canada in 2017* presenting seven policy recommendations related to health and climate change in Canada. The Canada brief is associated with the global report *Lancet Countdown: Tracking Progress on Health and Climate Change*, which finds that human symptoms of climate change are unequivocal, potentially irreversible and affecting the health of populations around the world today.
2017 Met with federal Health Minister (along with other NGOs) about the positive health impacts that would result from reforms to the *Canadian Environmental Protection Act* (CEPA) and to urge her to speak with the Minister of the Environment about tabling legislation by Spring 2018.

2018 Published Letter to Prime Minister Trudeau from over 500 scientists and doctors regarding the need to reform CEPA

CPHA External Committee Representation

Representation by CPHA on external environmental health committees has been extensive over the past four decades. The following identifies a limited number of these committees:

- Environment Canada - NOX/VOC
- Uranium Mining Task Force Northwest Territories
- Canadian Pesticide Registration Review Team
- Contaminated Sites Cleanup Program
- Consumers Regulations & Containers Review - Project C-50
- Canadian Healthy Communities Project - Steering Committee
- Advisory Committee to the Minister on the Green Plan Consultation Process
- Special consultation with Federal/Provincial Committee on Water Quality (Trihalomethanes)
- Brief Presented to the Special Committee of the House of Commons Studying Bill C-78
- SOER Environmental Indicator Workshop
- National Pollution Release Inventory
- Chemical Insensitivities and their Relevance to Psychiatric Disorders - Workshop
- Biotechnology Regulations Review / CEPA

CPHA National Health Research and Program Activities

CPHA has undertaken a wide range of public health research and program activities, many in collaboration with the federal and/or provincial/territorial governments:

1978-81 Study of Arsenic Exposure to Mine Workers and Members of the Yellowknife and Hay River Communities, Northwest Territories

- A two-and-a-half-year national study conducted by CPHA in partnership with Health and Welfare Canada, to determine the possible health hazards to workers and the general population from the gold mining operations in Yellowknife.

1980-82 Study of Fluoride Emissions Affecting Plant Workers and Community in Long Harbour, Newfoundland

- Two-year provincial project conducted by CPHA in partnership with the Newfoundland/Labrador Dept. of Health. The purpose was to determine possible health hazards to plant workers and the population in the Long Harbour region as a result of fluoride emissions from the Long Harbour Flouride plant.

1979-80 Research Activities on Acceptable levels of flouride in Drinking Water, Swimming

- Pool Water Standard and a Microbiological Quality Study of Drinking Water

1982 Study on Health Effects of Urea Formaldehyde Foam Insulation

1982 Pincher Creek, Alberta, Environmental Health Study (Sour Gas)

- A one-year study in partnership with the Department of Social Services, Government of Alberta, to identify scientific activities needed to determine whether or not an abnormal health problem existed in the Pincher Creek area.

1985 Comprehensive Review of the Toxicology of the Great Lakes Drinking Water

- Two-year study conducted by CPHA in partnership with Health Protection Branch, Health and Welfare Canada and the Ontario Ministry of the Environment. The purpose was to determine the degree of toxicology in the Great Lakes drinking water and to establish a database for future comparable studies on the Great Lakes.

1986-89 **Study of the Health Effects of Increased Flying Activity in the Labrador Area**

- A three-year program conducted by CPHA, at the request of the Government of Newfoundland and Labrador to study the potential health problems associated with military low-level flying in the Labrador area.

1989 **Regional Workshops on Human Health and Environmental Assessment**

- Four regional workshops sponsored by the Canadian Environmental Assessment Review Office, Environment Canada, Health and Welfare Canada and CPHA. The final report recommends ways in which those agencies and communities concerned can ensure proper and thorough consideration of health impacts related to all environmental impact assessments.

1990 **Health Dimensions of Environmental Issues Workshop**

- Supported by Health and Welfare Canada, CPHA held a workshop in July/August 1990 which explored the health-environmental issues within the context of the federal government's Green Plan.

1990 **Environmental Health Issues: A Vision for the Future**

- CPHA sponsored a national conference in the fall of 1990 with the support of Environment Canada, the Federal Environmental Assessment Review Office/Canadian Environmental Assessment Research Council and the Health Protection Branch, Health and Welfare Canada

1990/91 **CPHA Task Force on the Implications for Human Health of Global Ecological Change**

- This Task Force was Appointed and commissioned to write a major working document with a plan of action for CPHA.
- Approval and release of *Human and Ecosystem Health: Canadian Perspectives, Canadian Action*, the final report of the Task Force occurred in December 1991
- Development of a project proposal for a Human and Ecosystem Health Secretariat and a Demonstration Project for a Needs Assessment for the Design of a National Clearinghouse on Health and the Environment occurred in early 1992.

1993 ***Strengthening the Public Health Network:*** **A Cross-country Check-up on Environmental Health**

- Supported by Health and Welfare Canada, CPHA brought together provincial/territorial representatives to discuss the role of public health in environmental health and to share information on the various health and environmental issues underway.

1995 **National Surveillance System of Waterborne Diseases in Canada – A Needs Assessment and Feasibility Study:** ***Final Report***

- In April 1995, CPHA submitted the final report which indicated a high level of interest and strongly expressed need for a national waterborne surveillance system. It further outlines goals and principles for a national waterborne disease surveillance system, and makes recommendations for the scope, nature, functions, technological support, administration and funding for such a system.

1999 **Supporting Public Awareness Initiatives on the Health Effects of Climate Change & Air Pollution: Survey Report**

- CPHA commissioned a survey of public awareness initiatives on the health effects of climate change and air pollution in four sectors (health, education, environmental advocacy, and the private sector). The majority of organizations surveyed by the CPHA regarded the health effects of climate change and air pollution as major areas of concern.

2000 **The Roundtable on Health and Climate Change**

- CPHA in partnership with Health Canada, Environment Canada and Natural Resources Canada, organized a Roundtable on Health and Climate Change. The Roundtable was co-

chaired by Dr. David Butler-Jones, President of the CPHA, and Sandra Schwartz, Director of Environmental Programs with the Canadian Institute of Child Health. Over forty organizations participated in the Roundtable. Participants agreed on the need for strong public outreach and engagement on climate change and air pollution.

2001 **Strategic Plan on Health and Climate Change: A Framework for Collaborative Action**

- Building on the key findings of the Round Table, the strategic plan identified core elements to advance knowledge and action related to the health impacts of air pollution and climate change and some priority activities. The core elements included: policy development, research and knowledge, public outreach and engagement, adaptation and response capability, and promoting personal action.

2002 **Report - Development of Resources to Raise Public Awareness of the Health Impacts of Air Pollution and Actions that can be Taken to Improve the Current Situation**

- CPHA developed and disseminated resource materials and public awareness activities for Clean Air Day and beyond, targeting the general public, 2 at risk groups and health professionals. CPHA also designed and implemented a pilot workshop for health professionals.

2006 **Snapshot of Adaptation and Response Capacity in Public Health**

- CPHA conducted key informant interviews with the public health community in Canada to understand the degree to which they consider climate change risks in their policies and planning and their ability to respond to potential impacts.

2007 **Climate Change and Health Vulnerability Assessment**

- CPHA reviewed the draft technical and synthesis reports of the Climate Change and Health Vulnerability Assessment 2007 and commented on the tone, information, messaging, and selection of key issues as being of most interest and most appropriate for public health professionals in Canada.

2009 - **Pilot Heat Alert and Response Systems (HARS)**

2011

- CPHA was engaged to provide technical assistance to facilitate, monitor and report on lessons learned through the development and implementation of the pilot HARS.

2012 **Case Studies: Profiles of four (4) local Public Health units/regions in addressing environment impacts on public health**

- This report profiles four public health organizations (units, regions or authorities) that have had success in undertaking innovative and successful environmental health initiatives.

This is Exhibit "D" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.

LANCET COUNTDOWN: TRACKING PROGRESS ON HEALTH AND CLIMATE CHANGE

ASSOCIATION MÉDICALE CANADIENNE | CANADIAN MEDICAL ASSOCIATION

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The Voice of Public Health
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Lancet Countdown 2018 Report: Briefing for Canadian Policymakers

November 2018

Introduction

Climate change is the biggest global health threat of the 21st century,[1] and tackling it could be our greatest health opportunity.[2] In this era of strained ecological systems, is clear that our ability to optimize Planetary Health, defined as "the health of human civilization and the natural systems upon which it depends,"[3] will define wellness globally for generations to come.

This briefing, launched in parallel with the 2018 International *Lancet Countdown on Health and Climate Change*, focuses on the links between climate change and health, and their implications for Canadian policymakers. It has been developed in conjunction with the Canadian Medical Association and the Canadian Public Health Association, and draws on data provided by the *Lancet Countdown* to make evidence-informed recommendations.

Acknowledgements

The concept of this brief was developed by the *Lancet Countdown on Health and Climate Change*. This brief was written by Courtney Howard, MD; Caren Rose, PhD; and Nicholas Rivers, PhD. Scientific review was provided by Peter Berry, PhD and colleagues from Health Canada. Edits and review were provided by (alphabetical): Owen Adams, PhD; Sandra Allison, MD, MPH; Michael Brauer, ScD; Ian Culbert, Ashlee Cunsolo, PhD; Ian Hamilton, PhD; Trevor Hancock MB, BS, MHSc, HonFFPH; Katie Hayes, MA; Margot Parkes, MD, MBChB, MAS, PhD; Kim Perrotta, MSc; Andre Picard; Bora Plumptre, MSc; Robert Rattle, BSc; and Joe Vipond, MD. Contributions and review on behalf of the *Lancet Countdown* were provided by Dr Nick Watts.

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About the Lancet Countdown

The *"Lancet Countdown: Tracking Progress on Health and Climate Change"* is a global, interdisciplinary research collaboration between 27 academic institutions and inter-governmental organizations. It monitors progress on the relationships between health and climate, and their implications for national governments, reporting annually. The 2018 report presents data on 41 indicators selected following a consultation process in 2017. These span 5 domains, from health impacts and adaptation, to mitigation and the economic and political drivers of response.[2]

About the Canadian Medical Association

The Canadian Medical Association (CMA) unites physicians on national health and medical matters. Formed in Quebec City in 1867, the CMA's rich history of advocacy led to some of Canada's most important health policy changes. As we look to the future, the CMA will focus on advocating for a healthy population and a vibrant profession.

About the Canadian Public Health Association

The Canadian Public Health Association (CPHA) is a national, independent, non-governmental organization that advances public health education, research, policy and practice in Canada and around the world through the *Canadian Journal of Public Health*, position statements, discussion documents and other resources.

Recommendations for 2018

Recommendation 1

Coordinate federal governmental departments, local governments and national institutions to standardize surveillance and reporting of heat-related illness and deaths; develop knowledge translation strategies to inform the public about the threat of heatwaves to health; and generate a clinical and public health response plan that minimizes the health impacts of heat now, and anticipates worsening impacts to come as climate change progresses.

Recommendation 2

Rapidly integrate climate change and health into the curriculum of all medical and health sciences faculties.

Recommendation 3

Increase ambition in reducing greenhouse gas emissions and air pollution in Canada and twin this with an emphasis on Just Transition Policies to support an equitable transition for people who work in the fossil fuel industry as the energy economy transforms.

Recommendation 4

Phase out coal-powered electricity in Canada by 2030 or sooner, with a minimum of two thirds of the power replaced by non-emitting sources, and any gap made up by lowest-emitting natural gas technology in a system designed to minimize fugitive methane emissions.

Recommendation 5

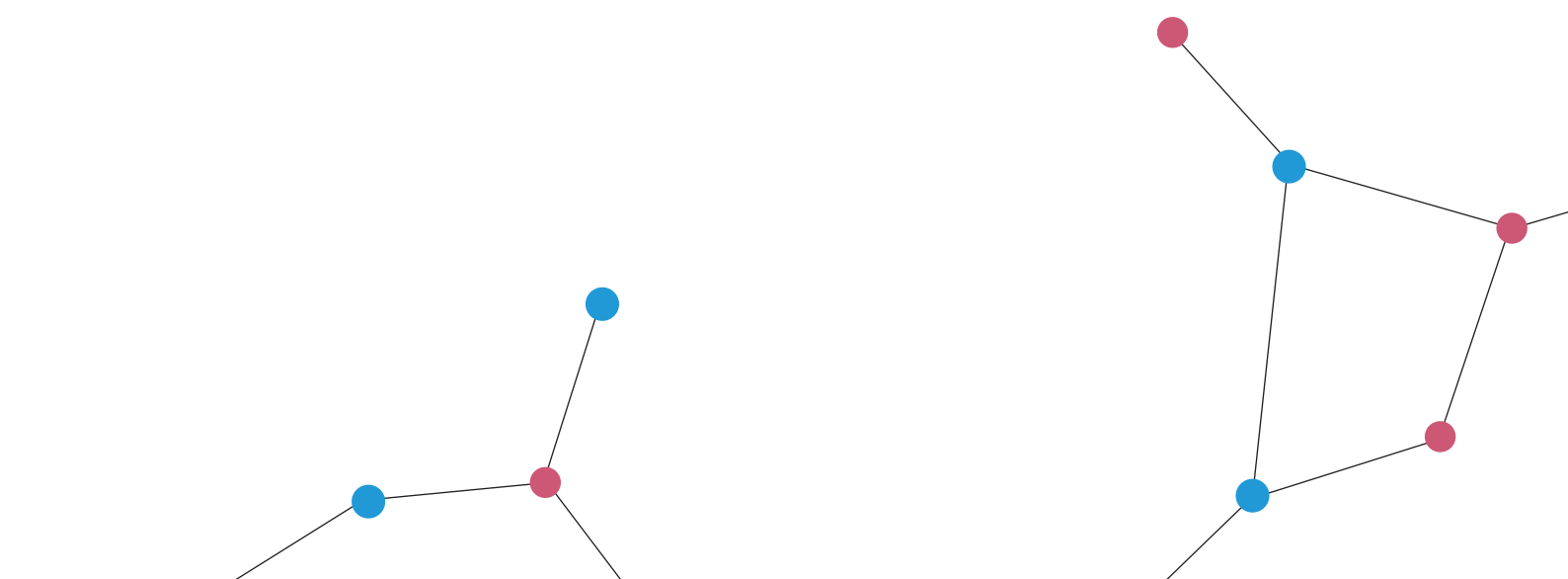
Apply carbon pricing instruments as soon and as broadly as possible, enhancing ambition gradually in a predictable manner, and integrate study of resulting air pollution-related health and healthcare impacts into ongoing policy decisions.

Recommendation 6

Ensure consistent, pro-active external communications by health-related organizations pointing out the links between climate change and health impacts in real time as events that have been shown to be increasing due to climate change (e.g. heat waves, spread of tick-borne disease, wildfires, extreme weather) occur.

Recommendation 7

Fund increased study into the mental health impacts of climate change and psychosocial adaptation opportunities.



Key Messages from the 2018 International Lancet Countdown Report

- Present day changes in labour capacity, vector-borne disease, and food security provide early warning of compounded and overwhelming impacts expected if temperature continues to rise. Trends in climate change impacts, exposures, and vulnerabilities demonstrate an unacceptably high level of risk for the current and future health of populations across the world.

- A lack of progress in reducing emissions and building adaptive capacity threatens both human lives and the viability of the national health systems they depend on, with the potential to disrupt core public health infrastructure and overwhelm health services.

- Despite these delays, trends in a number of sectors are breathing life in to the beginning of a low-carbon transition, and it is clear that the nature and scale of the response to climate change will be the determining factor in shaping the health of nations for centuries to come.

- Ensuring a widespread understanding of climate change as a central public health issue will be vital in delivering an accelerated response, with the health profession beginning to rise to this challenge.[2]

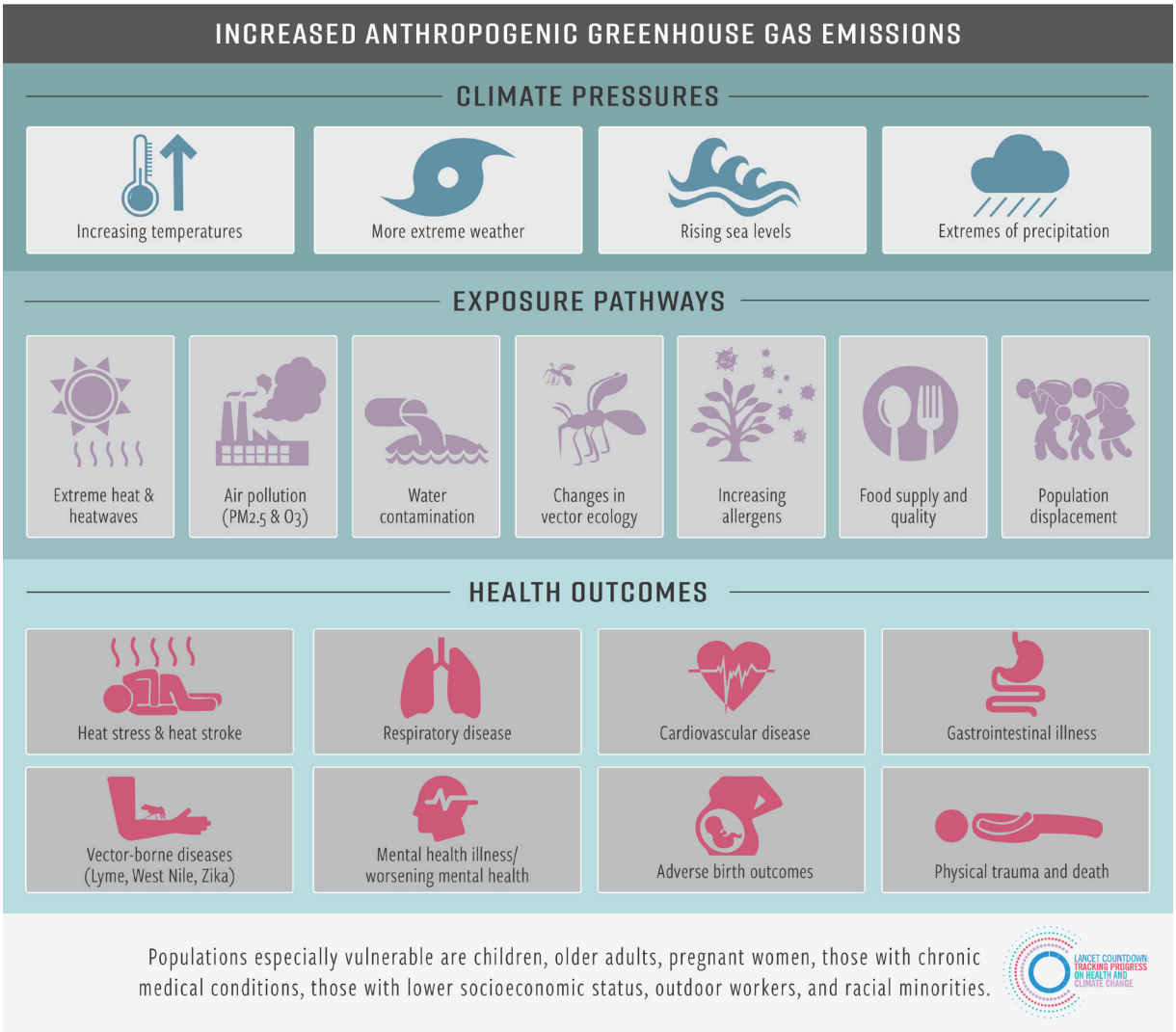


Figure 1: Health Impacts of Climate Change. Credit: M.Lee for the US *Lancet Countdown* Brief

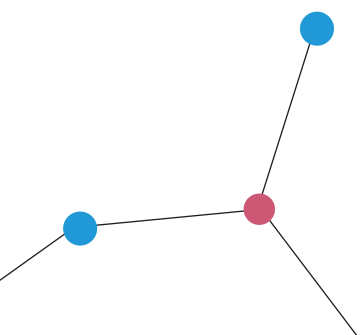
Overview of the Health Impacts of Climate Change in Canada

Though Canada's well-developed healthcare and public health system provides advantages in terms of initial adaptation to climate change, as a circumpolar country it contains some of the most rapidly-warming areas in the world: observed temperatures in Inuvik, Northwest Territories have increased by 3°C in the past 50 years.[4]

Rapid change in the Arctic is already increasing health risks from food insecurity due to decreased access to traditional foods,[5,6] decreased safety of ice-based travel, and mental health impacts from changed landscapes.[7,8]

Health concerns in the rest of Canada vary by region, but include increased heat stroke and death;[6,9] more intense and prolonged pollen seasons with the potential to cause additional hay fever and asthma exacerbations;[6] trauma, post-traumatic stress disorder and displacement from wildfire and floods;[10-12] spread of Lyme disease;[13,14] cardiorespiratory impacts from worsening air pollution due to wildfires,[15] and increased ground-level ozone.[6]

Milder winters and increased precipitation in parts of the country could potentially improve agricultural yields, and thus reduce food insecurity, but this is balanced by the possibility of crop-damaging severe weather and drought in other areas.[16] There is an increased risk of water-borne disease following changed precipitation patterns, and of greater exposure to higher levels of ultraviolet radiation.[6] The potential for 'tipping cascades' makes the risk of rapid and dramatic climate change impacts more difficult to predict and more likely.[17]



Heat-Related Health Impacts

Indicator 1.2 Health Effects of Temperature Change

The health impacts of warmer summers were vividly demonstrated in 2018, with more than 90 people suspected to have died as a direct result of a heat wave in Quebec in July.[18] Health-related impacts of heat include including heat rash, heat edema,[19] heat stress, heat stroke, cardiovascular disease and renal disease.[2] Preliminary evidence has also linked heat with increased suicide risk.[20] Impacts are most common in vulnerable populations such as adults over 65 years, the homeless,[21] urban dwellers and people with pre-existing disease.[2]

Humans around the globe are having to cope with hotter temperatures. The international *Lancet Countdown* report found that in 2017 the mean global summer temperature increase relative to the 1986-2008 reference period was 0.3°C, with the change experienced by humans (i.e., population-exposure-weighted) more than double that, at 0.8°C. This discrepancy results largely from the fact that populations are migrating in to the areas worst affected by climate change.

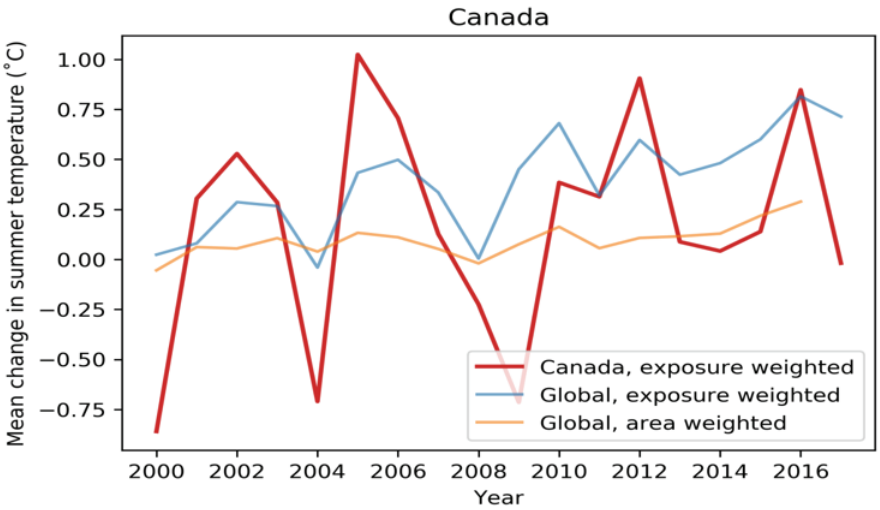


Figure 2: Mean area and population-exposure-weighted summer temperature change in Canada and globally from 2000 to 2017.

As a northern country that must also manage mortality due to cold temperatures,[22,23] health authorities in Canada are now increasing their response to the health risks of extreme heat.[24] Lives can be saved by having integrated surveillance and monitoring systems to gather data on heat-related illness and death, and integrating this into a pro-active public health response.[25] Elements of this include forecasting heat events and ensuring cooperation between public health, emergency management officials and community-members to issue alerts and ensure that vulnerable people such as the elderly have adequate access to water and cool-air shelters.[26] Longer term strategies include creating urban areas rich in green space that minimize the urban heat island effect, and buildings designed with natural ventilation in mind in order to reduce the need for air conditioning,[26] which can lead to increased energy use, and health-harming air pollution.[27]

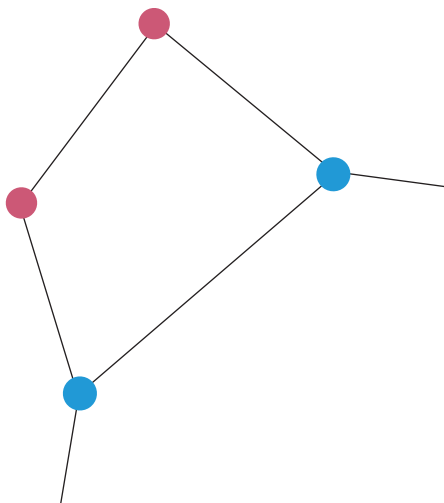
A well-trained workforce is required to respond to these challenges. The Canadian Public Health Association's Ecological Determinants Group on Education has been working to integrate an eco-social approach into public health education,[28] including facilitating the participation of the Canadian Federation of Medical Students in an International Federation of Medical Students' Associations initiative which seeks to see climate change and health gain a foothold in curricula by 2020 with fuller integration by 2025.[29]

Recommendation 1

Coordinate federal governmental departments, local governments and national institutions to standardize surveillance and reporting of heat-related illness and deaths; develop knowledge translation strategies to inform the public about the threats of heatwaves to health; and generate a clinical and public health response plan that minimizes the health impacts of heat now and anticipates worsening impacts to come as climate change progresses.

Recommendation 2

Rapidly integrate climate change and health into the curriculum of all medical and health sciences faculties.



Health Costs of Energy and Air Pollution

Towards a healthier, low-carbon world.

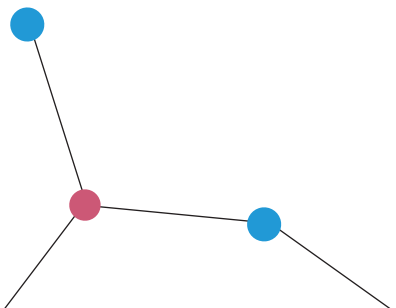
Canada is not doing its fair share to reduce greenhouse gas (GHG) emissions. In 2016, Canadian emissions were 704 MT CO_2eq, an actual *increase* of over one hundred megatonnes since 1990.[30] In contrast, the United Kingdom reduced its greenhouse gas emissions 41% between 1990 and 2016,[31] and China is hitting its greenhouse gas targets ahead of schedule.[32] The 2017 Canadian Federal Auditor General's report estimated that emissions in 2020 are projected to be 111 MT CO2eq above Canada's 2020 target of 620 MT CO^2eq.[33] In 2016, the Canadian transportation sector accounted for 25% of total national emissions, while the oil and gas sector accounted for 26% of total national emissions, having gone up 70% from 107 Mt CO_2eq in 1990 to 183 Mt CO_2eq in 2016, an increase that is mostly attributable to higher levels of production of crude oil and the expansion of the oil sands industry.[30]

Business-as-usual emissions trajectories currently have the world on course to 2.6-4.8°C of warming by 2100.[34] As the 2018 *Lancet Countdown* states, "present day changes in labour capacity, vector-borne disease, and food security provide early warning of compounded and overwhelming impacts expected if temperature continues to rise. Trends in climate change impacts, exposures, and vulnerabilities demonstrate an unacceptably high level of risk for the current and future health of populations across the world."[2]

In an effort to alter course, in December 2015, 195 countries, including Canada, signed the Paris Agreement, which pledges to keep the global mean temperature rise to well below 2°C. A recent report by the Intergovernmental Panel on Climate Change underlines the health benefits of keeping warming to 1.5°C,[13] but makes clear the magnitude of that challenge, stating, "global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate."[35] It finds that in order to stay below 1.5°C, "global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050."[35]

There are signs of progress: the 2018 *Lancet Countdown* reports that in 2017 there were 157 Gigawatts (GW) of new installed renewable energy, as compared to 70 GW of fossil fuel capacity; a 50% increase in the uptake of electric vehicles across the global rolling stock; and a cumulative total of $33.6 billion USD now divested of fossil fuels by health institutions.[2]

Many policies that reduce greenhouse gas emissions also decrease air pollution, resulting in immediate benefits to health and healthcare cost savings, as described in the next section.



Indicator 3.5.2 Premature Mortality from Air Pollution by Sector

Headline Finding: Data for Canada provided by the *Lancet Countdown* shows a total of 7142 deaths from chronic exposure to anthropogenic $PM_{2.5}$ air pollution in 2015, (Figure 3) resulting in a loss in economic welfare for Canadians valued at approximately $53.5 billion.[36]

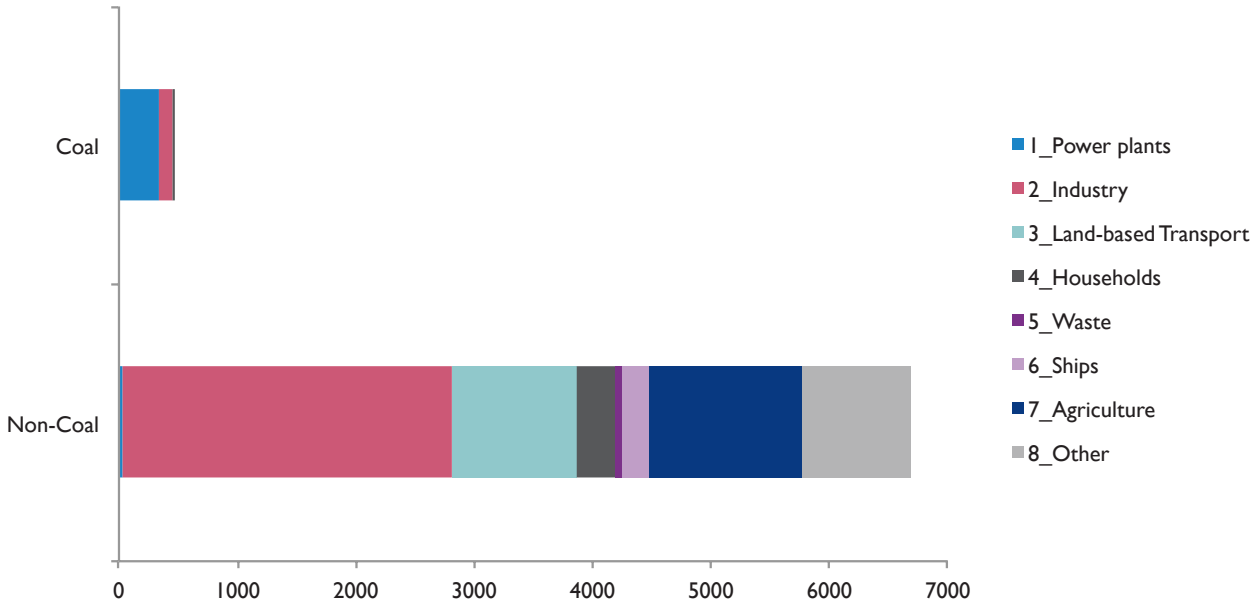


Figure 3: Annual Premature Deaths from Ambient $PM_{2.5}$ in Canada

The 2018 International *Lancet Countdown* report found that fine particulate ambient air pollution ($PM_{2.5}$) resulted in more than 2.9 million deaths globally in 2015, with coal responsible for about 16% of this.[2] These numbers are based on chronic exposure and include deaths from ischemic heart disease, stroke, lung cancer, acute lower respiratory infections and COPD.

Health Canada estimated in 2017 that 9,500 deaths per year in Canada are attributable to above-background concentrations of $PM_{2.5}$.[37] A 2016 report by the World Bank showed 9,466 deaths in Canada in 2013 due to PM2.5 with direct welfare costs of US$40.4 billion (2011 prices).[38] This analysis by the *Lancet Countdown* showed 7142 deaths including 345 deaths from coal-fired power plants; another 105 from coal-related industries; 2,762 deaths from non-coal industry; 1063 from Land-based Transport; and 1282 from Agriculture.[2] Using official Health Canada methodologies, this translates into a loss in economic welfare for Canadians valued at approximately $53.5 billion.[36]

In addition to its air-pollution-mediated mortality impacts, in 2016 the Canadian transportation sector accounted for 25% of national GHG emissions.[30] The 2017 *Lancet Countdown* Briefing for Canadian Policymakers showed that Canada has quite a low proportion of trips taken via means of sustainable transport including by transit, bike or on foot,[39] and recommended the development of a National Active Transport Strategy.[39] Multiple health benefits would stem from this: exercise reduces anxiety[40] and depression;[41] commuting on foot or by bike has been shown to decrease cardiovascular mortality, and cycling decreases all-cause mortality and mortality from cancer. [42]

To reduce coal-related morbidity, mortality, and greenhouse gas emissions, the Government of Canada has committed to an accelerated phase out of unabated coal-fired power by 2030.[43] As per the Regulatory Impact Analysis Statement of the proposed amendment to existing legislation on GHGs from coal-fired generation, the expected resulting reduction in cumulative GHG emissions is approximately 100Mt,[44] with $3.6 billion in avoided climate change damage benefits, and $1.3 billion in health and environmental benefits from air quality improvement.[44] The Pembina Institute previously

estimated health benefits of $5 billion in a scenario where coal-fired plants are shut down after 40 years of operation or by 2030, and which assumes the replacement of coal power by two thirds renewables and one third best-in-class gas-power.[45]

A transition which proceeds as much as possible directly from coal-fired to renewably-generated electricity is required. Methane, the primary component of natural gas, has 84 times the GHG potential of CO_2 over a twenty year period,[46] and the upstream extraction and transport system is leaky,[47-49] leading to near-term warming risks. Additionally, an increasing proportion of natural gas in Canada is being produced via hydraulic fracturing,[50] for which evidence is accumulating of negative impacts: a quantitative assessment of the peer-reviewed scientific evidence from 2009-2015 indicated that 84% of studies on public health, 69% of studies on water and 87% of studies on air quality showed concerning findings.[51]

Encouragingly, Canada's coal phase-out commitments enabled the Canadian Government to join forces with the United Kingdom at COP23 to launch the Powering Past Coal Alliance, which now has at least 60 national, provincial, state, city, business and organizational members.[52] In Canada, a Just Transition Task Force has been created to support coal workers as they move towards new employment.[53] This important initiative would do well to expand to support the social determinants of health of fossil-fuel-industry workers across Canada as the nation transforms its energy economy.

Recommendation 3

Increase ambition in reducing greenhouse gas emissions and air pollution in Canada and twin this with an emphasis on Just Transition Policies to support an equitable transition for people who work in the fossil fuel industry as the energy economy transforms.

Recommendation 4

Phase out coal-powered electricity in Canada by 2030 or sooner, with a minimum of two thirds of the power replaced by non-emitting sources, and any gap made up by lowest-emitting natural gas technology in a system designed to minimize fugitive methane emissions.

Financial and Economic Drivers of a Low-Carbon Transition

Indicator 4.7 Coverage and Strength of Carbon Pricing

This section co-authored by Nicholas Rivers, Canada Research Chair in Climate and Energy Policy.

Headline Finding: When the Chinese National Emissions Trading Scheme comes online this year, approximately 20% of global anthropogenic GHG emissions will be subject to a carbon price.[2]

The 2015 Lancet Commission on Climate Change and Health stated, "The single most powerful strategic instrument to inoculate human health against the risks of climate change would be for governments to introduce strong and sustained carbon pricing, in ways pledged to strengthen over time until the problem is brought under control. Like tobacco taxation, it would send powerful signals throughout the system, to producers and users, that the time has come to wean our economies off fossil fuels, starting with the most carbon intensive and damaging like coal."[54] On the basis of this argument, the Canadian Medical Association passed a motion at its General Council in 2015 to "promote the health benefits of a strong, predictable price on carbon emissions."[55]

News of increasing carbon pricing coverage internationally comes at a critical juncture for Canada. Carbon prices currently apply to 75% of greenhouse gas emissions in British Columbia, 72% in Alberta, 84% in Ontario, and 81% in Quebec, such that in total 61% of emissions in Canada are subject to a carbon price (42% after Ontario's proposed cap-and-trade elimination).[56]

The federal carbon pricing backstop is due to come into effect in 2019. It will start at a minimum of $10 per tonne in 2018, and rise by $10 per year to $50 per tonne in 2022.[57] Successful application of the federal carbon pricing backstop in 2019 will result in coverage of 79% of total Canadian emissions by a carbon price.[56] The current plan will be revenue-neutral at the federal level, with all proceeds staying in the province in which they were collected.[58] About 70% of Canadians will receive as much or more back in rebates as what they paid.[58]

A review of studies of BC's carbon tax showed that it has reduced emissions in the province by 5-15% compared to what they would have been without the tax, and that the tax has had negligible effects on aggregate economic performance.[59] Similar reductions in emissions in response to carbon prices have been found in other jurisdictions.[60,61]

A neglected part of the public conversation is the impact carbon pricing could have on human health, via decreases in the air-pollution-related deaths detailed in section 3.5.2. A study in the US found that "monetized human health benefits associated with air quality improvements can offset 26-1050% of the cost of US carbon policies."[62] Similarly, a recent study from China which simulated the impact of a price on CO_2 emissions consistent with China's pledge to reach a peak in CO_2 emissions by 2030, found that "national health co-benefits from improved air quality would partially or fully offset policy costs depending on chosen health valuation."[63] There is a critical need to carry out similar studies in the Canadian context.

Recommendation 5

Apply carbon pricing instruments as soon and as broadly as possible, enhancing ambition gradually in a predictable manner, and integrate study of resulting air pollution-related health and healthcare impacts into ongoing policy decisions.

Indicator 5.1 Media Coverage of Health and Climate Change

Headline Finding: Against a backdrop of a 42% global increase in media coverage between 2007 and 2017, the average aggregate number of articles per year referencing both climate change and health in 3 Canadian Newspapers (The Globe and Mail, The Toronto Sun, and The National Post) dropped 24% from 98 in 2009 to 75 in 2017. (Data courtesy of the *Lancet Countdown*)

Media coverage is critical for helping populations become aware of the risks of climate change, and in influencing public support for national policy change.[64] Research shows that presenting climate change in a health frame, as opposed to as an environmental or security issue, is the best way to elicit emotional reactions consistent with support for climate change mitigation and adaptation,[65] and that more strongly positive reactions are associated with information about the health benefits of mitigation policy (e.g. the number of asthma exacerbations that will be saved as a result of the phase-out of a coal-fired power plant) than with information about health risks.[66]

A 2017 poll commissioned by Health Canada demonstrates quite a high level of public concern related to climate change: 79% of Canadians are convinced that climate change is happening, and of these, 53% accept that it is a current health risk, and 40% believe it will be a health risk in the future.[67]

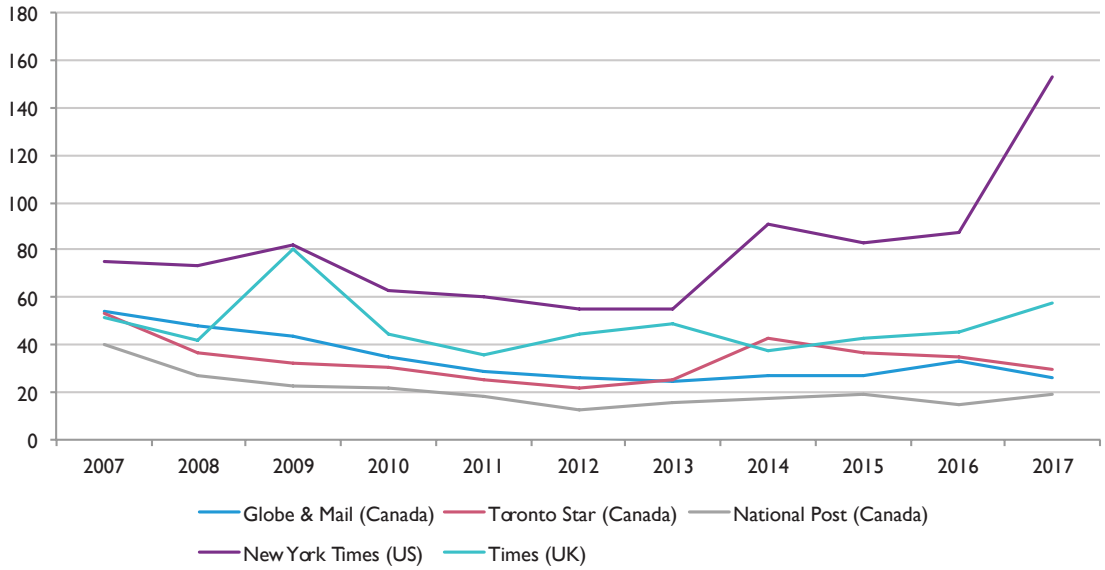


Figure 4: Number of articles in specific newspapers covering Climate Change and Health. Data provided by the *Lancet Countdown*.[2]

The three Canadian newspapers in the dataset, *The Globe and Mail, The Toronto Star,* and *The National Post*, each saw a drop in climate change and health coverage, with the average number of articles per year in Canada decreasing 24% from 98 in 2009 to 75 in 2017. In contrast, over the same period, the New York Times saw an increase of 86%. (Figure 4)

Recommendation 6

Ensure consistent, pro-active external communications by health-related organizations pointing out the links between climate change and health impacts in real time as events which have been shown to be increasing due to climate change (e.g. heat waves, spread of tick-borne disease, wildfires, extreme weather) occur.

Case Study: Canadian Contributions to Understanding of Climate Change, Mental Health and Ecological Grief

Climate-related weather events and environmental change have been linked to elevated rates of depression, anxiety, and pre-and-post-traumatic stress; increased drug and alcohol usage; and increased suicidal ideation, suicide attempts and death by suicide.[68] As a result, mental health considerations are likely to be increasingly included in climate vulnerability and impact assessments.[69] Research in Canada has particularly contributed to the evolution of concepts such as "solastalgia," explained as 'feeling homesick when you're still at home,' ecological grief and eco-anxiety.[68]

Canada's Arctic is one of the most rapidly-warming areas on earth, and has been inhabited for millennia by Indigenous communities whose close connection to and knowledge of the land make them sensitive observers of ecological change. A multi-year, community-driven enquiry into the mental health impacts of environmental change in the community of Rigolet, Nunatsiavut, demonstrated that climate change is "negatively affecting feelings of place attachment by disrupting hunting, fishing, foraging, trapping, and traveling, and changing local landscapes--changes which subsequently impact physical, mental, and emotional health and well-being." These results called for an understanding of place-based attachment as a vital indicator of health and well-being.[7]

Southwest of Rigolet, in the high subarctic area surrounding the Northwest Territories' capital of Yellowknife, the "SOS-Summer of Smoke" project investigated the health and wellness impacts of a prolonged smoke and fire exposure in 2014.[11] It found double the normal rates of emergency department visits for asthma, and interview analysis revealed strong themes of isolation, fear, loss of connection to the land and to traditional summertime activities; lack of physical activity; and a feeling of ecological grief or eco-anxiety, as participants placed the summer in the overall context of the changing climate and wondered if such summers would become the "new normal."[11]

A recent paper in Nature Climate Change defined ecological grief as, "the grief felt in relation to experienced or anticipated ecological losses.[68] It points out that, "grief is a natural and legitimate response to ecological loss, and one that may become more common as climate impacts worsen."[68]

Both the SOS study and the paper on ecological grief were published in spring 2018, just prior to one of western Canada's most severe wildfire seasons on record. As millions of Canadians sat blanketed in smoke, media interest in the concepts of solastalgia and ecological grief was unprecedented,[12,70] opening up new discussions that, at the very least, decrease people's feelings of loneliness in their grief. Grief and mourning has "we-creating" capacities, allowing for opportunities to reach across differences to connect with others.[68] Though difficult, these conversations may well create new possibilities in the pursuit of a healthy approach to climate change.

Recommendation 7

Fund increased study into the mental health impacts of climate change and psychosocial adaptation opportunities.

Follow-up on Recommendations from the 2017 Lancet Countdown Briefing for Canadian Policymakers

Policy Recommendation #1

Ensure funding of research and best practice information sharing between public health communities in different regions to fine tune adaptation capacity to severe weather events.

Health Canada recently launched a multi-year funding program to support approximately 10 projects and begin a Community of Practice to help the health sector develop vulnerability and adaptation assessments. The Public Health Agency of Canada also has an Infectious Disease and Climate Change Fund, and Indigenous Services has developed "Canada's Climate Change and Health Adaptation Program for First Nations South of 60°."[71]

Policy Recommendation #2

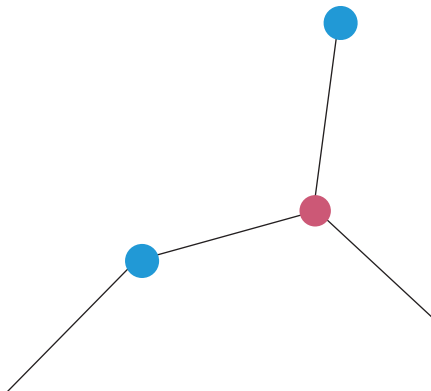
Phase out coal-powered electricity in Canada by 2030 or sooner, with a minimum of two thirds of the power replaced by non-emitting sources, and any gap made up by lowest-emitting natural gas technology. Track and cost the health benefits of the transition in Canada and globally.

Current situation described above in air pollution section.

Policy Recommendation #3:

Develop a National Active Transport Strategy for Canada to coordinate improvements to walking, cycling and transit environments. This should receive priority funding, with healthcare cost savings calculated in order to demonstrate the cost offset of the investments.

A NGO-led campaign requesting a national active transport strategy has now been endorsed by over 150 health, environmental and community organizations.[72]



Policy Recommendation #4

Enhance support for tele-commuting and telehealth options. Within health systems, gather and analyze data on kilometers, greenhouse gas emissions, air pollution and costs saved by telehealth in order to help drive systems change.

Various jurisdictions are investing in Telehealth, including the Northwest Territories, which increased the ability for emergency physicians to conduct video-based consultations on remote patients. Virtual medicine is a growing focus of Joule, the Canadian Medical Association's service and innovation arm.[73]

Policy Recommendation #5

Provide strong health-sector support for Health Canada's draft healthy eating guidelines, which emphasize plant-based sources of protein, with framing of these guidelines as being beneficial for both human and planetary health.

The 1st launch of the revamped Canada Food Guide will occur in late fall 2018.[74] The Food Guide is expected to maintain the emphasis on plant-based proteins that was presented in its draft version.

Policy Recommendation #6

Increase funding for research into the local health impacts of resource extraction, with a focus on impacts on Indigenous populations.

A September 2018 search of the Canadian Research Information database pulled up only 2 funded studies with the search term, "hydraulic fracturing," and 9 with "resource development" referring to natural resources. The BC Observatory for Population and Public Health and Northern Health recently released a report summarizing impacts of resource extraction and development on the social determinants of health in rural, remote and Indigenous communities.[75]

Policy Recommendation #7

Integrate Health Impact Assessments as a core component of the federal Environmental Assessment process.

In February 2018, the Government of Canada introduced new legislation to move to a more holistic Impact Assessment process for major development project approvals that includes consideration of economic, social and health effects including earlier and improved participation opportunities for Indigenous and non-Indigenous communities, consideration of traditional and community knowledge, gender-based analysis and a strong focus on sustainability.[76]

References

1. Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet 2009;373(9676):1693-733.

2. Watts N, Ammann M, Arnell N, Ayeb-Karlsson S, Belesova K, al. e. The 2018 Report of The Lancet Countdown on Health and Climate Change. The Lancet 2018.

3. Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, de Souza Dias BF, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-Lancet Commission on planetary health. Lancet 2015;386(10007):1973-2028.

4. Government of the Northwest Territories. Climate Observations in the Northwest Territories (1957-2012) Inuvik * Norman Wells * Yellowknife * Fort Smith.

5. Rosol R, Powell-Hellyer S, Chan HM. Impacts of decline harvest of country food on nutrient intake among Inuit in Arctic Canada: impact of climate change and possible adaptation plan. Int J Circumpolar Health 2016;75(1):31127.

6. Berry P, Clarke K, Fleury MD, Parker S. Human Health; in from Impacts to Adaptation: Canada in a Changing Climate. Natural Resources Canada,; 2014.

7. Cunsolo Willox A, Harper SL, Ford JD, Landman K, Houle K, Edge VL, et al. "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. Soc Sci Med 2012;75(3):538-47.

8. Health A. Impact of Wildfires on the Mental Health of Fort McMurray Residents: Neurotic Disorders, Daily Physician Visits within an Emergency Department 2015 vs. 2016. Alberta Health, Health Standards, Quality and Performance Division, Analytics and Performance Reporting Branch; 2016.

9. Toronto Public Health. A Climate of Concern:Climate Change and Health Strategy for Toronto 2015. 2015.

10. Cherry N, Haynes W. Effects of the Fort McMurray wildfires on the health of evacuated workers: follow-up of 2 cohorts. CMAJ Open 2017;5(3):E638-E45.

11. Dodd W, Scott P, Howard C, Rose C, Scott C, Cunsolo A, et al. Lived experience of a record wildfire season in the Northwest Territories, Canada. Accepted by Canadian Journal of Public Health 2018.

12. McCue D. Growing 'ecological grief' is the mental health cost of climate change. 2018 [October 26, 2018]; Available from: https://www.cbc.ca/radio/checkup/growing-ecological-grief-is-the-mental-health-cost-of-climate-change-1.4871666

13. Ebi K, Campbell-Lendrum D, Wyns A. The 1.5 Health Report--Synthesis on Health and Climate Science in the IPCC SR1.5. 2018 2018.

14. Ogden NH, St-Onge L, Barker IK, Brazeau S, Bigras-Poulin M, Charron DF, et al. Risk maps for range expansion of the Lyme disease vector, Ixodes scapularis, in Canada now and with climate change. Int J Health Geogr 2008;7:24.

15. Henderson SB, Johnston FH. Measures of forest fire smoke exposure and their associations with respiratory health outcomes. Curr Opin Allergy Clin Immunol 2012;12(3):221-7.

16. Government of Canada. Impact of climate change on Canadian agriculture. 2015-07-30 [Oct 22, 2017]; Available from: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/agriculture-and-climate/future-outlook/impact-of-climate-change-on-canadian-agriculture/?id=1329321987305

17. Steffen W, Rockström J, Richardson K, Lenton T, Folke C, al. e. Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Science 2018.

18. Woods A. More than 90 deaths now linked to heat wave in Quebec. 2018. [cited July 18, 2018]. Available from: https://www.thestar.com/news/canada/2018/07/18/89-deaths-now-linked-to-heat-wave-in-quebec.html.

19. Dover G, P. E, Gould R, Hayes J, Kenny G, Moore K, et al. Extreme Heat Events Guidelines: Technical Guide for Health Care Health Canada; 2018 2018-08-07.

20. Thompson R, Hornigold R, Page L, Waite T. Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. Public Health 2018;161:171-91.

21. Ramin B, Svoboda T. Health of the homeless and climate change. J Urban Health 2009;86(4):654-64.

22. Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet 2015;386(9991):369-75.

23. Chen H, Wang J, Li Q, Yagouti A, Lavigne E, Foty R, et al. Assessment of the effect of cold and hot temperatures on mortality in Ontario, Canada: a population-based study. CMAJ Open 2016;4(1):E48-58.

24. Guilbault S, Kovacs P, Berry P, Richardson G, Friedel N, Rogaeva A, et al. Cities adapt to extreme heat: celebrating local leadership. Health Canada Institute for Catastrophic Loss Reduction,; 2016.

25. World Health Organization. Operational framework for building climate resilient health systems. 2015.

26. Brown C, Chiotti Q, Davidson L, Dubous N, Hamel S, Hirst S, et al. Health Canada: Communicating the Health Risks of Extreme Heat Events. 2018 Aug 7, 2018.

27. Abel DW, Holloway T, Harkey M, Meier P, Ahl D, Limaye VS, et al. Air-quality-related health impacts from climate change and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary modeling study. PLoS Med 2018;15(7):e1002599.

28. Canadian Public Health Association. Ecological Determinants of Health Group on Education. 2018 [cited 2018 Octobe 25, 2018]; Available from: https://www.cpha.ca/EDGE

29. International Federation of Medical Students' Associations. 2020 Vision for Climate-Health in Medical Curricula. 2018 [cited 2018 October 9, 2018]; Available from: https://docs.google.com/forms/d/e/1FAIpQLSeMxig6Yhs4qJU8oboKXm0KqGXRj64fcso8o9IHBikNGX5RYA/viewform

30. Canada Go. Greenhouse Gas Emissions. 2018 [June 13, 2018.]; Available from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

31. United Kingdom National Statistics. 2016 UK Greenhouse Gas Emissions. 2018 [cited 2018 October 9 2018]; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/679334/2016_Final_Emissions_Statistics_one_page_summary.pdf

32. Qi Y, Stern N, He J, Lu J, King D, Lin T, et al. China's Peaking Emissions and the Future of Global Climate Policy. Brookings-Tsinghua Center for Public Policy; 2018.

33. Government of Canada. 2017 Fall Reports of the Commissioner of the Environment and Sustainable Development to the Parliament of Canada. Report 1—Progress on Reducing Greenhouse Gases—Environment and Climate Change Canada. 2017.

34. Intergovernmental Panel on Climate Change. Summary for Policymakers: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.; 2013.

35. Intergovernmental Panel on Climate Change. Global Warming of 1.5C--Summary for Policymakers. 2018 October 8, 2018.

36. Chestnut L, De Civita P. Economic valuation of mortality risk reduction : review and recommendations for policy and regulatory analysis. 2009.

37. Health Canada. Health Impacts of Air Pollution in Canada--an Estimate of Premature Mortalities. 2017.

38. Narain U, Sall C, Brauer M, Cohen A, Estep K, Forouzanfar M, et al. The Cost of Air Pollution: Strengthening the Economic Case for Action. World Bank and Institute of Health Metrics and Evaluation,; 2016.

39. Howard C, Rose C, Hancock T. Lancet Countdown 2017 Report: Briefing for Canadian Policymakers. Lancet Countdown and Canadian Public Health Association; 2017 October 31st, 2017.

40. de Souza Moura AM, Lamego MK, Paes F, Ferreira Rocha NB, Simoes-Silva V, Rocha SA, et al. Effects of Aerobic Exercise on Anxiety Disorders: A Systematic Review. CNS Neurol Disord Drug Targets 2015;14(9):1184-93.

41. Wegner M, Helmich I, Machado S, Nardi AE, Arias-Carrion O, Budde H. Effects of exercise on anxiety and depression disorders: review of meta- analyses and neurobiological mechanisms. CNS Neurol Disord Drug Targets 2014;13(6):1002-14.

42. Celis-Morales CA1 LD, Welsh P1, Anderson J2, Steell L1, Guo Y1, Maldonado R1, Mackay DF2, Pell JP2, Sattar N1, Gill JMR3. Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. British Medical Journal 2017;357(:j1456.).

43. Government of Canada. Powering our future with clean energy. 2016 [updated 2016-12-09; cited 2017 October 5]; Available from: https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/clean-energy.html

44. Government of Canada. REGULATORY IMPACT ANALYSIS STATEMENT: Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations. Department of the Environment and Department of Health,; 2018 Feb 17, 2018.

45. Israël B, E. F. Out With the Coal, in With the New: National benefits of an accelerated phase-out of coal-fired power. Pembina Institute; 2016.

46. Intergovernmental Panel on Climate Change. IPCC 2014; Climate Change 2014 Synthesis Report;Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.: Intergovernmental Panel on Climate Change; 2014.

47. Government of Canada. Canada's methane regulations for the upstream oil and gas sector. Environment and Natural Resources,; 2018 [cited 2018 Oct 24, 2018]; Available from: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/proposed-methane-regulations-additional-information.html

48. Balcombe P, Anderson K, Speirs J, Brandon N, Hawkes A. The Natural Gas Supply Chain: The Importance of Methane and Carbon Dioxide Emissions. ACS Sustainable Chem. Eng. 2017;5:3-20.

49. Atherton E, Risk D, Fougere C, Lavoie M, Marshall A, Werring J, et al. Mobile measurement of methane emissions from natural gas developments in Northeastern British Columbia, Canada. Atmos. Chem. Phys. Discuss. 2017.

50. Government of Canada. Environmental Considerations of Shale and Tight Resource Development. 2016.

51. Hays J, Shonkoff SB. Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015. PLoS One 2016;11(4):e0154164.

52. Government of the United Kingdom. Powering Past Coal Alliance: Partners. 2018.

53. Government of Canada. Just transition task force. 2018.

54. Watts N, Adger WN, Agnolucci P, Blackstock J, Byass P, Cai W, et al. Health and climate change: policy responses to protect public health. Lancet 2015;386(10006):1861-914.

55. Association CM. Resolutions Passed at General Council 2015 (confirmed). 2015.

56. Dobson S, Winters J, Boyd B. The greenhouse gas emissions coverage of carbon pricing instruments for Canadian provinces. University of Calgary; 2018.

57. Canada Go. Pricing carbon pollution in Canada: how it will work. 2017 [October 2018]; Available from: https://www.canada.ca/en/environment-climate-change/news/2017/05/pricing_carbon_pollutionincanadahowitwillwork.html

58. Tasker J. Trudeau promises rebates as Ottawa moves to levy carbon tax on provinces outside the climate plan. Canadian Broadcasting Corporation, . 2018. [cited October 23, 2018]. Available from: https://www.cbc.ca/news/politics/tasker-carbon-tax-plan-trudeau-1.4874258.

59. Rivers, N. British Columbia's Revenue Neutral Carbon Tax: A Review of the Latest 'Grand Experiment' in Environmental Policy. 2015.

60. Petrick S, Wagner U. The Impact of Carbon Trading on Industry: Evidence from German Manufacturing Firms. SSRN 2014.

61. Martin R, de Preux L, Wagner J. The impact of a carbon tax on manufacturing: Evidence from microdata. Journal of Public Economics 2014;117:1-14.

62. Thompson T, Rausch S, Saari R, Selin N. A systems approach to evaluating the air quality co-benefits of US carbon policies. Nature Climate Change 2014.

63. Li M, Zhang D, Li C, Mulvaney K, Selin N, Karplus V. Air quality co-benefits of carbon pricing in China. 2018;8 398-403.

64. Watts N, Amann M, Ayeb-Karlsson S, Belesova K, Bouley T, Boykoff M, et al. The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. Lancet 2017.

65. Myers T, Nisbet M, Maibach E, Leiserowitz A. A public health frame arouses hopeful emotions about climate change. Climate Change 2012;113:1105–12

66. Maibach EW, Nisbet M, Baldwin P, Akerlof K, Diao G. Reframing climate change as a public health issue: an exploratory study of public reactions. BMC Public Health 2010;10:299.

67. Environics Health Research. Public Perceptions of Climate Change and Health Final Report. Health Canada,; 2017.

68. Cunsolo A, Ellis N. Ecological grief as a mental health response to climate change-related loss. Nature Climate Change 2018;8:275-81.

69. Hayes K, Poland B. Addressing Mental Health in a Changing Climate: Incorporating Mental Health Indicators into Climate Change and Health Vulnerability and Adaptation Assessments. Int J Environ Res Public Health 2018;15(9).

70. Riley S. 'The lost summer': the emotional and spiritual toll of the smoke apocalypse. 2018. [cited Aug 21, 2018]. Available from: https://thenarwhal.ca/the-lost-summer-the-emotional-and-spiritual-toll-of-the-smoke-apocalypse/.

71. Berry P. Personal CommunicationHoward C. 2018 Located at.

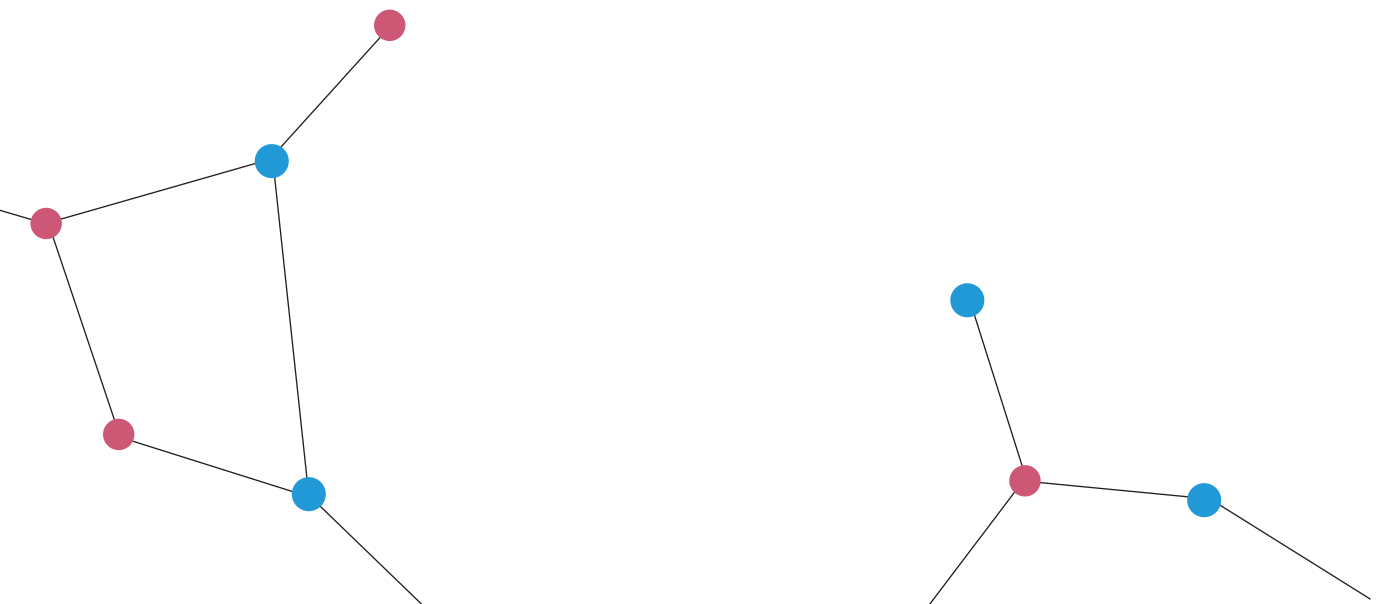
72. Canada Bikes CW, National Active and Safe Routes to School Working Group. Support the Call for a National Active Transportation Strategy. 2018 [October 25, 2018]; Available from: https://activetransportationcanada.weebly.com/

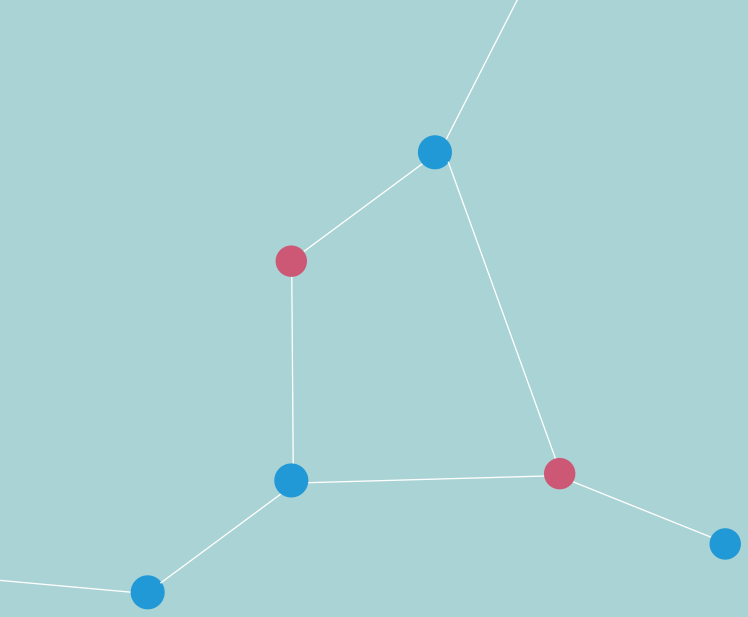
73. Joule. Virtual Care Connects. 2018 [October 25, 2018]; Available from: https://joulecma.ca/innovate/vc

74. Government of Canada. Revision process for Canada's Food Guide. Health Canada; 2018 [Oct 25, 2018]; Available from: https://www.canada.ca/en/health-canada/services/canada-food-guides/revision-process.html

75. Aalhus M. The Social Determinants of Health Impacts of Resource Extraction and Development in Northern Communities Northern Health Authority, British Columbia,: BC Observatory for Population and Public Health and Northern Health, BC Centre for Disease Control, BC Observatory Population and Public Health; 2018.

76. Government of Canada. A proposed new impact assessment system. 2018; Available from: https://www.canada.ca/en/services/environment/conservation/assessments/environmental-reviews/environmental-assessment-processes.html





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LANCET COUNTDOWN: TRACKING PROGRESS ON HEALTH AND CLIMATE CHANGE

ASSOCIATION MÉDICALE CANADIENNE

CANADIAN MEDICAL ASSOCIATION

CANADIAN PUBLIC HEALTH ASSOCIATION

ASSOCIATION CANADIENNE DE SANTÉ PUBLIQUE

The Voice of Public Health
La voix de la santé publique

This is Exhibit "E" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.

The Chief Public Health Officer's

Report on the State of Public Health in Canada

2008

Addressing Health Inequalities

Canada

CHAPTER 2

Public Health in Canada

What is public health?

In Canada, there is a tendency to equate health with health care. That is understandable, given that Medicare is not only a source of national pride but also an important contributor to Canadians' health. Yet, there is certainly more to health than hospitals and medical services.[3, 4]

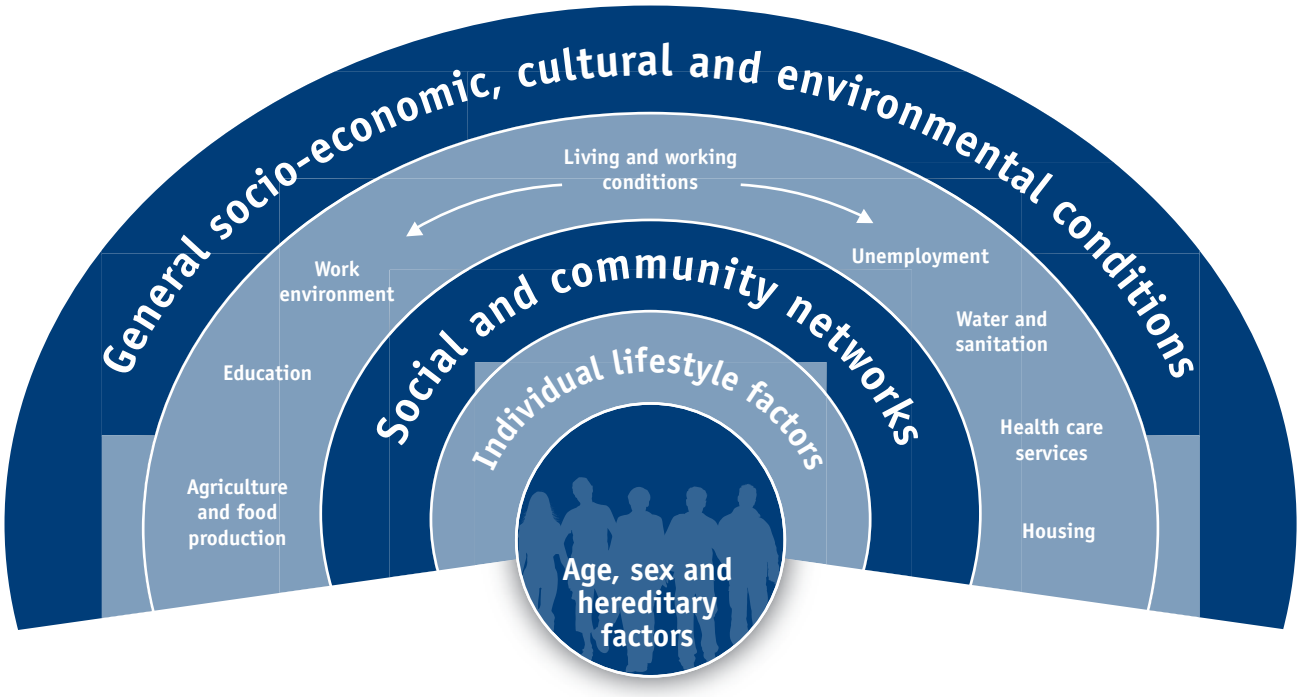
Public health is defined as the organized efforts of society to keep people healthy and prevent injury, illness and premature death. It is a combination of programs, services and policies that protect and promote the health of all Canadians.[5]

While health care focuses on treating individuals who are not well, public health works to keep people from becoming sick or getting sicker. Both work to limit the impact of disease and disability.[3] While individuals receive and benefit from services of the public health system, public health programs target entire populations – not just individuals – by identifying and reducing health threats through collaborative action involving many sectors of society.[2, 6]

Public health challenges Canadians to recognize that physical and mental health are intricately connected to the environment and society.[7] The way Canada, as a country, deals with issues such as poverty, housing, sanitation and environmental protection directly and indirectly influences the health of the population. The presence or lack of family support and social networks, access to education and jobs, workplace safety, and community cohesion and development also influence health.[8]

Those involved in public health are often invisible to Canadians until serious health events such as SARS, Avian Influenza or West Nile Virus occur. Emergency preparedness and response, in the face of infectious disease outbreaks or other health-related emergencies, is certainly one of the primary functions of public health. However, disease and injury prevention, and the promotion of healthy lifestyles and environments are also central responsibilities of public health.[6] Unhealthy eating habits, too little

Figure 2.1 Factors that influence our health[9]



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physical activity, smoking, alcohol and drug abuse are major contributors to many chronic diseases, as are environmental factors and social conditions that do not support healthy lifestyles or that directly impair health. For this reason, disease prevention and health promotion efforts are applied to a range of largely avoidable or deferrable conditions such as heart disease, diabetes, cancer and Human Immunodeficiency Virus-Acquired Immune Deficiency Syndrome (HIV-AIDS).

Although Canadians are among the healthiest people in the world, public health data and research reveal that some groups are more likely to experience poorer health and earlier death than others.[2] Understanding the causes of these inequalities through health surveillance and population health assessment activities, and developing interventions that reach these groups are also essential elements of public health action.[10]

Public health is a responsibility shared by many actors including federal, provincial and territorial governments, municipalities as well as Aboriginal Peoples' organizations and their governments.[3] Governments enact laws and regulations to protect the public from health hazards posed by such things as contaminated water, second-hand smoke or working conditions that endanger employee health and safety. Health professionals, in a variety of settings, work under or in concert with these laws and regulations at the community level.[6] Among other things, they monitor and assess health conditions and chronic diseases, investigate infectious disease outbreaks, inspect restaurant kitchens and water supplies, provide vaccinations, and offer advice and support/counselling on issues including nutrition, physical activity, tobacco and alcohol control, injury prevention and sexual health.

While governments enact laws, develop policies and provide resources to fund public health organizations, it takes the combined effort of networks both within and outside the public health system to address population-wide health challenges. These health networks include professionals such as physicians, nurses, public health inspectors, health promoters, dental workers and nutritionists.[6] They may also include community agencies, volunteer organizations, the academic community and international bodies that work toward common goals. Equally vital are indirect players, including media outlets that report health-related news in Canada and provide healthy living information, social marketers, fitness instructors, adults who set good examples for children by taking care of their own health, and employers who provide time or flexible work arrangements for employees to be physically active and to care for children or older or sick relatives. So too, are engineers and transportation workers who make Canada's highways safer, food producers who follow regulations to ensure that what we eat is safe, and not-for-profit groups that fight poverty and encourage Canadians to get active, recycle and reduce energy consumption.

While there are many ways to describe public health activities, within Canada and in the legislation for the Public Health Agency, the below six activities are generally referenced.

Health protection – Actions to ensure water, air and food are safe, a regulatory framework to control infectious diseases, protection from environmental threats, and expert advice to food and drug safety regulators.

Health surveillance – The ongoing, systematic use of routinely collected health data for the purpose of tracking and forecasting health events or health determinants. Surveillance includes: collection and storage of relevant data; integration, analysis and interpretation of this data; production of tracking and forecasting products with the interpreted data, and publication/dissemination of those products; and provision of expertise to those developing and/or contributing to surveillance systems, including risk surveillance.

Disease and injury prevention – Investigation, contact tracing, preventive measures to reduce the risk of infectious disease emergence and outbreaks, and activities to promote safe, healthy lifestyles to reduce preventable illness and injuries.

Population health assessment – Understanding the health of communities or specific populations, as well as the factors that underlie good health

or pose potential risks, to produce better policies and services.

Health promotion – Preventing disease, encouraging safe behaviours and improving health through public policy, community-based interventions, active public participation, and advocacy or action on environmental and socio-economic determinants of health.

Emergency Preparedness and Response – Planning for both natural disasters (e.g. floods, earthquakes, fires, dangerous infectious diseases) and man-made disasters (e.g. those involving explosives, chemicals, radioactive substances or biological threats) to minimize serious illness, overall deaths and social disruption.[6, 11]

The population approach to improving health is not really new; it has played out in various forms over the history of humankind. As it has evolved, it has not been without serious challenges and failures. Many health problems that have plagued the developed world in the past – such as previously common infectious diseases, unsafe water and sewage, and workplace hazards – may no longer seem important, but their absence should not be taken for granted. It is important to remember that public health advances often involved great struggles to overcome major obstacles and sometimes fierce opposition. As well, societies' solutions may not have always been appropriate and, in some cases, may even have worsened the problems or helped some people but not others.

Obesity – An Illustration of the Public Health Approach

In Canada, 65% of men and 53% of women are either overweight or obese.[12] Among children and youth (aged 2 to 17 years), rates of obesity have almost tripled – from 3% in 1978 to 8% in 2004, and another 18% are considered overweight.[13] Obesity is a key risk factor for heart disease, joint problems and Type 2 diabetes, so it is critical that Canada find a way to reverse this trend.[14]

How is this done? The public health approach first requires an understanding of the causes of obesity in the population and then of the ways to influence or mitigate these causes. On the surface, the cause of obesity may seem simple: individuals consume more energy, or calories, than they burn. But why do some people consume more calories than others and/or lead less active lives? Is it simply that people do not realize the impact of their choices? Or is it that behaviours are part of a broader situation determined by life experience: early childhood development; education; the stress and pace of life; the cost, availability and accessibility of nutritious food; super-sizing; and lack of opportunities for physical activity?

To address obesity, then, there needs to be an understanding of these broader influences, how to help people make healthy choices the easy choices and how to create conditions for better health. This will, in turn, involve an examination of the factors that affect access to healthy food, food choices, consumption, recreation and physical activity. These include, for example, agriculture practices, food processing, advertising, education, income, time pressures, urban planning, transportation systems, urban green spaces and recreation facilities.

The more the causes and effects of obesity are examined, the clearer it becomes that solutions must address a complex and inter-connected network of underlying issues. It requires the right mix of interventions, followed by an evaluation of those interventions. This is a difficult, but worthwhile, endeavour. When this type of effort is made and the root causes of obesity are examined and tackled, other positive impacts on health and quality of life result.

CHAPTER 2

Public Health in Canada

Canada's public health history

Prior to Europeans arriving and settling in North America, Canada was inhabited by millions of Indigenous peoples.[15] The origins of public health in this country can be traced back to traditional Aboriginal teachings that highlight the importance of maintaining and restoring balanced health through social and environmental sensitivity.[16, 17] These long-standing traditions were jeopardized following the arrival of European settlers who brought new diseases and a way of life that led to a serious deterioration in the lives of Canada's Indigenous Peoples.[16]

The threat of infectious diseases began to impact Indigenous peoples in North America in the early seventeenth century, with the first historically recorded outbreaks occurring between 1734 and 1741. The arrival of settlers not only meant illness and death for Aboriginal Peoples, but also a loss of traditional lands, resources and livelihoods – creating a new lifestyle involving competition, exploitation and a loss of long-standing norms, values, and societal and spiritual practices. These factors, along with others, allowed for an all too easy transition from a state of good health to ill health.[16]

1830-1900

Early settlers were not spared from infectious diseases.[15] In 1832, an estimated 20,000 lives were lost in Upper and Lower Canada from a cholera epidemic. In an attempt to contain the disease, the Lower Canada Board of Health created a quarantine station for new arrivals on Grosse Île in the St. Lawrence River. Quarantine measures were enforced by the military to prevent the spread of the disease through Upper and Lower Canada.[18]

In 1847, the next wave of infectious disease, typhus, killed 6,000 of the estimated 100,000 Irish settlers fleeing the potato famine in their home country.[19] Again, quarantines of new immigrants were instituted. Unfortunately, this may have actually fuelled the spread of typhus since people in quarantine were more likely to contract the disease.

The Aboriginal population was exceptionally susceptible to these disease outbreaks because they lacked immunity to the new infections and their resistance to disease was further jeopardized through exposure to less healthy ways of life. Countless Aboriginal people succumbed to epidemics of smallpox, tuberculosis, diphtheria, typhus, measles and syphilis. In some cases, whole communities all but disappeared.[15]

While Canada battled these waves of disease, research was underway in Europe to identify the sources of, and potential solutions to, these challenges. In 1842, a British report, *The Sanitary Conditions of the Labouring Population of Great Britain*, concluded that clean water, sewers and adequate housing were essential to prevent the spread of infectious disease.[20] The report led directly to the first *Public Health Act* in the United Kingdom in 1848, which established a central Board of Health with local boards.[21] The Board of Health often felt opposition from those who considered the Act to be a threat to "property rights and personal freedom" and the British government refused to renew the Act after the first five years.[22]

In 1867, Britain established the *British North America Act* (became the *Constitution Act* in 1982). The Act was used to create the Canadian Confederation and enforced the division of power between the provinces and the federal government. Within Sections 91 and 92, the newly created Dominion of Canada was responsible for the creation of quarantine and marine hospitals and the provinces were responsible for the establishment, maintenance and management of hospitals and asylums.[23]

Few public health initiatives were developed and activities were haphazard during the remainder of the 19th century, varying from city to city and from province to province. This may have been because, by the turn of the century, there was "a very remarkable decrease in the communicable diseases with which we are familiar" (*1900 Annual Report of the Provincial Board of Health for Ontario*), thanks in large part to improvements in water and sanitation and public infrastructure.[24]

Water, Sanitation and Health in Canada

The link between water, sanitation and health has been known for centuries – tainted water supplies and deficient sanitation practices can cause illness and death among those exposed to these conditions.[25, 26] Although Canada has an abundance of fresh water, disease outbreaks related to water and sewage practices were commonplace among early settlers. It wasn't until the beginning of the last century that officials embraced the water/waste/health connection and began to actively pursue adequate sanitation and clean water systems with an eye to improving and maintaining public health.

There is no doubt that advances in sanitation, water treatment and distribution directly contributed to a reduction in mortality rates in Canada and the elimination of water-borne diseases such as cholera and typhoid.[27, 28, 29]

Today, standards and policies supporting legislation exist at all levels of government to deal with water quality and sanitation.[30] The majority of citizens have the benefit of high-quality water treatment systems, although some Canadian communities – particularly those that are small, rural and remote – may face boil water advisories. These are issued to reduce the risk of waterborne diseases when conditions suggest possible increases of microbiological contamination.[31]

Canada is continuing its work on developing and employing innovative technologies while maintaining a careful watch on water and sanitation systems across the country.[32] At the same time, it is shifting its focus toward a more sustainable use of fresh water that favours reduced water demand over increased supply.[33]

While waterborne diseases came mostly under control, other contagious diseases remained the leading causes of death in Canada.[34] Diseases including scarlet fever, diphtheria, measles, whooping cough, and tuberculosis continued to put the public's health at risk.[15] In Ontario alone, 36,000 children died from diphtheria between 1880 and 1929.[35] In the mid-1880s smallpox remained a threat, with Montréal experiencing the last major epidemic in a North American city.[36]

1900-1950

In the early part of the 20th century, public health activities continued to be largely uncoordinated and mostly in response to infectious disease outbreaks. Aboriginal Peoples' health and social conditions reached a low point, as traditional ways of life (e.g. consuming whole foods, maintaining high activity levels, practicing natural medicine) continued to be significantly weakened and suppressed.[16]

However, some significant public health developments did emerge during this period. For example, immunization against smallpox and diphtheria had begun in Ontario schools.[37, 38] About the same time, cities such as Toronto and Montréal began to pasteurize milk against bovine tuberculosis and towns, such as Peterborough, began using chlorination to disinfect drinking water.[39, 40, 41]

Public health activities accelerated when Canadian soldiers returned home from the First World War, bringing with them the Spanish influenza of 1918-1919.[42] An estimated 40 to 50 million people were killed worldwide by the pandemic, including approximately 50,000 Canadians.[42, 43] Once on Canada's shores, the virus spread quickly across the country, even to remote communities.[43]

Conscious of the need to manage federal health functions, the Canadian Public Health Association played a key role in advocating for the creation of a Department of Health in 1919.[44, 45] The department retained functions of quarantine and ensuring food and drug standards, but also acquired new responsibilities to implement campaigns against sexually transmitted infections (STIs) and tuberculosis, as well as to promote child welfare.[45]

CHAPTER 2 Public Health in Canada

The next two decades were periods of major contrasts. Most Canadians' standard of living was on the rise as employment and incomes increased and education and housing improved, resulting in better living conditions and enhanced nutrition. Childhood immunization against infectious diseases was becoming commonplace, life-altering scientific discoveries – such as insulin and penicillin – led to treatments for diabetes and infection, and new techniques were introduced to treat injuries, all of which helped to improve the health of Canadians.

However, the Canadian economy and society were dealt a serious blow during the Great Depression of the 1930s. As farmers went bankrupt and industries in towns and cities collapsed, people lost their homes and livelihoods. The uprooted and unemployed became migrants and, in some cases, vagrants – homeless, hungry and frequently ill. The Depression was quickly followed by the Second World War (1939-1945), which again took a toll on the health of individuals and the well-being of society. As well, the prevalence of polio, another highly contagious, frequently disabling and sometimes fatal disease, during this era reinforced that infectious diseases remained a serious threat to public health.[46]

These events laid the groundwork for contemporary concepts of public health as Canada recognized its obligation to look after returning soldiers and the population at large. A range of initiatives were launched to strengthen the social fabric of the country, from the construction of new housing to the provision of education for returning soldiers and their families.[47, 48, 49]

The Case for Immunization

Before the benefit of mass immunization, generations of Canadians lived with the threat of a range of debilitating diseases that frequently swept through their communities.

Polio, for example, left many people paralyzed or otherwise disabled. At its peak in 1953, it caused nearly 500 deaths in Canada. Two years later, an injectable polio vaccine was introduced and incidence of the disease dropped dramatically.[46] By 1994, all of the Americas were certified polio free.[50] Today, it has been eliminated from most parts of the world.

Measles is another contagious disease that has afflicted millions worldwide. According to the WHO (2002), it is the leading global cause of vaccine-preventable death in children under the age of five.[51] Before the introduction of a measles vaccine in the early 1960s, Canada averaged 300,000 to 400,000 annual cases.[52] By 1995, that number had dropped to 2,362 and adopting an improved two-dose program in 1996 has resulted in a further decline.[53]

Canada's success in reducing and eliminating vaccine-preventable diseases can be largely attributed to high vaccine coverage rates. However, work in this area is ongoing as certain populations continue to exhibit lower coverage rates.[54, 55] This may be the result of barriers to awareness and access, or because of differing cultural norms.[56]

Today, Canada maintains various surveillance systems to assure Canadians that vaccines continue to be safe and effective and to allow early interventions and control measures to be implemented in the event of a disease outbreak.[54, 56]

Canada's first food guide was introduced in 1942 to reduce nutritional deficiencies resulting from wartime food rationing.[57] This development was followed by the 1944 family allowance, a universal program to help families raise healthier children.[58] In 1947, Saskatchewan introduced the first hospital insurance program to ensure that personal finances would not be a barrier to receiving health treatment.[59]

During this same period, a broader understanding of health was emerging at the international level by global bodies like the World Health Organization (WHO). In 1948, the WHO defined health as: "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[60] The newly formed organization set standards and agreed on regulations to promote health among member countries and began providing assistance to promote disease surveillance.[61]

1950-present

Following the Second World War, the country prospered and the health of the population improved. By 1950, mortality rates were reduced by one quarter compared to those of 1921 (9 per 1,000 compared with 12 per 1,000) and the number of deaths attributable to infectious diseases was significantly reduced.[34, 62]

The post-war economic boom resulted in new jobs and rising affluence. More people were completing higher levels of education and more women participated in the workforce.[63, 64] While women of the previous generation had advocated for the right to vote, women of the post-war era fought for better educational and job opportunities, equal wages, and paid maternity leave, resulting in an improvement to the factors (or determinants) that impact health.[63, 65] In addition, broad social programs such as the Canada Pension Plan (CPP) and Old Age Security (OAS) were introduced.[66] Access to acute hospital services was guaranteed through the 1957 *Hospital Insurance and Diagnostic Services Act*, while the 1966 *Medical Care Act* afforded access to insured medical services.[59] In 1962, the Medical Services Branch of the Department of National Health and Welfare was established with a primary mandate of supporting Indian and Inuit Health.[67]

Trimming Tobacco Use in Canada

A hundred years ago, it was believed that tobacco was beneficial and its use was encouraged. By 1965, half the Canadian population over 15 years old smoked.[78] As smoking rates continued to rise, research uncovered the truth – tobacco use is an addiction that harms the health of the smoker and those exposed to second-hand smoke.[79] Once these dangers were understood, Canada began to take action through tobacco control strategies involving concerted effort across all levels of government, including: education and promotion, taxation, introduction of smoking by-laws and cessation support.

The most recent data from the 2006 Canadian Tobacco Use Monitoring Survey (CTUMS) show that these efforts have paid off. Only 19% of the Canadian population now smokes.[80] In addition:

- more than half of Canadians who have ever smoked have quit;
- every region in the country is experiencing success in decreasing smoking rates among all age groups; and
- Canada is one of the first countries in the world to see a decrease in youth smoking.

Today, Canada is universally recognized as a leader in tobacco control and shares its experience with other nations under the WHO *Framework Convention on Tobacco Control*.[81]

Despite these achievements, Canada needs to continue pursuing tobacco reduction efforts – especially among populations with higher rates of smoking and where children are still regularly exposed to second-hand smoke.

This period also presented new challenges, however, as people were living longer and chronic diseases and injuries increasingly became the more common cause of disability and death.[68] Other trends emerged, such as widespread smoking, increased social drinking, the recreational use of drugs, a resurgence of STIs and the introduction of new infections like HIV-AIDS. Meanwhile, the proliferation of cars led to a reduction in physical activity as well as an increase in smog, air pollution, and injury and death related to motor vehicle crashes.[69, 70, 71]

The discipline of epidemiology began to explore the causes of these trends with a view to their prevention.[5] Many studies identified associations between smoking and lung cancer; diet, physical activity and heart disease; seatbelt use and road traffic injuries; and air pollution and worsening of asthmatic conditions.[72, 73, 74, 75, 76, 77]

Globally, Canada was at the forefront of the public health approach with the 1974 Federal publication of *New Perspectives on the Health of Canadians* by then Minister of Health Marc Lalonde. The report helped Canadians to understand that achieving good health requires more than just a good health care system and it emphasized the importance of human biology, environment, lifestyle, health care organization and the need to "understand what contributes to sickness and death, and to facilitate the identification of courses of action that might be taken to improve health." It also highlighted the impacts of social influences on health and underscored that social inequalities can lead to health inequalities. And the report emphasized the need for greater inter-sectoral collaboration in research, community development, social marketing and public policy to adequately address the various factors that determine health.[82]

The Lalonde Report had a profound impact on public health practice around the globe, highlighting the benefits of investment in promoting health and preventing illness and injury to reduce pressure on the health care system.[83] It led to renewed efforts to develop new approaches in health promotion, community advocacy and the use of legislation.

The Proven Benefits of Buckling Up

Between 1975 and 2003, traffic fatalities decreased by over 50% in Canada even though the number of drivers and cars on the road increased substantially.[84] Part of the reduction may be credited to an increase in seatbelt use with 90% of Canadians now buckling up when riding in or driving a motorized vehicle.[85]

Achieving this improvement was not easy. Seatbelts did not become standard equipment in Canadian vehicles until the late 1960s.[86] Use was voluntary and very limited until the next decade when medical professionals linked the use of seatbelts in traffic crashes with lower incidences of serious injury and death.[87]

Public awareness campaigns followed, as did legislation making seatbelt use mandatory. The first law was passed in Ontario in 1976. By the late 1980s, all provinces and territories had adopted similar legislation.[88]

Although rates of traffic deaths and injuries have greatly improved, more can be done – especially with respect to child safety. Roadside checks have shown that just 51% of children are buckled up and more than 80% of car seats are improperly installed.[89]

As a result, new public awareness campaigns have been launched and legislation for mandatory vehicle booster-seat use has been passed by seven provinces to ensure the safety of children too big for a car seat but too small for an adult seatbelt.[90]

In the early 1980s, the *Canada Health Act* was passed, updating the preceding *Hospital Insurance and Diagnostics Services Act* and the *Medical Care Act*. It ensured comprehensive, universal and accessible insured health care services to all Canadians without cost or discrimination based on age, health status or financial situation.[91] During this decade, Canada further developed the concept of health promotion with the publication of *Achieving Health for All: A Framework for Health Promotion* as tabled by then Minister of Health Jake Epp in 1986.[92] The Epp Report placed greater focus on the determinants of health – specifically identifying income-related health inequalities as an area for priority action and recognizing that health behaviours are not just a by-product of personal choice, but also of the surrounding environment.[93] In the same year, Canada responded to the growing international public health movement by hosting the first *International Conference on Health Promotion*. The Ottawa Charter for Health Promotion, presented at the conference, called on countries to establish strategies and programs for health promotion through building healthy public policy, creating supportive environments, strengthening community actions, developing personal skills and reorienting health services.[94]

In keeping with the Ottawa Charter, the decade that followed was a productive one for Canada in the health and health promotion fields. Early in the 1990s, the creation of a Breastfeeding Committee for Canada sought to establish breastfeeding as the cultural norm across the country and a new Canadian Institute for Health Information provided an independent means of amassing essential data and imparting analysis on Canada's health system and the health of Canadians.[95, 96] Several key reports were also released, including the *Report of the Royal Commission on Aboriginal Peoples* (1996) and the first and second reports on the *Health of Canadians* (1996 and 1999).[97, 98] The *Tobacco Act*, passed in 1997, provided new regulations on the manufacture, sale, labelling and promotion of tobacco products.[99] And at the end of the decade, efforts to improve the nation's understanding of population health culminated in the creation of a Canadian Population Health Initiative (CPHI).[100] The growing burden of HIV infections and outbreaks of invasive meningococcal disease that affected school and college-aged youths served once again as reminders that infectious diseases remained a challenge.[101, 102, 103, 104]

Another reminder came in 2003 with the arrival of Severe Acute Respiratory Syndrome (SARS) in Canada. Caused by a virus that originated in Asia, SARS claimed the lives of 30 Canadians and significantly damaged segments of the Canadian economy.[105] In the aftermath of SARS, it became clear that the next infectious disease emergency may now be just a plane ride away. Canadians also realized that, for all the strengths of Canada's health care system, exceptional care alone is not enough to protect them from the full range of threats to their health and safety.

The lessons of SARS, including recommendations from Dr. David Naylor's report, *Learning from SARS: Renewal of Public Health in Canada*, were the primary drivers behind the creation of the Public Health Agency of Canada in 2004.[2, 6] The Agency has essential responsibilities related to preventing diseases and injuries, promoting good health, preparing for emergencies and strengthening the public health infrastructure in Canada. Additionally, it strives to understand and address the basic factors that determine individual and population health in Canada.[107]

Public Health Agency of Canada

Mission

To promote and protect the health of Canadians through leadership, partnership, innovation and action in public health.

Vision

Healthy Canadians and communities in a healthier world.[106]

Also in 2004, Canada's First Ministers committed to the development of "goals and targets for improving the health status of Canadians through a collaborative process".[108] The following year, the Public Health Agency of Canada led the broad consultation and validation process that culminated in a set of goals (the Health Goals for Canada) that were agreed on by the Federal, Provincial and Territorial Ministers of Health (see Appendix C).

CHAPTER 2 Public Health in Canada

Most recently, Canada hosted the 19th International Union for Health Promotion and Education World Conference – *Health Promotion Comes of Age: Research, Policy & Practice for the 21st Century*. The event, held in 2007, provided an opportunity to reaffirm the commitment and vision of the Ottawa Charter, as well as the chance to look to the future and enhance partnerships and inter-sectoral collaborations for health promotion.[109]

A work in progress

Canada has made great strides in implementing public health initiatives to maintain and improve the health of Canadians. Considerable challenges remain however, as recent decades have seen the rise of new diseases as well as the continuation of old problems that still threaten the health of the population.

For example, 2,923 Canadians lost their lives on Canada's roads in 2005 despite safety improvements over the years.[110] Although this number is in decline due to better roads and safer cars, speeding, and dangerous and impaired driving are still serious risks.

Physical environments can also result in adverse health effects. Conditions associated with climate change – such as rising temperatures and extreme weather events – and migrating species/diseases, such as West Nile Virus, can lead to illness and death among vulnerable populations.[111] Air quality is of great concern as the number of 'smog days' is increasing in Canadian cities and the impact on health for children, seniors and those suffering from pre-existing illness such as cardiovascular and respiratory diseases, is significant.[112]

The necessity of clean water and reliable infrastructure was reinforced with the *E.coli* contamination of the community water supply in Walkerton, Ontario in 2000 where the water-borne infection claimed seven lives and left almost half the town's population ill.[113] The following year, the community water supply in North Battleford, Saskatchewan was contaminated with cryptosporidia which caused between 5,800 and 7,100 people to become ill.[114]

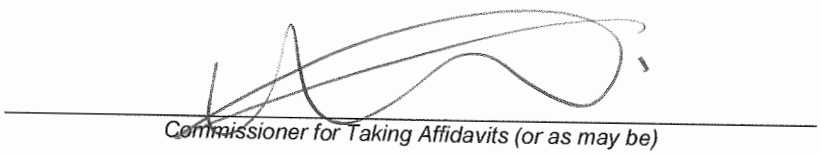
Sedentary lifestyles and escalating obesity rates are risk factors for preventable conditions, such as Type 2 diabetes, which reduce Canadians' quality of life and put their lives at risk.[12, 14] Each year in Canada, about three quarters of all deaths result from circulatory diseases, cancers, diabetes and respiratory illnesses.[115] Moreover, 51% of all years lost to premature death were caused by cancer, circulatory diseases and respiratory diseases in 2001.[116]

Serious health challenges such as stress, mental illnesses and suicide also continue to be major problems. One in five participants in the 2002 Mental Health and Well-being Survey indicated that they had experienced a mental illness (such as anxiety disorders, depression and substance dependence) at some point during their lifetime. Mental illnesses affect people in all occupations, education levels, socio-economic conditions and cultures. And, despite the fact that most Canadians will be affected by mental illness themselves, or through a family member, friend or colleague, reducing the stigma associated with mental illness continues to be the greatest challenge to treatment and care.[117, 118]

There is also an unequal distribution of health in Canada. Poverty, which is often linked to low education and employment levels, is also linked to people being less healthy on average. Research has shown repeatedly that persons with low incomes are more likely to experience illness and use the health care system, and those who are ill are often more likely to become economically disadvantaged.[119, 120, 121] Studies also show that other factors like education, early childhood development and social support can compound or mitigate these inequalities.[7, 122] Poverty then is not simply an issue of lack of money, but a cluster of disadvantages of which economic poverty is a key driver. This will be explored further in Chapters 3 and 4.

For all the progress that has been achieved to date, it is clear that considerable work remains to be done. However, these ongoing challenges do not diminish the extraordinary strides in Canada's public health history. In the past century, life expectancy for women has soared from 50 to 83 years and from 47 to 78 years for men.[123, 124] Improved sanitation, living conditions, community development measures, and innovations such as immunization have dramatically demonstrated effectiveness in preventing premature death and improving Canadians' health and quality of life. Continuous improvement in public health action will be required throughout the 21st century to sustain this impressive record.

This is Exhibit "F" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018



Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat, a Commissioner, etc., Province of Ontario, while a Student-at-Law. Expires May 1, 2020.

CANADIAN PUBLIC HEALTH ASSOCIATION
DISCUSSION PAPER

Global Change and Public Health:

Addressing the Ecological Determinants of Health

May 2015

Founded in 1910, the Canadian Public Health Association (CPHA) is the independent voice for public health in Canada with links to the international community. As the only Canadian non-governmental organization focused exclusively on public health, CPHA is uniquely positioned to advise decision-makers about public health system reform and to guide initiatives to help safeguard the personal and community health of Canadians and people around the world. CPHA is a national, independent, not-for-profit, voluntary association. CPHA's members believe in universal and equitable access to the basic conditions which are necessary to achieve health for all.

Our Vision

A healthy and just world

Our Mission

CPHA's mission is to enhance the health of people in Canada and to contribute to a healthier and more equitable world.

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ASSOCIATION CANADIENNE DE SANTÉ PUBLIQUE

Canadian Public Health Association
Discussion Document

Global Change and Public Health: Addressing the Ecological Determinants of Health

May 2015

Foreword

The future of life on Earth cannot be taken for granted as our species has the capacity to influence that future – for good or ill. Armed with a new understanding of key principles, concepts and values, we can create a healthier, more just, more sustainable future. Fortunately, a vast informal movement is already at work for the common good and a better future with goals that reflect the essence of the public health tradition to galvanize public health workers and organizations in Canada and around the globe.

This discussion document is based on a 2015 report about the ecological determinants of health developed by a Canadian Public Health Association (CPHA) working group.[1] The first two chapters of the report address the context for thinking about the ecological determinants of health, while chapters 3 through 5 identify the challenges we face – the main ecological changes, the social forces behind those changes and their health implications. Chapters 6 and 7 turn from a review of the past and the troubling health implications of declining ecological functions to consider the reasons for finding hope for the future. Chapters 8 and 9 describe an agenda for action. This document reflects the structure and summarizes the key elements of that report.

This paper is not the definitive word on the topic of the ecological determinants of health. Its goal is to begin a conversation, stimulate debate and ultimately motivate the public health community to action. The 100-page condensed version of the working group's complete 350-page technical report can provide readers with considerable detail on the topics touched upon here.

Many people were involved in the development of this body of work. CPHA's Board of Directors gratefully acknowledges the contributions of the members of the working group, reference group, volunteers and student practicum placements. See Appendix A for a complete list of contributors.

Table of Contents

Executive Summary

The relationship between human beings and the ecosystems of which they are a part is profound. The links between health and the environment are as old as human culture. Human evolution takes place within ecosystems, and there are deep psychological, social and cultural connections to ecosystems that go well beyond mere physiological needs.

In the late 20th and early 21st centuries, myriad threats to the health of the Earth's environment have become apparent. There is a growing recognition that the Earth is itself a living system and that the ultimate determinant of human health (and that of all other species) is the health of the Earth's life-supporting systems. The ecosystem-based 'goods and services' that we get from nature are the ecological determinants of health. Among the most important of these are oxygen, water, food, fuel, various natural resources, detoxifying processes, the ozone layer and a reasonably stable and habitable climate.

Public health in the 21st century must augment its scope to address the natural world; encompass concepts such as One Health and Ecohealth; and specifically target the health challenges of human-induced global climate change, resource depletion, ecotoxicity and loss of biodiversity.

Our knowledge of the health impacts of global ecological change is surprisingly limited. What we know is imprecise, preliminary and often speculative; we have some idea of the big picture, but the details are lacking. Even in the case of climate change, we have only a modest sense of the potential health impacts, although this has been the focus of some well-resourced research over the past few decades, both globally and in Canada.

We do know that the indirect health effects of global ecological change – those mediated through natural and human systems – are likely to be much greater than the direct effects (such as heat waves), although they are harder to quantify and attribute directly to a specific global change. This difficulty in quantifying the indirect health effects is part of the uncertainty with which we must deal.

The key human forces driving changes in ecosystem functioning are population growth and urbanization, economic growth and development, technological changes and advances, and social changes and movements aligned to these forces. Underlying and shaping these drivers are societal and cultural values, which for the past 200 to 300 years have emphasized 'progress' or modernization, transforming human societies from rural and agrarian to secular, urban and industrial. The long history of modernization helps us to understand our current social, political, economic and cultural conditions, and, perhaps, to anticipate a post-modern society that enables us to stabilize and reverse these harmful ecological changes.

We will need some fundamental shifts in societal values, and with that new principles, and new ways of knowing, measuring and governing. Fortunately, we do not have to invent these from scratch as we have precedents and newly-emerging practices that can help provide a foundation for the new future we need to create. The fields of health promotion and Ecohealth offer conceptual and procedural guidance to catalyze a transformation toward public health equity for future populations.

If we understand the forces that shape us and the future we face, we are better equipped to make choices, express our values in a vision and then work to create it. Within public health, we need to explore scenarios of plausible futures, and help people create visions describing their preferred future.

CPHA's vision of healthier, more sustainable, more just societies and communities will not be achieved in isolation from wider social processes. Realizing any such vision will demand transitions both within and outside public health and the larger health sector, including an explicit re-engagement with the values of public health.

Introduction

The relationship between human beings and the ecosystems of which they are a part is profound. The links between health and the environment are as old as human culture. For thousands of years, Indigenous peoples have viewed the Earth as Mother and have understood health in the context of community and the environment. Two and a half thousand years ago, Hippocrates wrote "On Airs, Waters, and Places", investigating the relationships between places, health and disease. Human evolution takes place within ecosystems, and there are deep psychological, social and cultural connections to ecosystems that go well beyond mere physiological needs.

In more recent history, modern public health originated in the struggle to overcome sickening environmental and social conditions that resulted from urbanization and industrialization. The emphasis was on sanitation and hygiene, water supply and treatment, improved living and working conditions and later on immunization, domestic hygiene, and improved nutrition.

The 1974 Lalonde Report that positioned socioeconomic factors as determinants of health, the World Health Organization's (WHO) 'Health for All' approach of the late 1970s and the rise of health promotion in the 1980s ushered in a 'new' public health, based in a socio-ecological model. Health promotion recognized stable ecosystems and sustainable resources as prerequisites for health and championed healthy public policy and a settings approach, launching the Healthy Cities and Communities approach.[2] In the early 1990s, the concept of population health emerged in Canada with a focus on the determinants of health nationally and internationally, and specifically on the 'social' determinants that include housing and the built environment. These movements culminated in the WHO Commission on the Social Determinants of Health, which tabled its final report in 2008 on avoidable health inequalities and social justice.

In the late 20th and early 21st centuries, myriad threats to the health of the Earth's environment have become apparent. The first United Nations (UN) Conference on the Environment was held in Stockholm in 1972, when the UN Environment Program was established (led by a Canadian, Maurice Strong). The UN has worked hard to maintain that focus on and voice for the global environment, with the World Commission on Environment and Development (WCED, referred to as the Brundtland Commission) declaring the importance of sustainable development so that we can "meet the needs of the present without compromising the ability of future generations to meet their own needs."[3] Subsequent international organizations, reports and events, such as the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, as well as the 1992 Rio and 2012 'Rio + 20' Earth Summits have tried to demonstrate the human health implications of global ecological change.

As this work unfolds, there is a growing recognition that the Earth is itself a living system and that the ultimate determinant of human health (and that of all other species) is the health of the Earth's life-supporting systems. The ecosystem-based 'goods and services' that we get from nature are the ecological determinants of health. Among the most important of these are oxygen, water, food, fuel, various natural resources, detoxifying processes, the ozone layer and a reasonably stable and habitable climate.

In recent years, public health has expanded its scope beyond its traditional environmental concerns with domestic and community hygiene and sanitation, infectious disease control, air and water pollution, food safety and toxic chemicals to address (or more accurately, renew our understanding of) the health implications of the built environment. We recognize, for example, that North Americans are 80-90% urbanized and spend 90% of their time indoors. Now we need to deepen and broaden our analysis, acknowledging that we live 100% of the time on a small planet and within natural ecosystems that constitute the ecological determinants of health. Public health in the 21st century must augment its scope to address the natural world; encompass concepts such as One Health and Ecohealth; and specifically target the health challenges of human-induced global climate change, resource depletion, ecotoxicity and loss of biodiversity.

Critical to the success of these efforts is the understanding that the changes in the Earth's ecological systems are driven principally by our social and economic systems, and by the collective values and institutions that support them. As such, we see that the social and ecological determinants of health intertwine and interact, influencing each other and ultimately the health of people, communities and societies, along with the health of countless other species with whom we share the planet.

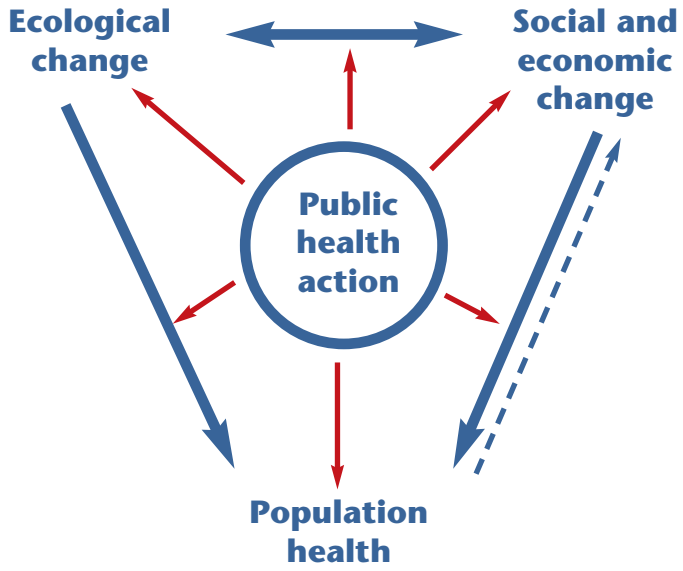

Figure 1: An Ecosocial Framework for Public Health Action

Faced with both growing social inequities and an ecologically unsustainable way of life, public health is now being called upon to adopt what can be best described as an 'ecosocial' approach to health (see Figure 1). We are well positioned to articulate and catalyze a wide range of partners from the public, non-profit, and private sectors, and the faith and academic arenas to address the social and ecological determinants of health from the local to global levels.

Humanity, nature and the Anthropocene

For most of human history, the natural world has been viewed with a mixture of reverence, awe and fear. But over time, humans have developed an attitude of superiority to nature; all too often it is considered something separate from us that we attempt to subdue and control. Our efforts to tame nature have been significant enough to influence, unofficially, the naming of the present geological epoch in which we now live as the 'Anthropocene',[4] reflective of humanity's power over nature.

"The term Anthropocene suggests: (i) that the Earth is now moving out of its current geological epoch, called the Holocene and (ii) that human activity is largely responsible for this exit from the Holocene, that is, that humankind has become a global geological force in its own right."[4]

Nature remains bountiful, with its ecosystems providing the basic necessities of life as they always have. But this bounty is becoming strained, particularly over the past 100 years. As Duwamish Chief Seattle is reported to have said in the mid-19th century, "Man did not weave the web of life; he is merely a strand in it. Whatever he does to the web, he does to himself." In the face of the ecological disturbances we now confront, we may think that the environment is threatening us, but we would be wrong. It is our species that is behind today's global environmental change, the warming of the Earth, the harming of the lifecycles of many species, and the threatening of the Earth's fundamental life-supporting functions. It is we who are creating mass extinctions and depleting both renewable and non-renewable resources. Our ongoing damage to Earth's ecological integrity is being returned, as Chief Seattle said, to harm us. Urgent attention needs to be given to this matter so that we can reverse damaging trends, prevent further declines and avoid potential disaster.

Ecological determinants of health

There are many ecological processes and natural resources essential for the health and well-being of humans and other species. They constitute Earth's life-supporting systems, which serve the needs of humans and of all life. The view that humans are inherently more important than other forms of life ignores the reality that human survival fundamentally depends on a diversity of other life forms, which in turn are interdependent themselves.

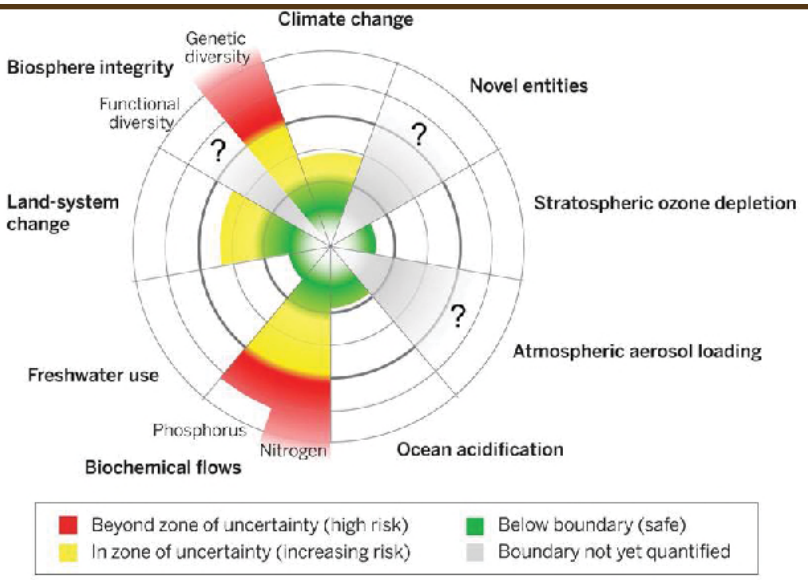

Figure 2: Safe operating boundaries
Source: Steffen et al, 2015.[6]

We recognize that all life plays a role in maintaining human health and, as such, we need to take into account how our actions affect the natural world and deepen our respect, care and sensitivity towards the diversity of life on the planet. Our health and our continued existence as a species depend on healthy natural ecosystems, and on the interdependent web of life comprising these ecosystems.

The ecological determinants of health upon which life depends include at the most basic level adequate amounts of:

- oxygen;
- water; and
- food.

Other vitally important ecological processes and natural resources include the:

- ozone layer that protects Earth's surface from high levels of UV radiation;
- nitrogen and phosphorus cycles that circulate nutrients needed for plants and thus for all our food;
- systems to detoxify wastes through natural processes; and
- abundant fertile soil, fresh water and marine aquatic systems to grow food and other plants.

For humans, particularly for the development of human cultures and civilizations, three further requirements are:

- materials to construct our shelters and tools;
- abundant energy; and
- reasonably stable global climate with temperatures conducive to human and other life forms.

Collectively, the natural systems that produce these ecosystem 'goods and services' are the fundamental determinants of human health and well-being.

Global ecological change

Global ecological change is a normal process in the geological and biotic evolution of the Earth. What makes it a concern today is the unprecedented speed and scale of declines in ecological functioning that are attributable to human activity over the past century, and especially over the last 50 years.[5] We are approaching, and sometimes exceeding, critical ecological thresholds that presage ecosystem collapse. We have passed the boundaries for rate of biodiversity loss (extinctions per million species-years, E/MSY), disruption of the nitrogen and phosphorus cycles, land system change and climate change, with the first two in a high-risk zone and the other two in a zone of increasing risk (see Figure 2).[6]

Another form of change is possible in ecosystems and is even more alarming. State shift, or rapid non-linear change, is an emergent property of many complex, adaptive living systems. Examples on a global scale of rapid shift in status include the 'Big Five' mass extinctions in geological history when abnormally large numbers of species died out simul-

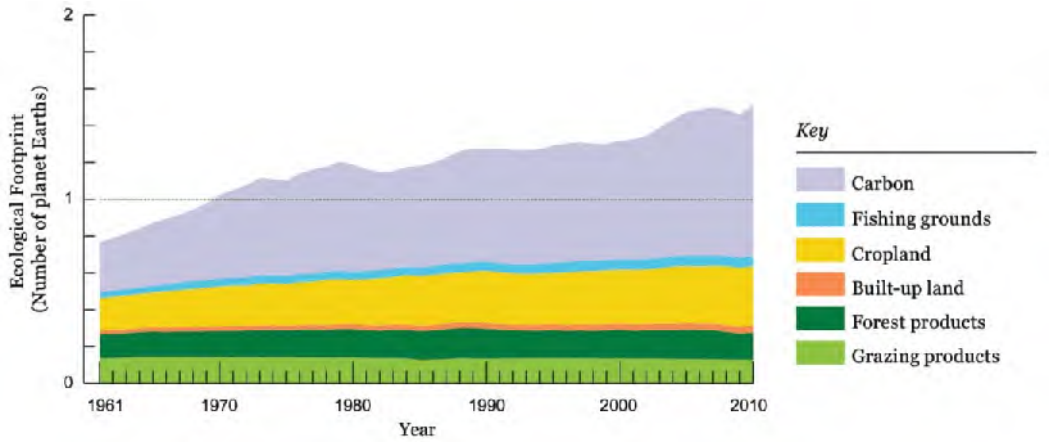

Figure 3: Global ecological footprint, 1961-2010
Source: WWF Living Planet 2014 Report: Summary, p. 10.[12]

taneously,[7] the loss of Arctic sea ice, and the potentially catastrophic release of methane from thawing permafrost or undersea methane hydrates.[8]

The prospect that humans can trigger transitions on this scale is worrying. Science cannot predict such changes as we have no prior data upon which to base forward projections. We do know that indefinite growth of resource consumption in a finite system, such as Earth, is not sustainable; it harms and can severely damage the Earth's ecosystems. Our planet is unique, it is finite, and it contains all we have. We must live within the limits of its resources, capacity and functioning ecosystems.

In the more than 20 years since the first CPHA report on human and ecosystem health,[9] the state of our planetary ecosystems and natural resource sustainability have declined substantially. The 2005 report of the United Nation's Millennium Ecosystem Assessment found that "approximately 60% (15 out of 24) of the ecosystem services examined during the Millennium Ecosystem Assessment are being degraded or used unsustainably… ."[10] In summarizing the report, the Board of the Millennium Ecosystem Assessment wrote:

"At the heart of this assessment is a stark warning. Human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted."[11]

Two key global summary indicators are the Ecological Footprint (EF) and the Living Planet Index (LPI). The global EF measures the amount of biologically productive land and water required to produce all the resources consumed, and absorb the waste produced, by a given population. The EF has increased steadily and dramatically from 7.6 billion global hectares (gha) in 1961 to 18.1 billion gha in 2010. Even though global biocapacity has increased over that same period (from 9.9 to 12 billion gha), it has not kept pace with either population growth or rising consumption levels. Consequently, per capita biocapacity has declined from 3.2 to 1.7 gha, and we currently use the regenerative capacity of 1.5 Earths each year (see Figure 3).[12] Wealthier countries and wealthier populations have larger footprints than poorer ones. If the entire world had the same EF as does the United States or Denmark, our global footprint would be the equivalent of almost four planets.

The LPI tracks the state of the world's biological diversity based on average changes in vertebrate species from terrestrial, freshwater and marine habitats. Globally, it declined by an astonishing 52% between 1970 and 2010 (see Figure 4), but by 58% in low-income countries and by 18% in middle-income countries, while increasing 10% in high-income countries.[12] This suggests that the high-income countries may be restoring their biodiversity by exploiting the resources of the low- and middle-income countries, leading to a massive decline in their LPI.

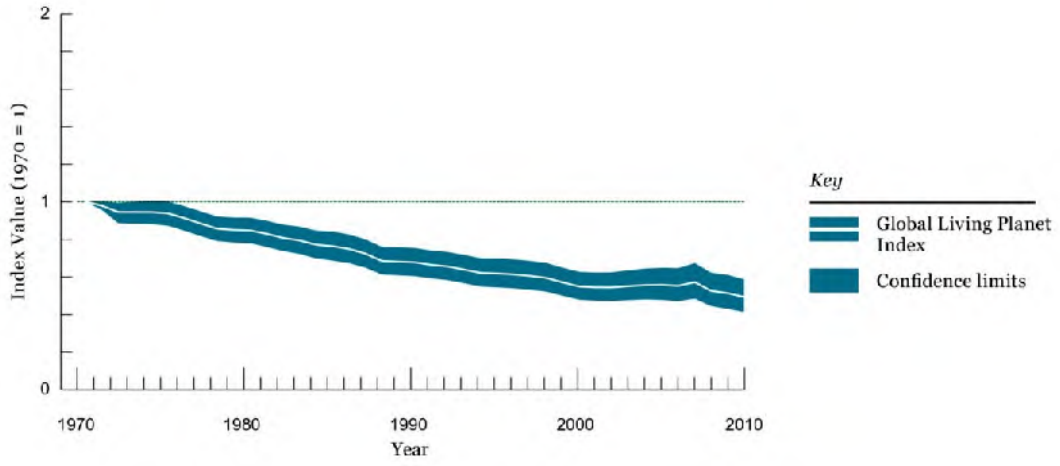

Figure 4: The Living Planet Index, 1970-2010
Source: WWF Living Planet 2014 Report: Summary, p. 8.[12]

Canada's EF and LPI have also been determined. As expected for a high-income country, the Canadian EF is large, but marked differences in EF exist within Canada, based on income, with the EF of the richest 10% of the population being nearly 2.5 times larger than that of the poorest 10%.[13] Canada's LPI is based on a smaller sample of species, with 1,057 population trends from 393 vertebrate species. While the LPI slowly increased from 1970 until 1995, there was a worrying decrease of almost 25% between 1995 and 2003.[14]

More generally, in Canada, there is serious concern with several aspects of our environmental performance, including weaknesses in monitoring, research, information management and reporting on biodiversity.[15] Canada's Commissioner of the Environment and Sustainable Development recently noted concern with respect to the federal government's actions on environmental assessment and public engagement processes.[16]

Key areas of global change

Climate change

Average annual global carbon dioxide (CO_2) emissions increased by 52% from 1992 to 2012,[17] and between 2012 and 2013, they increased more than during any other year since 1984.[18] "The amount of CO_2 in the atmosphere reached 396.0 parts per million (ppm) in 2013. The atmospheric increase of CO_2 from 2012 to 2013 was 2.9 ppm, which is the largest annual increase for the period 1984-2013."[12] As a result, the average annual global temperature (January-December) has increased from 14.19°C in 1992 to 14.60°C in 2013.[19] The US National Oceanic and Atmospheric Administration reported in January 2015 that "[t]he globally averaged temperature over land and ocean surfaces for 2014 was the highest among all years since record keeping began in 1880."[20] In Canada, the average temperature increased by 1.6°C over the past 66 years.[21]

Urgent action is needed as evidenced by recent reports of the Intergovernmental Panel on Climate Change (IPCC). In 2013, the IPCC reported that "[m]ost aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2."[22] A year later, the IPCC stated that "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. … [moreover, the] continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems."[23]

In Canada, the Commissioner of the Environment and Sustainable Development reported in 2014: "In 2012, we concluded that the federal regulatory approach was unlikely to lead to emission reductions sufficient to meet the 2020

Copenhagen target. Two years later, the evidence is stronger that the growth in emissions will not be reversed in time and that the target will be missed."[24]

To keep global warming advances below the 2°C threshold, it has been estimated that no more than about 1 trillion metric tons of carbon can be added to the atmosphere. Already we are past the halfway mark, and if current trends persist, we will pass the trillion metric tons mark in the 2040s.[25] It is important to understand that if the total resource base of fossil fuel were burned, we would greatly exceed that 2°C threshold, which leads to suggestions that about 80% of known fossil fuel reserves should never be burned.[26] A recent report suggests that in Canada, even with carbon capture and storage technologies in place, 74% of oil reserves , 99% of 'unconventional oil' (i.e., Alberta's oil sands), 71% of unconventional gas reserves (i.e., hydraulic fracturing, or "fracking") and 75% of coal is 'unburnable'.[27] This 'unburnable' carbon becomes a stranded asset and represents a major liability for the fossil fuel industry and those who invest in it, notably pension funds. [28]

Ecotoxicity

We have created many toxic organic chemicals in the past century that are novel for which no natural detoxifying mechanisms exist.[5] Many of these chemicals are designed to be stable and thus will persist in the environment, with the effects of their persistence remaining largely unknown. We do know that tiny amounts of persistent chemicals, and some heavy metals, already spread widely in the environment, can have enormous biological effects as they become bio-concentrated up the food chain, reaching levels in top predators (including humans) millions of times higher than in the source. This means that everyone born or living since World War II carries a lifelong body burden of multiple and persistent organic pollutants with health consequences that are unknown. [29]

Resource depletion

Resource depletion refers to the gradual loss of resources provided by nature that humans use to meet their needs. These resources include, water, land, soil, forests, energy, minerals, fish and other wildlife. Some resources, such as water, forests, soil, and foods such as fish, are renewable as long as their exploitation does not exceed the rate of renewal and as long as the necessary ecosystem services can enable that renewal.

Renewable resources are unlikely to peak and decline, but they could peak in functional availability or because competing interests limit access to them. If this 'peak' occurs, the cost of these resources will be driven up, becoming unaffordable to the majority of people on Earth. Other resources, particularly metals and fossil fuels, are non-renewable on any scale relevant to humans; there is a finite supply of retrievable/extractable resources. Our society may be reaching limits in the global production of many non-renewable resources; thus, we face peak oil,[30] gas,[31] coal,[32] phosphorus,[33] uranium,[34] minerals,[35] and from the perspective of journalist and educator Richard Heinberg, "peak everything".[36]

Species extinction

Experts report that the rapid loss of species we are experiencing today is between 1,000 and 10,000 times higher than the natural extinction rate. The combination of all the human-driven ecological changes outlined above, as well as human intrusion and destruction of habitats, is creating the sixth mass extinction of species –the first to be induced by humans.[37]

Oceans in trouble

One of the consequences of the higher levels of CO_2 is the acidification of the oceans,[38] which could have significant consequences in altering species composition, disrupting marine food webs and ecosystems, thus affecting marine-based diets of people worldwide.[39] Recent comprehensive reviews have found that overall, marine degradation is happening at a faster rate and at a greater scale than was previously believed.[40] In particular, while marine defaunation (destruction of animal species) began later in the oceans than on land. "Humans have profoundly decreased the abundance of both large… and small… marine fauna".[41]

Unprecedented challenges

Clearly, we – and more particularly our descendants – face some daunting challenges that are compounded by the fact that these global ecological changes interact and their collective impacts may be far greater.[42] For example, the Millennium Ecosystem Assessment coordinated by the United Nations Environment Programme (UNEP) designed four scenarios exploring ecosystem changes to the year 2050. Under all four scenarios, the projected changes in the underlying driving forces result in significant growth in the consumption of ecosystem services, continued loss of biodiversity and further degradation of some ecosystem services.[43]

We are facing novel challenges, unprecedented in human history, and we can only 'feel our way' towards solutions. The ecological decline that is already underway will continue for decades to come, even if we were to start doing everything right today. But, we know we will not do everything right from now on, given the inertia and time lag built into our social systems, so we will continue to create an ecological deficit.

Moreover, this decline is not likely to be a smooth, linear and predictable affair. The potential for rapid non-linear change – state shift – exists. Should that happen, ecosystem decline would become collapse, thus dooming the human societies that are embedded within and dependent upon those ecosystems.[44] Therefore, we must view ecological decline as a present-day reality, not as an improbable future to ignore or wish away. Prudence and concern for future generations should guide us to take responsibility and adopt a precautionary approach and assume the worst. If we assume the worst and are found wrong, the cost to society is far less than the price of doing nothing and facing collapse unprepared.[45]

We know that making the necessary changes will be slow and difficult, which is why we have a sense of urgency. It could be decades before beneficial social changes become widespread, and even longer before beneficial ecological changes are seen. Thus, the time for public health action on the ecological determinants of health is now!

Societal and human forces driving change

The key human forces driving changes in ecosystem functioning are population growth and urbanization, economic growth and development, technological changes and advances, and social changes and movements aligned to these forces. Underlying and shaping these drivers are societal and cultural values, which for the past 200 to 300 years have emphasized 'progress' or modernization, transforming human societies from rural and agrarian to secular, urban and industrial.[46] The long history of modernization helps us to understand our current social, political, economic and cultural conditions, and, perhaps, to anticipate a post-modern society that enables us to stabilize and reverse these harmful ecological changes.

Twenty years of business-as-usual

In 1992, the CPHA report on global change and public health was published as a clarion call for transforming our society from unsustainable growth to sustainable progress. Regrettably, the past two decades have been marked by a business-as-usual societal posture, with little attention to the ecological determinants of health on the part of population and public health professionals and organizations as a whole.

The Earth's population is growing and migrating. Focused on growth, world economies cycle between booms and busts. Resources and natural environments are exploited and degraded, and technology is advancing rapidly, outstripping society's ability to keep pace with the ramifications of these innovations. Social conditions and values are transforming, some strengthening the harmful aspects of economic growth and development, while others counter them.

The rate and scale of change of the socio-economic forces that drive ecological change grew rapidly in the past century, especially in the past 50 years.[5] The enormous growth of human impact (see Figure 5)[47] over roughly the last century can be understood as a function of population growth (P), multiplied by affluence (A) and by technology (T).[48] These societal forces and their underlying social values are briefly discussed below.

Population growth

Global population is projected to reach 8.1 billion in 2025, 9.6 billion in 2050 and 10.9 billion by 2100.[49] But this growth is not uniform; in the recent past, most growth has occurred in the Global South. While population increased in the more developed regions by about 50% from 1950 to 2005, it more than tripled in the less developed parts of the world.[50]

Canada's population grew from 29.6 million in 1996 to 35.1 million in 2013, an increase of 18.6% in 17 years. The annual growth rate over the past 30 years has averaged 1.1%, which is roughly the same as the world population's rate of growth. From 2009 to 2036, Canada's population is projected to grow from 33.7 million to between 40.1 million and 47.7 million.[51] A more recent and longer-term projection is that Canada's population will grow to 51 million people by 2063.[52]

Urbanization

For the first time in human history, we live in an urban world. At the start of the 21st century, more than 50% of the

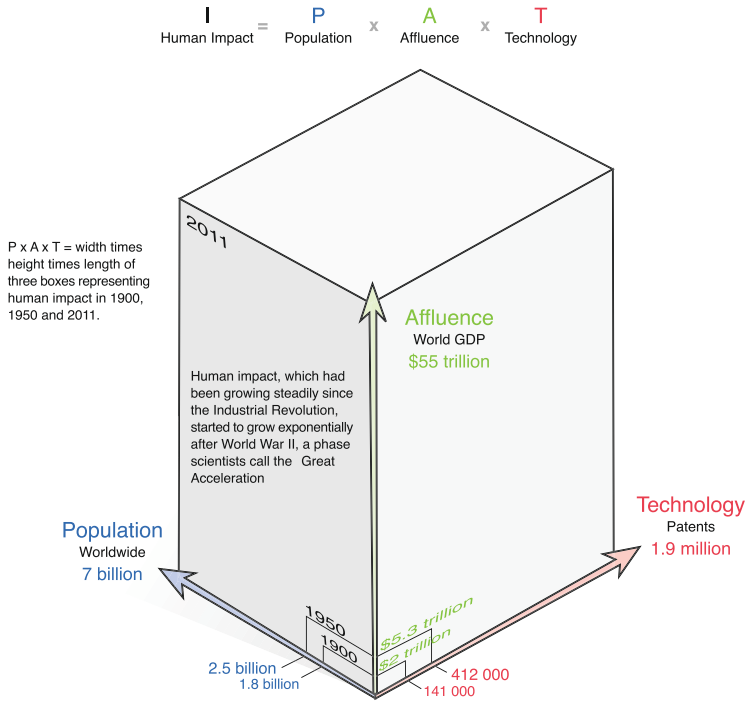

Figure 5: A depiction of the I = P x A x T formula for human impact
Source: Steffen et al, 2011.[47]

world's population are urbanites; and by 2050, 67% of the globe's population will be living in urban settings, with 86% urbanized in more developed regions and 64% in less developed regions.[53] Almost a billion people, one third of the world's urban population, live in slums and informal settlements.[54] These residents bear the burden of ever-widening inequalities in income within countries, inequitable distribution of wealth, and a greater burden of environmental hazards.

Moreover, many cities are located in areas of natural hazard – severe and extreme weather and climate events. The number of people exposed to these hazards is exacerbated by two factors: the growth of cities into areas of hazard, and the expansion of the zones of hazard due primarily to the impacts of climate change, including rising sea levels, more severe weather events and drought.[53] Those at greatest risk are mainly the poor in the Global South.

Urbanization has very complex effects on Earth's natural systems. Often these effects are harmful, but paradoxically, well-designed and planned sustainable cities can have significant environmental benefits,[55] while simultaneously providing significant economic and social benefits.[56] Clearly, we are tasked with making our cities ecologically sustainable. An important means is to limit urban sprawl, especially given its harmful health effects.[57] If done well, urbanization holds out the promise of reducing ecological harm and economic costs, while improving health.

Economic growth and development

Economic affluence underlies the damaging human impact on the planet in several ways. Most often measured as either income or wealth, affluence beyond the meeting of reasonable needs becomes a negative force because of the inherent consumption and waste, as well as the fact that increased affluence does not result in increased well-being.

The most common measure of economic activity is the Gross Domestic Product (GDP), although its developer cautioned against its use as a measure of social welfare.[58] The world's GDP increased four-fold between 1961 and 2001.[59] In the past twenty years, it has increased 75%, which, once population growth is taken into account, represents an increase of 40% in GDP per capita (GDPpc). However, this growth is unevenly distributed, with the GDPpc increasing much more (80%) in low- and middle-income countries between 1992 and 2010, a necessary accomplishment if people are to be lifted out of poverty. Nonetheless, a six-fold difference exists in GDPpc between low- and middle-income

countries and high-income countries.[38] In Canada, total GDP more than doubled from $568 billion CAD in 1992 to $1.33 trillion in 2010, while GDPpc almost doubled in that same period from just over $20,000 CAD in 1992 to $39,170 in 2010.[60] By 2013, the GDP (in 2013 USD) was estimated to be $1.5 trillion and GDP per capita was $43,100.[62]

Much of the ecological footprint of wealthier countries, and richer populations within all countries, is their carbon footprint resulting mostly from fossil fuel energy consumption. Therefore, growth in GDP also means likely growth in ecological impact. Since GDP growth remains a prime objective for all nations, the massive scale of such growth has troubling environmental and health implications. In its World Economic Outlook, the International Monetary Fund (IMF) projected a growth in world GDP (Purchasing Power Parity or PPP-adjusted) from $79 trillion in 2011 to almost $116 trillion in 2018 (an increase of 46%).[61,62,63] The same report series projected that Canada's GDP would grow from $1.42 trillion in 2011 to almost $1.9 trillion in 2018, a 31% increase. Overall, the world's economy is expected to almost quadruple in the next half century.[64] While not all of this growth will translate into resource extraction, pollution production or loss of species and biodiversity, much of it will.

On another front, growth in economic activity is generally considered good, because economic development is seen to lift people out of poverty, and there is good evidence that this is true for low- and middle-income countries. However, above $20,000 GDPpc, there is no relationship at all between GDP per capita and life expectancy or a number of other health and social measures. What matters much more for middle- and high-income countries is the degree of social equity, given that health and social problems are worse in countries that are more unequal.[65] Interestingly, GDP growth has been accompanied by growing inequity. One study found that the global Gini Index (a key measure of inequality) grew from 43.0% in 1820 to 56.0% in 1870, grew only slowly from 1950 (64.0%) to 1980 (65.7%) and then jumped to 70.7% in 2002.[66] This increase in inequality is also seen in Canada, where the Gini Index rose markedly in the 1990s and has continued to rise, albeit more slowly, in the 2000s.[67]

Thus, the GDP is a poor means for measuring the well-being of society because it includes harmful economic activity (such as the tobacco industry or the clean-up costs of pollution or a disaster event) and excludes all the non-monetized contributions that people make to social progress, such as volunteerism, growing our own food, caring for family and friends, and so on. In short, GDP puts the economy before any considerations of society or the environment.[68]

Technological change

Technological change is a key characteristic of our times and is driven by economic imperatives and social values. The effects of technological change are mixed; it is clearly part of the problem, but also can be part of the solution. Three characteristics distinguish our technological development over the past two hundred years: its power, scale and pervasiveness. Technology's power is now enormous, and both impressive and scary, while the scale at which it operates is global, and is simultaneously awesome and awful. Finally, the sheer pervasiveness of technology means that our chemicals, nanoparticles and genetically-engineered organisms are becoming ubiquitous in the Earth's natural ecosystems with unknown consequences. Together, their combined impact is what underlies the designation of our current era as the Anthropocene.

On the other hand, the emergence of the Internet and social media has had powerful and important social consequences. One example is Telehealth, which links patients to physicians remotely. It can reduce emissions, increase safety and improve patient access to services; Canadian experience is confirmed by similar results in Australia and Portugal.[69,70] While the full consequences remain unknown, what is clear is that the social movements and social changes these technologies facilitate will be fundamental in shaping society in the 21st century.

Social values and social change

While changes in population, affluence and technology are important, the underlying social and cultural values and norms will drive positive change, as they underlie economic and social beliefs and practices as well as technology usage. Without changes in values and norms, there is little prospect for change in our:

- Social and economic activities and goals;
- Understanding of our relationships with and responsibilities for other people, other species and the Earth;
- Understanding of growth and development; and
- Openness to engage in what we may perceive today as radical change.

The Earth Charter – "a universal expression of ethical principles to foster sustainable development" - is one document that addresses these concerns in full.[71]

The problem is – and we know this from our experience in public health –there is little evidence that values can be changed through simple education or appeals to 'right living', or that changes in values will necessarily result in shifts in behaviour. However, we have also learned that the effective shifting of social norms is feasible, even though it may take decades to occur.

If society is to become more just, sustainable and healthy, public health needs to challenge the prevailing economic norms within society, governments and corporations that increasingly shape public policy. In particular, it means challenging the financial interests that steer economic growth and promote it as the solution to today's problems in ways that rarely consider population or ecosystem health. [72, 73,74]

This is why the power and policies created by some corporations needs to be challenged, particularly because governments appear to prefer protecting these corporations rather than the public. Legitimate confrontational strategies can be used in protecting the health of the public and Earth's natural systems; these techniques have worked in the past and can be applied in the future. Similarly, public health can support, encourage and showcase forward-thinking corporations that demonstrate social and ecological innovations.

Equally importantly, if, as the Brundtland Commission puts it, "the needs of the present are to be met without compromising the needs of future generations,"[3] we must develop a new societal paradigm, one that has been described as post-materialist. Such values are emerging, although it is by no means certain that they will prevail. Studies of global and Western countries' values have shown some evidence that an intergenerational shift from materialist to post-materialist priorities is occurring. However, evidence also exists that the shift towards a post-materialistic culture has tapered off in the wealthy and industrialized West, suggesting no major shift towards de-growth is likely to occur, while materialistic values are on the rise in the rapidly growing and industrializing South.[75] If this is so, the pressures on the world's ecosystems will increase even more. Again, a change in values and a shift in the world's dominant paradigm are needed if we are to live fairly, well and within the limits of the Earth's natural systems.

Implications for population health

While this discussion paper is directed mainly to Canadian public health professionals and educators, and the organizations for which they work, the biophysical and societal effects described here are global. These effects will probably be more extreme in lower-income countries; however, Canadians do not and cannot stand in isolation of those impacts, both on basic moral grounds and because the negative consequences of ecological change felt elsewhere will also affect us.

Our knowledge of the health impacts of global ecological change is surprisingly limited. What we know is imprecise, preliminary and often speculative; we have some idea of the big picture, but the details are lacking. Even in the case of climate change, we have only a modest sense of the potential health impacts, although this has been the focus of some well-resourced research over the past few decades, both globally and in Canada.

We do know that the indirect health effects of global ecological change – those mediated through natural and human systems – are likely to be much greater than the direct effects (such as heat waves), although they are harder to quantify and attribute directly to a specific global change. This difficulty in quantifying the indirect health effects is part of the uncertainty with which we must deal.

Also, we know that massive change is occurring, across multiple ecosystem components and at all scales from the cellular to the global; that the rate of change is rapid, in ecological and geological terms, and to some degree even in human terms; and that we are unprepared. Given the novel conditions we are experiencing, our level of ignorance is likely greater than we recognize. Equally troubling is the level of human denial of the problem, which seriously hinders active efforts towards adaptation and mitigation.

Despite all this uncertainty, the seriousness with which the health community is beginning to take this issue is exemplified by *The Lancet*'s recent publication of a manifesto for planetary health and the joint establishment with the Rockefeller Foundation of a Planetary Health Commission.[76,77]

Some key health impacts of global ecological change are briefly discussed here. Table 1 shows the estimated numbers of people,

Category of health risk	Size/proportion of populations at risk	Types of GECs involved
Malaria	40% of world population	Climate change and land use change
Dengue fever	3 billion	Climate change, urbanisation, world trade
Diarrhoeal diseases (associated with water quality/quantity)	1 billion people	Climate change, land cover change, pollution, irrigation and freshwater shortage, urbanisation
Malnutrition (especially food shortages)	840 million	Climate change, land use, freshwater shortage, biodiversity change
Health consequences of desertification: malnutrition; respiratory diseases; impacts of population displacement	250 million people	Climate change, land use, land cover change
Skin cancer, eye disorders, immune system depression	Mid-high latitude populations (1-2 billion)	Stratospheric ozone depletion

Table 1: The global estimated numbers of people at risk from selected major examples of the adverse health impacts of global environmental changes
Source: Global Environmental Change and Human Health, 2007.[78]

globally, at risk from selected adverse health impacts of global environmental changes.[78] It is obvious that a multitude of impacts stem from a variety of causes, and that the populations at risk are very large, ranging from hundreds of millions to billions of people. The health impacts of some of these key areas of global environmental change are worth highlighting.

Health impacts of climate change

The most recent report by the Intergovernmental Panel on Climate Change (IPCC) assesses the probability of major increases in ill health by the mid-21st century due to climate change as follows:

- Very high confidence
  - Greater risk of injury, disease and death due to more intense heat waves and fires
  - Increased risks of food-borne and water-borne diseases
- High confidence
  - Increased risk of under-nutrition due to diminished food production in poor regions
  - Consequences for health of lost work capacity and reduced labour productivity in vulnerable populations
- Medium confidence
  - Increased risks of vector-borne diseases[79]

The IPCC also points out that health co-benefits exist from reducing emissions of other climate-altering pollutants released by fossil fuel combustion, that have important implications for policy in the areas of energy, transportation and agriculture.

One estimate is that climate change already causes 400,000 deaths annually, while another 4.5 million deaths annually are linked to air pollution, hazardous occupations and cancer associated with our carbon-intensive energy system. This could rise to 700,000 and 6 million annual deaths respectively by 2030.[80] In addition, the economic losses due to heat-induced lost productivity could be very large.[81] One study found that by 2050 there could be 30 million work years lost annually just in the East Asia region.[82]

Pollution and ecotoxicity

According to a recent assessment published by the WHO, the most important health effects at a global level that arise from pollution are:

- Diarrhoeal disease, of which 94% is due to unsafe drinking water and poor sanitation;
- Lower respiratory infections (LRTIs), of which 42% in low- and middle-income countries and up to 20% in high-income countries are due to indoor air pollution, largely from burning biomass indoors for cooking and heating and to a lesser extent outdoor air pollution; and
- Malaria, of which 42% may result from policies and practices regarding land use, deforestation, water resource management, settlement siting and house design.[83]

The WHO also notes that our knowledge of the health impacts of ten chemicals of major public health concern is limited.[84] This is a concern because environmental pollution

has been a public health concern for decades and in the case of some pollutants, for centuries. The reasons for this lack of knowledge are manifold, but three key reasons are:

- Continued use of a reductionist scientific approach to assess health effects;
- Chemicals' commercial value and potential bias in detecting adverse effects; and
- Our ignorance of what to look for, how to measure it, and how to interpret the findings.

Our ignorance of ecotoxicity – the hazards of simultaneous life-long exposures to many chemicals, which interact in unknown ways – is even greater.[29] In fact, such an assessment is likely beyond our abilities. For example, the (US) President's Panel on Cancer examined the impact of environmental factors on cancer risk and concluded that "the true burden of environmentally induced cancer has been grossly underestimated".[85] In addition, almost 800 chemicals are known or suspected to be endocrine-disrupting chemicals (EDCs), but very few have been properly tested, even though ample evidence exists of widespread and simultaneous exposure of both humans and wildlife to multiple EDCs.[86]

Of particular concern is the exposure to persistent organic pollutants (POPs) and EDCs, as well as heavy metals *in utero* and during childhood, especially puberty, because the developing foetus, infants and young children are particularly vulnerable to toxic chemicals.[87] Yet, while finding some evidence for the health impacts of prenatal and childhood exposure, two recent Canadian reviews of the literature found many associations had limited or inadequate evidence, mainly because of an insufficient number of studies or methodological problems such as small sample size, a limited range of exposure or poor exposure indices.[88,89]

Resource depletion

Many resources necessary for continued social and economic functioning are in decline or starting to decline, while the global population is growing and societal expectations are rising. A recent study suggests that for 16 of 27 global resources, peak rates of use centred on 2006 (1989-2008) and "18 of the 20 renewable resources have passed their peak rate of appropriation".[90] Some resource losses will pose inconveniences, but for others such as energy, water, fisheries and soil, the effects will be catastrophic locally and potentially globally. As with other global changes, the impacts of resource scarcity will be felt most in low-income countries and among low-income and disadvantaged populations around the world. Among the major concerns are the depletion of water, soil, agricultural land and fisheries, since they provide the most basic requirements for life and health. They are also intimately linked with the issue of energy supply. An integrated strategy to address the nexus of the key resource issues of energy, food and water is needed.[91]

For example:

- Inadequate water supply may be a major factor in determining population health in many parts of the world, not least because of its impact on food production.[10] Yet we know of many proven ways to reduce water consumption in agricultural, resource extraction, industrial and domestic settings; we simply need to apply what we already know.
- World food production will need to double within the next 50 years, yet it is threatened by inadequate water supply, soil degradation and loss, as well as threats to the ocean and to fish stocks. Again, we have many tested strategies that are not fully applied, including better storage, more equitable distribution and less waste.
- Seventy-five percent of the world's agricultural land is used for raising animals. This is problematic because an animal-based diet is a much less efficient way of providing food than a plant-based diet. A shift to a low-meat or vegetarian diet would have a number of direct health benefits.[92]

In addition, energy, especially fossil fuel energy and electricity, is a major determinant of health in our modern world. But fossil fuel energy is at risk of depletion in the relatively near future or subject to drastically curtailed use if we heed concerns about the planetary carbon budget.[93] Fossil energy has driven the vast majority of social and economic development for the past 200 years; the effects of its loss are difficult to imagine yet we must plan for such loss.

Again, we know what to do; the potential of energy conservation and efficient use is well established. "Increasing energy end-use efficiency – technologically providing more desired service per unit of delivered energy consumed – is generally the largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services."[94] Just as there are health benefits from a shift to a low-meat or vegetarian diet, so too health benefits will accrue from a shift from fossil fuels to conservation and renewable energy. The opportuni-

ty cost of failing to invest in energy efficiency "may represent a cost that we cannot afford to bear."[95]

Loss of species/biodiversity

Many of the ecosystem goods and services on which we depend are created through the actions of other species, from bacteria and phytoplankton to corals, insects and birds.[96] The Sixth Great Extinction currently underway represents the most profound, most difficult to quantify, and least understood threat to human health. Humans must pay attention to the health of other species and populations, not just our own. A recent report from the Secretariat of the Convention on Biological Diversity and WHO has started to address this question in more detail.[97]

Looking at future impacts

In 1994, the Canadian Global Change Health Panel reported, "there is no comprehensive approach to health aspects of global change in Canada."[98] This statement is still largely true. We have little good data on the environmental burden of disease in Canada, never mind the burden of disease related to ecological change. For example, the terms 'ecosystem' and 'ecological' do not occur in a recent report on the environmental burden of disease in Canada.[99]

However, we do not lack knowledge. A recent Canadian government report on climate change and human health found stronger evidence since the previous assessment in 2008 that "a wide range of health risks to Canadians are increasing as the climate continues to change".[100] Health Canada has been monitoring environmental chemicals in Canadians since 2007.[101] One area of particular concern is the high level of persistent organic pollutants in the food chain and the bodies of Inuit living in the Arctic.[102]

Canada is a large, wealthy and highly industrialized nation, and as such is able to protect itself somewhat from the impacts of many forms of global ecological change, at least in the short to medium term. But we share the planet as part of a global community and global economy, so there is a real limit to self-protection.

As hard as it is to measure the current health effects of global ecological change, it is even more difficult to provide good estimates of future health impacts. Many social, political and economic factors constituting the social determinants of health will influence those impacts, along with the degree of societal development, the commitment to social solidarity and equity, as well as local geography and environmental conditions.

Given the trends in ecosystem functioning described here and the unremitting pressures of growing populations, growing per capita demand, more powerful and pervasive technology and the dominant paradigm of modernization, it is likely that adverse health impacts will worsen. However, the real danger lies in sudden, rapid and largely unpredictable, non-linear changes triggered as we pass ecological boundaries, or tipping points. Varying degrees of ecological collapse, from local to global, and aligned societal decline or collapse will have large, sudden and difficult to resolve health impacts. Moreover, we know those health impacts will be inequitably distributed, in inverse relationship with power, money and resources. In fact, ecological decline is likely to widen inequalities in power, wealth, access to resources and the related level of health.[103]

Such a future need not be inevitable. As we have seen time and again, when faced with extraordinary situations, people, communities and nations are capable of extraordinary actions. Whether it is the industrial slums of 19th century England, the choking smog of early 20th century industrial cities or the disappearance of the stratospheric ozone layer, we have risen to the challenge. But we must act decisively and soon to create a different society, based on different values. Public health has been in the forefront of action to address previous massive threats to the health of populations, and must play that vital role again in confronting what is the largest threat to health that humanity has ever seen.

Imagining a better future

Issues arising at the interface of health, ecosystem sustainability and social justice constitute what some call a 'wicked problem'. Such problems challenge the way a society operates and call for changes in that society.[104] We will need some fundamental shifts in societal values, and with that new principles, and new ways of knowing, measuring and governing. Fortunately, we do not have to invent these from scratch as we have precedents and newly-emerging practices that can help provide a foundation for the new future we need to create.

First and foremost, we acknowledge the precedents and insights offered by Canada's Indigenous communities. It is imperative to build on the rich traditions and wisdom of First Nations, Métis and Inuit communities' holistic understanding of the interconnectedness of individuals, communities and the environment. Secondly, we draw on public health's long history of leading social, urban and political reform that accompanied industrialization and urbanization in the past. We have precedents and foundations in research, education and practices in the fields of Ecohealth and One Health, resulting from decades of leadership by Canadian and international scholars and practitioners. Finally, we can draw upon the social and ecological practices rooted in communities across Canada (and the world) addressing issues such as the cod fishery collapse in Newfoundland; the Sydney tar-ponds in Cape Breton, Nova Scotia; asbestos mining in Asbestos, Quebec; chemical pollution in Sarnia, Ontario affecting the Walpole Island First Nation; radiation pollution in Port Hope, Ontario; oil sands development affecting First Nations and Métis in northern Alberta; and forestry practices affecting First Nations in Clayoquot Sound, British Columbia, to name but a few.

The fields of health promotion and Ecohealth offer conceptual and procedural guidance to catalyze a transformation toward public health equity for future populations. Public health is in an ideal position to lead the integration of the social determinants of health, which focus on health equity of current populations, with the ecological determinants of health. In order to do this, we need:

- **New ways of knowing and of gaining knowledge** – Complexity means being or becoming comfortable with ambiguity. More important than just gaining knowledge is gaining wisdom, so that the knowledge we have is used appropriately.

- **New understanding of development** – Development needs to be understood as more than growth in an economic context, expanding to embrace the development of human potential, which is society's greatest resource. Progress should be measured in terms of the growth in human (not economic) development and potential.

- **New form of economics** – The economy is a social construct intended to serve humanity, not the other way around. Alternative approaches to economics, new understandings of capitalism in the 21st century and new ways to measure social progress are hopeful signs and provide an important way of (re)connecting the social and ecological determinants of health.

- **New forms of governance** – Governance is "the sum of the many ways individuals and institutions, public and private, manage their common affairs",[105] collectively solving their problems and meeting society's needs. The 'Health in All Policies' approach is a re-working of the health promotion strategy to create healthy public policies. If we understand that health has ecological as well as social determinants, then public health will need to involve those working in urban planning, agriculture and food security, environment, natural resource extraction, energy policy, forestry and all related issues.[106,107]

That said, appeals to loftier values or the pursuit of technical solutions, while necessary are unlikely to be sufficient engines of change if the underlying dynamics of inequitable power relations, wealth accumulation and exploitation remain unaddressed.[108] Fortunately, public health has a strong set of precedents in linking health, equity and sustainability concerns from local level work that that has explicitly sought to integrate social and physical environments, including settings approaches and neighbourhood-focused work (e.g., healthy schools, workplaces, communities).

First steps towards the future we prefer

If we understand the forces that shape us and the future we face, we are better equipped to make choices, express our values in a vision and then work to create it. Within public health, we need to explore scenarios of plausible futures, and help people create visions describing their preferred future.[109, 110] Scenarios are useful because each one embodies a set of implicit values, which people understand as they engage with them. They can then assess which scenario best fits their own values, and thus constitutes for them a vision of their preferred future.

We need a transformative approach, where we do better things rather than simply doing the same things better. This involves recognizing the limits to what we know (or think we know) and working in partnership with many other disciplines. Opportunities can be found and gains can be made even during dramatic and unexpected change. In these situations, resilience is not the ability to bounce back to the

former (problematic) situation, but to bounce forward to a new, more sustainable and healthy future.

We anticipate both opportunity and tension to arise as the public health community considers building on its existing work and developing new approaches. We must explicitly account for the ecological as well as the social determinants of health when we start visioning – and consciously changing – the future.

Finding hope

The challenges we face are daunting, and can even seem overwhelming. But hope can be thought of as "the commitment to positivity in the face of adversity".[111] We seek a happy medium between starry-eyed optimism based on a naïve belief in the ability of science and technology to overcome all of our problems, and a deep pessimism that says we are all doomed. The helplessness and despair people may feel in the face of the ecological crisis can be addressed through a process called 'Active Hope'.[112] This requires us to:

- Take in a clear view of reality;
- Identify our vision for what we hope will happen; and
- Take active steps to help bring that vision about.[113]

In fact, the shift to a more ecologically sustainable society could result not only in health gains from avoiding harm, but also in a healthier way of living. In working towards a more healthy future, there are messages of hope specifically for the public health community:

- We have successfully helped to create major societal shifts in favour of health numerous times before. We know how to do it, and we can do it again. While the changes we seek are large, and the forces we face are powerful, that was also the case in the long struggle to address the health problems created by the industrial revolution in the 19th century.

- We are not alone. We have many partners among environmental and community organizations and municipalities, private sector businesses and some state/provincial and national governments.

- For the most part we have a good sense of what should be done and daily we learn more. We have known the general direction to take for a long time; that we have not yet succeeded in making the necessary changes is regrettable, but no reason to give up. Indeed, it can strengthen our resolve to keep trying.

- We have already made some progress. Many examples exist of people, organizations, businesses, communities, cities, and entire nations doing the right things and setting examples. Now we need to adopt these practices within our public health and health care organizations and help our partners scale up these activities.

We see signs of hope at a societal and community level in three key areas:

- The conceptual and strategic rethinking going on internationally with respect to development and economics;
- The anticipated health benefits of a more sustainable society; and
- The many inspiring efforts at the local level to build on local capacity and create healthier, more sustainable and more just communities.

While there is no question that when one looks at the global situation and the extent and rapidity of ecological change there is much to worry about, as we look locally, there is cause, if not for great optimism, then at least for hope.

Rethinking development and economics

There are several major developments in the transformation of our concepts of development and economics. In its 1986 Declaration on the Right to Development, the UN General Assembly stated that "the human person is the central subject of development" and followed that with the 1990 creation of the Human Development Index (HDI) and its adoption by the UN Development Program.[114]

Then in 1987, the World Commission on Environment and Development championed sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[3] The Commission's work spawned a large and sustained effort that continues today among NGOs, governments at all levels, many corporations and individuals. In recent decades, an increasing number of corporations have moved towards sustainability, social justice and equity. International efforts such as the ISO standards for environmentally responsible business practice, corporate reporting on sustainability and the emergence of the concept of corporate social responsibility are all desirable steps that must be encouraged and supported.

There is also a long history of the creation of alternative, human-centred, socially just and ecologically sustainable economic models.[68, 115, 116] A key tenet of these forms of ecological economics is that at least five forms of capital exist: natural, social, human, economic and built capital. Moreover, much of the world's true wealth lies in its natural, social and human capital.[117] Of these, human capital (which includes health and well-being) is the major concern of health and human development professions. Together, these comprise community capital at the local level.[118]

As stated earlier, the GDP is a poor measure for our purposes as it emphasizes economic rather than human development and progress. It fails to account for the harmful impacts of economic activity and excludes non-monetized contributions to social welfare. Below are several alternative measures of progress more suited to measuring sustainable social well-being and human development.

- The **Genuine Progress Indicator (GPI)** starts with the same personal consumption data that underlies the GDP and adjusts for factors such as income distribution, adds factors such as the value of household and volunteer work, and subtracts factors such as the costs of crime and pollution.[119] A recent study compared the GDP and GPI for 17 countries for the period from 1955 to 2005. While global GDP has increased more than three-fold since 1950, the GPI has decreased since 1978. Moreover, beyond about $7,000 GDP per capita, further increases in GDP per capita are negatively correlated with GPI.[120]

- The **Canadian Index of Wellbeing (CIW)** "tracks changes in eight quality-of-life categories. From 1994 to 2010, while Canada's GDP grew by 29%, our CIW improved by only 5.7%."[121]

- The UK New Economics Foundation's **Happy Planet Index** measures environmental impact on well-being, with country ranking on the number of long and happy lives they produce per unit of environmental input.[122] In 2012, the top three countries were Costa Rica, Vietnam and Colombia; Canada placed 65th with an ecological footprint more than 2.5 times as large as Costa Rica's.

- A radical alternative indicator of progress is **Gross National Happiness (GNH)**. This measure, developed in the Buddhist Kingdom of Bhutan, is calculated from 124 weighted indicators collected in 33 clusters, which are based in one of nine domains.[123] Countries, regions and communities around the world are working on versions of this indicator.

Health and other co-benefits of a more sustainable society

There are very large health costs to our current way of life, and thus very large potential health benefits from a shift to a more sustainable society. The application of a health and sustainability lens to public policy would result in healthier public policies and healthier societies and communities. The key policy areas with significant health and sustainability co-benefits include energy, agriculture and food, urban design and transportation.

The direct global health impacts of energy systems have been likened in scale to tobacco, alcohol, and high blood pressure, and exceeded only by malnutrition. One study estimated they "directly cause as many as five million premature deaths annually and more than 5% of all ill health when measured as lost healthy life years."[124] Numerous studies have reached similar conclusions: renewable energy (wind and solar) and conservation have much smaller health and environmental impacts.[125,126] Clearly, very significant health benefits may result if we move away from carbon-based energy use, with conservation and renewable energy systems offering a much healthier future. In addition, recent reports have pointed to the significant economic benefits of energy efficiency,[95] a reduction of greenhouse gases and a shift to a 'new climate economy'.[22,57]

Our current food system provides a highly processed diet that is low in fibre and high in animal protein and is based on an environmentally harmful agricultural system. If we are to dramatically increase global food production to meet growing populations and demands, and simultaneously reduce environmental harm, we need a very different agricultural system and diet. There are important health benefits to a low-meat diet and an agricultural system based on ecological principles: conservation of land, soil, water and biodiversity, reduction of greenhouse gas emissions and pesticide and herbicide use; and direct health benefits, including reduced rates of cardiovascular disease, diabetes and cancer.[94]

The health impacts of urban design, specifically of urban sprawl, have become more widely understood in recent

years. Health impacts of urban sprawl include those of climate change because urban sprawl is energy-inefficient,[58] requiring the use of a car for many of the daily activities of life.[127] There is a growing body of evidence on the health benefits of improved urban design; indeed, the health benefits of Smart Growth (a key urban development solution to urban sprawl) have been likened to a "medical miracle."[58] Moreover, the economic benefits of building "better connected, more compact cities based on mass public transport" are very significant.[57]

In short, a more environmentally-sustainable way of life brings with it many health benefits that are often overlooked. Public policies and community and societal actions in the areas of energy, transportation, urban planning, architecture, agriculture, fisheries, food and many other policy areas that move us in the direction of a more sustainable society are in fact healthy public policies.

Advances at the local level

The local level, where we lead our lives, provides visible signs of hope. Commonly, in these settings, small groups "think globally and [mainly] act locally."[128,129,130] The remarkable achievements of many small groups and the community-based organizations that nurture them are inspirational. Small local actions have great power when they become linked into larger networks at the national and international levels. As Margaret Mead stated: "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has."[131]

Local community groups are in fact a major component of a community's assets and form the basis for asset-based community development (ABCD), which is an important contributor to hope at the local level. ABCD is an approach that empowers both individuals and communities by focusing on community strengths and on the assets and skills of community members. Instead of concentrating on needs, problems and services, communities look at the capacities, skills and assets of people, community organizations and institutions and the physical assets of their neighbourhoods. By shifting to a capacity-oriented emphasis, communities take ownership of their issues.[130]

Community-level action is very important for public health, since most public health staff work at the local level. As well, public health has made many important contributions, and until recently, was closely related to local government. The Healthy Communities approach has been around as long as the concept of sustainable communities and linkages between health and sustainability at the community or municipal level have been proposed for at least twenty years.[132] Most healthy community or healthy city initiatives include a strong focus on sustainability, which remains a key theme in the WHO Europe Healthy Cities network and in the provincial Healthy Community initiatives in Canada. There are numerous examples of policies and programs that advance the cause of health and sustainability, and many resources are available. In addition, other settings (homes, schools, workplaces, hospitals, etc.) should be engaged as integral parts of these community initiatives.

It is not, however, just about having the right policies, they must also be implemented effectively by using processes that engage communities, their relevant governing agencies, and their citizens. Experience has shown that this involves a formal political commitment, community engagement and asset-based community development, multi-sectoral collaboration and healthy public policy.[133]

Towards transformative change

There are more grounds for optimism when we look at how far we have come. In the case of ecologically sustainable development, we have seen the concept and practices become commonplace in some parts of governments and the private sector, and we have seen standards and guidelines developed and become the norm. We have even seen some national governments begin to question basic concepts behind our current economic models and our measures of progress, and we have seen major international organizations make sustainable human development their central concern.

Above all, we have seen millions of people in countries around the world working to create healthier, more sustainable and more just communities and societies. There is a sense that we are poised not only on the cusp of disaster, but also on the cusp of transformative change. Our task as public health professionals is to take our place in this vast movement and help ensure we embrace transformative positive change.

An agenda for action

CPHA's vision of healthier, more sustainable, more just societies and communities will not be achieved in isolation from wider social processes. Realizing any such vision will demand transitions both within and outside public health and the larger health sector, including an explicit re-engagement with the values of public health.

This agenda for action on the ecological determinants of health is designed for public health professionals and organizations. The emphasis is on individual public health professionals because we firmly believe that unless each of us better understands and accepts the reality of the health challenges posed by human-induced ecological changes identified here, we will not be effective as members of public health organizations in working with others to address these issues.

There are nine major categories of recommended actions.

1. **Expand the guiding principles of public health**
   We view the following six guiding principles as fundamental for our collective future, while noting their origin in the values, knowledge and actions of Indigenous peoples over millennia. These principles should guide societal and public health action with respect to the ecological determinants of health:

   - Expand our thinking from one centring on humans to one that considers all life – a combination of anthropocentrism and ecocentrism. While we maintain a concern for human health and well-being, we need to view humans as part of the web of life, and understand that human health depends on the effective functioning of ecosystems, the health of other species and the sustainable use of available resources.

   - Embrace intergenerational equity. We have a duty towards future generations to ensure that they can expect a decent quality of life and good health.

   - Acknowledge and enshrine the right of present and future generations to a healthy environment by supporting calls for the Canadian Constitution to be amended to recognize the right to a healthy environment.

   - Adopt the principle of environmental justice, which means ensuring that disadvantaged groups or communities do not suffer damaged ecosystems and increased health risks because of their disadvantaged status.

   - Adhere to the prevention imperative that requires us to avoid further harm to ecosystems that impairs their functioning and thus undermines our own life-supporting systems. This will involve reconsidering our needs, lifestyles and economic system.

   - Apply the precautionary principle (as defined in the Rio Declaration),[134] already present in some public health legislation, to the ecological determinants of health. Public health organizations and practitioners should use the legislative powers available to them to support and apply the precautionary principle in addressing global ecological change and its implications for population health.

   In addition, the application of two key mechanisms are required in societal decision-making:

   - Apply comprehensive impact assessments that address the ecological, social, health and economic impacts of all major public policies and private sector developments.

   - Apply the concept of full-cost accounting for ecological change throughout our economy, as well as the principle that when harm is done, the polluter pays.

   These principles and mechanisms should be adopted by public health organizations, incorporated in the Public Health Core Competencies and professional codes of practice, and taught as part of the core public health curriculum.

2. **Understand and address the ecological determinants of health**
   Public health professionals and organizations must improve their capacity to understand and address the ecological determinants of health and how they interact with the social determinants of health. Accordingly, we propose the following set of strategies to enact the principles and mechanisms noted above:

   - **Integrate the ecological determinants of health into population health frameworks:** We need to revise our population health frameworks to become true socio-ecological models that give greater weight to

the ecological determinants of health and to interactions between them and the social determinants of health.

- **Educate public health professionals about the ecological determinants of health:** To do so, we must revise our core competencies, our training and licensing curricula and foster an interdisciplinary and multi-sector approach to social change.

- **Monitor, assess and report regularly on the ecological determinants of health with respect to immediate and longer term public health needs:** We must identify and promulgate key health indicators for conditions plausibly related to ecological change, for use within impact assessments and as early-warning or sentinel conditions to be monitored.

- **Fund and support research into the ecological determinants of health:** A significant and ongoing, long-term commitment to supporting research on the health impacts of ecological change is required. This will include research on the relationship between the ecological and social determinants of health, and effective strategies and interventions for the prevention and mitigation of health impacts and adaptation to ecological change. The goal here is to strengthen knowledge translation and exchange.

- **Establish a UN Commission on the Ecological Determinants of Health:** We call upon the UN to establish a Commission on the Ecological Determinants of Health to undertake work and continue the important investment in knowledge, similar to that of the Commission on the Social Determinants of Health.

For specific suggestions for action, see Appendix B.

3. Walk the talk: Environmentally responsible health care

Public health organizations and their parent health care organizations should apply the principles and practices of environmentally responsible health care, consistent with established national and international standards and codes of practice (e.g., Leadership in Energy & Environmental Design (LEED), International Organization for Standardization (ISO), etc.).

For specific suggestions for action, see Appendix B.

4. Change social norms and values

Public health must join others in working towards a fundamental shift in the values and social norms of Canadians in order to create change and effectively address the emerging ecological crisis. To do this, public health organizations and practitioners need to listen to and learn from those already working toward more positive futures, and foster alliances with other efforts that demonstrate socio-ecological approaches to the health of present and future generations.

For specific suggestions for action, see Appendix B.

5. Change the focus of development and the way it is measured

Public health professionals and organizations must consistently and persistently argue for measurement of social development and progress, at all levels, that reflect the ecological determinants of health and are focused on sustainable health, wellbeing and human development. Public health should champion a pan-sectoral focus under the banner of "Health in All Policies".

For specific suggestions for action, see Appendix B.

6. Strengthen ethical purchasing and investment policies

All public health organizations should develop ethical and ecological purchasing and investment policies and criteria to exclude receiving financial benefits from those economic activities deemed to be the most harmful to local or global ecosystems.

For specific suggestions for action, see Appendix B.

7. Protect people and communities from harm and health inequity

Public health practitioners and organizations should examine how to use public health legislation to address the public health impacts of ecological change, and should request the Minister, Provincial Health Officer or other appropriate public health officials to initiate an inquiry or investigation where their Public Health Act requires or enables such an action.

For specific suggestions for action, see Appendix B.

8. Protect people and communities from the adverse impacts of ecological change

The public health sector at all levels must address real and potential adverse impacts of ecological change

using two main approaches: first, to reduce vulnerability and protect the vulnerable, and secondly to increase resilience and adaptation.

For specific suggestions for action, see Appendix B.

9. Work with others to establish policies and practices that create more ecologically sustainable and healthy societies and communities.

Public health must find allies and forge partnerships with those individuals and organizations at all levels and in all sectors of society that share our vision to create a more just, sustainable, and healthy society. Policies and practices in the public and private sectors should be examined from a population health perspective, as part of comprehensive impact assessments. Those that are consistent with improving or not harming the ecological determinants of health should be adopted or encouraged, those that would do harm must be amended or dropped. As a general principle, public health should support the transfer of public subsidies and tax incentives from economic activities that worsen the ecological crisis to those that improve ecological functions and resource sustainability.

For specific suggestions for action, see Appendix B.

References

1. Hancock T, Spady DW, Soskolne CL. Global Change and Public Health: Addressing the Ecological Determinants of Health – The Report in Brief. May 2015. Available at http://www.cpha.ca/uploads/policy/edh-brief.pdf
2. World Health Organization (WHO). The Ottawa Charter for Health Promotion. Geneva: WHO, 1986. 5pp. Available at: http://www.phac-aspc.gc.ca/ph-sp/docs/charter-chartre/pdf/charter.pdf
3. World Commission on Environment and Development. Our Common Future. Oxford: Oxford University Press, 1987.
4. Steffen W, Grinevald J, Crutzen P, McNeill J. The Anthropocene: conceptual and historical perspectives. *Philosophical Transactions A*. 2011; 369(1938): 842-867.
5. Steffen W, Broadgate W, Deutsch L, Gaffney O, Ludwig C. The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*. 2015; 2(1): 81–98.
6. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, et al. Planetary boundaries: guiding human development on a changing planet. *Science*. 2015; 347: 6223.
7. Barnosky AD, Hadly EA, Bascompte J, Berlow EL, Brown JH, Fortelius M, et al. Approaching a state shift in earth's biosphere. *Nature*. 2012; 486: 52-58.
8. Climate Change Science Program (CCSP). Abrupt Climate Change: Final Report, Synthesis and Assessment Product 3.4. Reston: Diane Publishing Co., 2008. 477pp. Available at: http://digital.library.unt.edu/ark:/67531/metadc12027/m2/1/high_res_d/sap3-4-final-report-all.pdf
9. Canadian Public Health Association (CPHA). Human and Ecosystem Health. Ottawa: CPHA, 1992. 12pp. Available at http://www.cpha.ca/uploads/policy/human-ecosystem_health_e.pdf
10. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Washington, D.C: Island Press, 2005. 155pp. Available at: www.unep.org/maweb/documents/document.356.aspx.pdf
11. Millennium Ecosystem Assessment. Living Beyond Our Means: Natural Assets and Human Well-being. Statement from the Board, 2005. 28pp. Available at: http://www.unep.org/maweb/documents/document.429.aspx.pdf
12. World Wide Fund for Nature (WWF). Living Planet Report 2014. Gland: WWF International, 2014. 180pp. Available at: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/
13. Mackenzie H, Messinger H, Smith R. Size matters: Canada's ecological footprint, by income. Toronto: Canadian Centre for Policy Alternatives, 2008. 31pp. Available at: http://www.policyalternatives.ca/sites/default/files/uploads/publications/National_Office_Pubs/2008/Size_Matters_Canadas_Ecological_Footprint_By_Income.pdf
14. World Wide Fund for Nature (WWF). Canadian Living Planet Report 2007. Toronto: WWF Canada, 2007. 23pp. Available at: http://awsassets.wwf.ca/downloads/canadianlivingplanetreport2007.pdf
15. Federal, Provincial and Territorial Governments of Canada. Canadian Biodiversity: Ecosystem Status and Trends 2010. Ottawa: Canadian Councils of Resource Ministers, 2010. 152pp. Available at http://www.biodivcanada.ca/A519F000-8427-4F8C-9521-8A95AE287753%5CEN_CanadianBiodiversity_FULL.pdf
16. Commissioner of the Environment and Sustainable Development of Canada. Report of the Commissioner of the Environment and Sustainable Development: The Commissioner's Perspective. Ottawa: Office of Auditor General of Canada, 2014. 14pp. Available at: http://www.oag-bvg.gc.ca/internet/docs/parl_cesd_201410_00_e.pdf
17. Oliver JGJ, Janssens-Maenhout G, Muntean M, Peters JAHW. Trends in global CO2 emissions; 2013 Report. The Hague: PBL Netherlands Environmental Assessment Agency; Ispra: Joint Research Centre, 2013. 64pp. Available at: http://edgar.jrc.ec.europa.eu/news_docs/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf
18. World Meteorological Organization (WMO). Greenhouse Gas Bulletin #10. Geneva: WMO, 2014. 8pp. Available at: http://www.wmo.int/pages/prog/arep/gaw/ghg/documents/GHG_Bulletin_10_Nov2014_EN.pdf
19. National Aeronautics and Space Administration (NASA). Global Land-Ocean Temperature Index in 0.01 degrees Celsius (base period: 1951-1980). Goddard Institute for Space Studies, 2015. Available at: http://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts+dSST.txt (Accessed July 19, 2014).
20. NOAA National Climatic Data Center. State of the Climate: Global Analysis for December 2014. U.S. Department of Commerce, 2015. Available at: http://www.ncdc.noaa.gov/sotc/global/2014/12 (Accessed January 17, 2015).
21. Environment Canada. Climate Trends and Variations Bulletin - Annual 2013. Government of Canada, 2013. Available at: http://www.ec.gc.ca/adsc-cmda/default.asp?lang=En&n=8C7AB86B-1 (Accessed February 10, 2014).
22. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2013: The Physical Science Basis – Summary for Policy Makers. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2013. 28pp. Available at http://www.climatechange2013.org/report/
23. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014: Synthesis Report - Summary for Policymakers. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC, 2014. 32pp. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf
24. Commissioner of the Environment and Sustainable Development of Canada. Report of the Commissioner of the Environment and Sustainable Development: Chapter 1- Mitigating Climate Change. Ottawa: Office of Auditor General of Canada, 2014. 48pp. Available at: http://www.oag-bvg.gc.ca/internet/docs/parl_cesd_201410_01_e.pdf
25. Allen MR, Frame DJ, Huntingford C, Jones CD, Lowe JA, Meinshausen M, et al. Warming caused by cumulative carbon emissions: towards the trillionth tonne. *Nature*. 2009; 458: 1163-1166.
26. Leaton J, Ranger N, Ward B, Sussams L, Brown M. Unburnable Carbon: Wasted Capital and Stranded Assets. London: Carbon Tracker and Grantham Research Institute, LSE, 2013. 40pp. Available at: http://carbontracker.live.kiln.it/Unburnable-Carbon-2-Web-Version.pdf
27. McGlade C, Ekins P. The geographical distribution of fossil fuels unused when limiting global warming to 20C. *Nature*. 2015; 517: 187-190.
28. Lee M, Brock E. Canada's Carbon Liabilities: The Implications of Stranded Fossil Fuel Assets for Financial Markets and Pension Funds. Canadian Centre for Policy Alternatives, 2013. 58pp. Available at: http://www.policyalternatives.ca/sites/default/files/uploads/publications/National%20Office,%20BC%20Office/2013/03/Canadas%20Carbon%20Liabilities.pdf
29. Hall RH, Chant D. Ecotoxicity: Responsibilities and Opportunities. Ottawa: Canadian Environmental Advisory Council, 1979.
30. Sorrell S, Miller R, Bentley R, Speirs J. Oil futures: A comparison of global supply forecasts. *Energy Policy*. 2010; 38(9): 4990 – 5003.
31. Aleklett K, Campbell CJ. The peak and decline of world oil and gas production. *Minerals and Energy - Raw Materials Report*. 2003; 18(1): 5-20.
32. Zittel W, Schindler J. Coal: Resources and future production. Ottobrunn: Energy Watch Group, 2007.47pp. Available at: http://energywatchgroup.org/wp-content/uploads/2014/02/EWG_Report_Coal_10-07-2007ms1.pdf

33. Cordell D, White S. Peak phosphorus: clarifying the key issues of a vigorous debate about long-term phosphorus security. *Sustainability*. 2011; 3(10): 2027-2049.

34. Dittmar M. The end of cheap uranium. *Science of the Total Environment. 2013;* 461-2: 792–798.

35. Diederen A. Metal minerals scarcity: A call for managed austerity and the elements of hope. Rijswijk: TNO Defence, Security and Safety, 2009. Available at: http://europe.theoildrum.com/node/5239

36. Heinberg R. Peak Everything: Waking Up To The Century of Declines. Gabriola: New Society Publishers, 2007.

37. World Wide Fund for Nature (WWF) . How Many Species are we Losing? WWF, n.d. Available at: http://wwf.panda.org/about_our_earth/biodiversity/biodiversity/ (Accessed March 6, 2014)

38. United Nations Environment Programme (UNEP). Keeping Track of Our Changing Environment: From Rio to Rio+20 (1992-2012). Nairobi: UNEP, 2011. 110pp. Available at http://www.unep.org/geo/pdfs/keeping_track.pdf

39. United Nations Environment Programme (UNEP). UNEP Emerging Issues: Environmental Consequences of Ocean Acidification: A threat to food security. Nairobi, UNEP, 2010. 12pp. Available at http://www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf

40. Rogers A, Laffoley, D. Introduction to the special issue: The global state of the ocean; interactions between stresses, impacts and some potential solutions. Synthesis papers from the International Programme on the State of the Ocean 2011 and 2012 workshops. *Marine Pollution Bulletin*. 2013;*74(2): 491-4*.

41. McCauley DJ, Pinsky ML, Palumbi SR, Estes JA, Joyce FH, Warner RR. Marine defaunation: Animal loss in the global ocean. *Science. 2015;*347(6219).

42. Millennium Alliance for Humanity and the Biosphere (MAHB). Scientific Consensus on Maintaining Humanity's Life Support Systems in the 21st Century: Information for Policy Makers. Consensus Statement from Global Scientists, 2013. Available at http://mahb.stanford.edu/consensus-statement-from-global-scientists/

43. Corvalan C, Hales S, McMichale A. Ecosystems and Human Well-being: Health Synthesis. A report of the Millennium Ecosystem Assessment. France: World Health Organization (WHO), 2005. 64pp. Available at: http://www.who.int/globalchange/ecosystems/ecosys.pdf?ua=1

44. Diamond J. Collapse: How Societies Choose to Fail or Succeed. New York: Viking Press, 2005.

45. Hancock T. Managing decline: Global change requires local action. In: Butler C, Dixon J, Capon T (Eds.), Healthy Work, Health Places, Health Planet. (In press): 2014.

46. Kumar K. Modernization. In: Encyclopedia Britannica [Internet], 2014. Available at http://www.britannica.com/EBchecked/topic/387301/modernization (Accessed March 10, 2014).

47. Steffen W, Persson A, Deutsch L, Zalasiewicz J, Williams M, Richardson K, et al. The Anthropocene: From Global Change to Planetary Stewardship. *AMBIO*. 2011;40(7):739-761.

48. Ehrlich PR, Holdren JP. Impact of population growth. *Science*. 1971;171(3977),1212-17.

49. United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2012 Revision, Key Findings and Advance Tables. New York: United Nations, 2013. 54pp. Available at: http://esa.un.org/wpp/documentation/pdf/wpp2012_%20key%20findings.pdf

50. United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2004 Revision, Key Findings and Advance Tables. New York: United Nations, 2005. 105pp. Available at: http://www.un.org/esa/population/publications/WPP2004/2004Highlights_finalrevised.pdf

51. Statistics Canada. Population Projections for Canada, Provinces and Territories: 2009 to 2036. *Catalogue No. 91-520-X*. Ottawa: Minister of Industry, 2010. 248pp. Available at: http://www.statcan.gc.ca/pub/91-520-x/91-520-x2010001-eng.pdf

52. Statistics Canada. Population projections: Canada, the provinces and territories, 2013 to 2063. *The Daily*. 2014 September 17. 4pp. Available at http://www.statcan.gc.ca/daily-quotidien/140917/dq140917a-eng.pdf

53. United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2011 Revision - Highlights. New York: United Nations, 2012. 318pp. Available at: http://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf

54. United Nations (UN) Habitat, World Health Organization (WHO). Hidden Cities: Unmasking and Overcoming Health Inequities in Urban Settings. Geneva: WHO, 2010. 126pp. Available at: http://www.who.int/kobe_centre/publications/hidden_cities2010/en/

55. United Nations Environment Programme (UNEP). Global Environment Outlook 3: Past, present and future perspectives. London: Earthscan Publications Ltd., 2002. 34pp. Available at: http://www.unep.org/geo/geo3/english/pdfs/prelims.pdf

56. The Global Commission on the Economy and Climate. Chapter Two – Cities. In: Better Growth, Better Climate: The New Climate Economy Report, n.d. Available at http://newclimateeconomy.report/

57. Frumkin H, Frank L, Jackson R. Urban Sprawl and Public Health: Designing, Planning and Building for Healthy Communities. Washington: Island Press, 2004.

58. Kuznets S. National Income, 1929–1932. In: National Bureau of Economic Research Book. Cambridge: NBER, 1934; 1-12. Available at: http://www.nber.org/books/kuzn34-1

59. World Bank. World Development Indicators (CD-ROM). Washington, D.C., 2001.

60. Index Mundi. Canada GDP – Per Capita (PPP). Index Mundi, 2014. Available at: http://www.indexmundi.com/canada/gdp_per_capita_%28ppp%29.html (Accessed March 14, 2014).

61. International Monetary Fund (IMF). World Economic Outlook: Slowing Growth, Rising Risks. Washington, D.C.: IMF, 2011. 241pp. Available at: http://www.imf.org/external/pubs/ft/weo/2011/02/pdf/text.pdf (Accessed March 14, 2014).

62. International Monetary Fund (IMF). World Economic Outlook: Global Recovery Stalls, Downside Risks Intensify. Washington, D.C.: IMF, 2012. 7pp. Available at: http://www.imf.org/external/pubs/ft/weo/2012/update/01/pdf/0112.pdf (Accessed March 14, 2014).

63. International Monetary Fund (IMF). World Economic Outlook: Hopes, Realities, Risks. Washington, D.C.: IMF, 2013. 204pp. Available at: http://www.imf.org/external/pubs/ft/weo/2013/01/pdf/text.pdf (Accessed March 14, 2014).

64. World Bank Group. 2050 Projections Suggest Today's Choices are Crucial [World Bank Press Release No: 2005/108/ESSD]. World Bank, 2004. Available at: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20263094~pagePK:64257043~piPK:437376~theSitePK:4607,00.html

65. Wilkinson R, Pickett K. The Spirit Level: Why Equality is Better for Everyone. New York: Bloomsbury Press, 2010.

66. Milanovic B. Global Inequality and the Global Inequality Extraction Ratio: The Story of the Past Two Centuries. Washington, D.C.: The World Bank, 2009. 29pp. Available at: http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-5044

67. Conference Board of Canada. Hot Topic: Canada Income Inequality. Is Canada becoming more unequal? Conference Board of Canada, 2011. Available at: http://www.conferenceboard.ca/hcp/hot-topics/caninequality.aspx (Accessed July 22, 2014).

68. Victor PA. Managing Without Growth: Slower by Design, Not Disaster. Northampton: Edward Elgar Publishing. Inc., 2008.
69. Smith C, Patterson V, Scott R. Reducing your carbon footprint: how telemedicine helps. *BMJ*. 2007;335(7629):1060.
70. Oliveira TC, Barlow J, Goncalves L, Bayer S. Teleconsultations reduce greenhouse gas emissions. *J Health Serv Res Policy*. 2013;18(4):209–214.
71. The Earth Charter Initiative. Welcome: The Earth Charter is a Universal Expression of Ethical Principles to Foster Sustainable Development. Earth Charter International, 2012. Available at: http://www.earthcharterinaction.org/content/
72. Freudenberg N. Lethal But Legal: Corporations, Consumption, and Protecting Public Health. New York: Oxford University Press, 2014.
73. Hastings G. Why corporate power is a public health priority. *BMJ*. 2012;345:e5124.
74. Wiist WH. Health and the anticorporate movement: rationale and recommendations. *Am J Public Health*. 2006;96(8):1370-75.
75. Ingelhart R. Changing values among western publics from 1970 to 2006. *West European Politics*. 2008;31(1–2):130-146.
76. Horton R, Beaglehole R, Bonita R, Raeburn J, McKee M, Wall S. From public to planetary health: a manifesto. *The Lancet*. 2014; 383(9920):847.
77. Horton R. Offline: reimagining the meaning of health. *The Lancet*. 2014;384 (9939):218.
78. Confalonieri U, McMichael A. Global Environmental Change and Human Health: Science Plan and Implementation Strategy. Earth System Science Partnership, 2007. 94pp. Available at: http://www.gechh.unu.edu/FINAL_GECHH_SP_UPDATED.pdf
79. Intergovernmental Panel on Climate Change. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press, 2014;709-754.
80. Fundación DARA Internacional. Climate Vulnerability Monitor 2nd Edition: A Guide to the Cold Calculus of a Hot Planet. Madrid: Estudios Gráficos Europeos, S.A., 2012. 62pp. Available at: http://www.daraint.org/wp-content/uploads/2012/09/CVM2ndEd-FrontMatter.pdf
81. Kjellstrom T, Kovats RS, Lloyd S, Holt T, Tol R. The direct impact of climate change on regional labor productivity. *Arch Env Occup Health*. 2009;64(4):217-227.
82. Kjellstrom T, Lemke B, Venugopal V. Occupational Health and Safety Impacts of Climate Conditions. In: Pielke RA, Adgoke J, Wright CY (Eds.). Climate Vulnerability: Understanding and Addressing Threats to Essential Resources. China: Elsevier Inc., 2013.
83. Prüss-Üstün A, Corvalán C. Preventing Disease through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease. Geneva: World Health Organization (WHO), 2006. 106pp. Available at: http://www.who.int/quantifying_ehimpacts/publications/preventingdisease.pdf
84. World Health Organization (WHO). Action is Needed on Chemicals of Major Public Health Concern. WHO, 2010. Available at: http://www.who.int/ipcs/assessment/public_health/chemicals_phc/en/
85. President's Cancer Panel. Reducing Environmental Cancer Risk: What We Can Do Now: 2008-2009 Annual Report. Bethesda: National Cancer Institute, 2010. 240pp. Available at: http://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf
86. United Nations Environment Programme (UNEP), World Health Organization (WHO). State of the Science of Endocrine Disrupting Chemicals–2012. Geneva: UNEP and WHO, 2013. 296pp. Available at: http://www.who.int/ceh/publications/endocrine/en/
87. Landrigan PJ, Goldman LR. Children's vulnerability to toxic chemicals: a challenge and opportunity to strengthen health and environmental policy. *Health Affairs*. 2011;30(5):842-50.
88. Wigle DT, Arbuckle TE, Walker M, Wade MG, Liu S, Krewski D. Environmental hazards: evidence for effects on child health. *J Toxicol Environ Health B Crit Rev*. 2007;10(1-2):3-39.
89. Wigle DT, Arbuckle TE, Turner MC, Berube A, Yang Q, Liu S, et al. Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. *J Toxicol Environ Health B Crit Rev*. 2008;11(5-6): 373-517.
90. Seppelt R, Manceur AM, Liu J, Fenichel EP, Klotz S. Synchronized peak-rate years of global resources use. *Ecology and Society*. 2014;19(4):50.
91. Webber M. A puzzle for the planet. *Scientific American*. 2015;312(2):63-67.
92. McEvoy CT, Temple N, Woodside JV. Vegetarian diets, low-meat diets and health: A Review. *Public Health Nutr*. 2012;15(12):2287-94.
93. Mohr S. Projection of World Fossil Fuel Production with Supply and Demand Interactions [thesis]. Newcastle: University of Newcastle, 2010. Available at: http://www.theoildrum.com/node/6782
94. Lovins AB. Energy End-Use Efficiency. Snowmass: Rocky Mountain Institute, 2005. 25pp. Available at: http://www.rmi.org/Knowledge-Center/Library/E05-16_EnergyEndUseEfficiency
95. Ryan L, Campbell N. Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. Paris: Economic Co-operation and Development (OECD), International Energy Agency (IEA), 2012. 37pp. Available at: http://www.iea.org/publications/insights/ee_improvements.pdf
96. Chivian E, Bernstein A. How our Health Depends on Biodiversity. Cambridge: Center for Health and the Global Environment, Harvard Medical School, 2010. 24pp. Available at: http://www.chgeharvard.org/sites/default/files/resources/182945%20HMS%20Biodiversity%20booklet.pdf
97. Secretariat of the Convention on Biological Diversity, World Health Organization (WHO). Connecting Global Priorities: Biodiversity and Human Health, a State of Knowledge Review. Montreal: WHO, 2015. 35pp. Available at: https://www.cbd.int/getattachment/health/stateofknowledge/SOK-Summary-Finalv4_reduced-%282%29.pdf
98. Canadian Global Change Health Panel. Implications of Global Change for Human Health Ottawa: Canadian Global Change Program. Ottawa: Royal Society of Canada, 1994.
99. E Risk Sciences. Systematic Review of Environmental Burden of Disease in Canada (Final Report). Vancouver: National Collaborating Centre for Environmental Health, 2010. 68pp. Available at: http://www.ncceh.ca/sites/default/files/Env_Burden_Disease_Oct_2010.pdf
100. Berry P, Clarke K, Fleury MD, Parker S. Human Health. In: Warren FJ, Lemmen DS (Eds.), Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Ottawa: Government of Canada, 2014. 292pp. Available at: http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2014/16309
101. Health Canada. Second Report on Human Biomonitoring of Environmental Chemicals in Canada. Ottawa: Health Canada, 2013. 444pp. Available at: http://www.healthyenvironmentforkids.ca/sites/healthyenvironmentforkids.ca/files/HumanBiomonitoringReport__EN.pdf
102. Dewailly É. Canadian Inuit and the arctic dilemma. *Oceanography*. 2006;19(2):88-9.
103. McMichael AJ, Nyong A, Corvalan C. Global Environmental Change and Health: Impacts, Inequalities, and the Health Sector. *BMJ*. 2008;336(7637):191-4.
104. Brown V, Harris J, Russel J. Tackling Wicked Problems: Through the Transdisciplinary Imagination. New York: Earthscan, 2010.

105. The Commission on Global Governance. Our Global Neighborhood. Oxford: Oxford University Press, 1995. Available at: http://www.gdrc.org/u-gov/global-neighbourhood/

106. Parkes M, Bienen L, Breilh J, Hsu L, McDonald M, Patz J, et al. All hands on deck: transdisciplinary approaches to emerging infectious disease. *EcoHealth*. 2005;2(4):258-272.

107. Northern Health, University of Northern British Columbia. Position on the Environment as a Context for Health: An Integrated Settings Approach - Version 2.0. Prince George: Northern Health, 2012. 24pp. Available at: https://www.northernhealth.ca/Portals/0/About/PositionPapers/documents/EnvironmentContext%20Health_V2_20120725_WEB.pdf

108. Baum F, Sanders D. Ottawa 25 years on: a more radical agenda for health equity is still required. *Health Promot Int*. 2011;26(S2):ii253-ii257.

109. Henchey N. Making sense of future studies. *Alternatives*. 1978;7:24-29.

110. Bezold C, Hancock T. Possible futures, preferable futures. *Healthc Forum J*. 1994;37(2):23-29.

111. Dutt M, Brcic V. Medicare can still rise to meet its challenges. Times Colonist 2014, Aug 9 pp A11.

112. Macy J, Johnstone C. Active hope: how to face the mess we're in without going crazy. Novato, Calif: New World Library; 2012.

113. Macy J, Johnstone C. Active hope training. Active hope: how to face the mess we're in without going crazy. Available at: http://www.activehope.info/styled-4/index.html

114. United Nations Development Program (UNDP). Human Development Index (HDI). UNDP, n.d. Available at: http://hdr.undp.org/en/content/human-development-index-hdi

115. Rubin J. The End of Growth. Toronto: Random House of Canada Ltd., 2012.

116. Heinbery R. The End of Growth: Adapting to our New Economic Reality. Gabriola Island: New Society Publishers, 2011.

117. World Bank. Monitoring Environmental Progress: A Report on Work in Progress. Washington, D.C.: World Bank, 1995. 100pp. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1995/09/01/000009265_3961219103652/Rendered/PDF/multi_page.pdf

118. Hancock T. People, partnerships and human progress: building community capital. *Health Promot Int*. 2001;16(3):275-280.

119. Redefining Progress. Genuine Progress Indicator. Redefining Progress, n.d. Available at: http://rprogress.org/sustainability_indicators/genuine_progress_indicator.htm

120. Kubiszewski I, Costanza R., Franco C, Lawn P, Talberth J, Jackson T, et al. Beyond GDP: measuring and achieving global genuine progress. *Ecol Econ*. 2013;93:57–68.

121. Canadian Index of Wellbeing. Composite Index. University of Waterloo, Faculty of Applied Health Sciences, n.d. Available at: https://uwaterloo.ca/canadian-index-wellbeing/our-products/composite-index

122. Abdallah S, Michaelson J., Shah S, Stoll L, Marks N. Happy Planet Index: 2012 Report, A Global Index of Sustainable Wellbeing. London: New Economics Foundation, 2012. 27pp. Available at: http://www.happyplanetindex.org/assets/happy-planet-index-report.pdf

123. Centre for Bhutan Studies & GNH Research. Gross National Happiness: Home. Centre for Bhutan Studies & GNH Research, 2015. Available at: http://www.grossnationalhappiness.com/ (Accessed July 14, 2014).

124. Smith KR, Balakrishnan K, Butler C, Chafe Z, Fairlie I, Kinney P, et al. Energy and Health. In: Johansson TB, Nakicenovic N, Patwardhan A, Gomez-Echeverri L (Eds.), Global Energy Assessment: Toward a Sustainable Future. Cambridge: Cambridge University Press, 2012.

125. Smith K, Frumkin H, Balakrishnan K, Butler C, Chafe Z, Fairlie I, et al. Energy and human health. *Ann Rev Public Health*. 2013; 34:159–88.

126. Krewitt W, Hurley F, Trukenmüller A, Friedrich R. Health risks of energy systems. *Risk Analysis*. 1998;18(4): 377–383.

127. VandeWeghe J, Kennedy C. A spatial analysis of residential greenhouse gas emissions in the Toronto census metropolitan area. *J Ind Ecol*. 2007;11(2):133-144.

128. Hirsch J, Moberg C. René Jules Dubos: 1901-1982. Washington, D.C.: National Academy of Sciences, 1989. Available at: http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/dubos-rene.pdf

129. Diers J. From the Ground Up: Community's Role in Addressing Street Level Social Issues. Calgary: Canada West Foundation, 2008. pp18. Available at: http://cwf.ca/pdf-docs/publications/from-the-ground-up-2008.pdf

130. Kretzmann J, McKnight J. Building Communities from the Inside Out: A Path Toward Finding and Mobilizing a Community's Assets. Evanston: ACTA Publications, 1993.

131. Lutkehaus NC. Margaret Mead: The Making of an American Icon. Princeton: Princeton University Press, 2008; 261.

132. Hancock T. Healthy communities must be sustainable communities too. *Public Health Reports*. 2000,115(2-3),151-156.

133. BC Healthy Communities. Healthy Communities Approach. BC Healthy Communities, 2015. Available at: http://bchealthycommunities.ca/healthycommunities?&PHPSESSID=d701a2f6008f336588602f49759f73f9 (Accessed July 14, 2014).

134. United Nations Conference on Environment and Development. Rio Declaration on Environment and Development. United Nations Environment Program, 1992. Available at: http://www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163

135. Earth Charter Initiative. Read the Charter. Earth Charter International. Available at: http://www.earthcharterinaction.org/content/pages/Read-the-Charter.html

Appendix A: Acknowledgements

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Appendix B: From Ideas to Action

Public health professionals and organizations need to improve their capacity to understand and address the ecological determinants of health and how these interact with the social determinants of health. The following recommendations for action aim to enact the principles and mechanisms noted in this discussion paper. They provide a starting point for in-depth discussions within the public health community and among the various stakeholders on the way forward.

Understand and address the ecological determinants of health

Educate public health professionals about the ecological determinants of health:

- Update Canada's set of Core Competencies for Public Health to give greater prominence to the ecological determinants of health, ensuring that public health practitioners have the ability to address both the ecological and social determinants of health;
- Revise the curricula in Canada's Schools and Programs of Public Health to reflect a broader understanding of population health and its determinants, incorporating core concepts or courses that address the ecological determinants of health and links with social determinants;
- Encourage awareness of combined approaches to ecological and social determinants of health that will align public health with a range of existing movements spanning environmental, Indigenous, conservation, labour, social justice, climate change efforts, etc. and;
- Include learning of a wide range of change-oriented practices employed by diverse actors involved in complexity science, community organizing, social practice theory, interdisciplinary work on governing societal transitions, transformative learning, Theory U, generative dialogue, etc.

Monitor, assess and report regularly on the ecological determinants of health with respect to immediate and longer term public health needs:

- The Public Health Agency of Canada, the Canadian Institutes for Health Information (CIHI), and Statistics Canada should develop and test a set of indicators of the ecological determinants of health to be used to monitor and report on these issues across all four orders of government (i.e., federal, provincial, municipal and First Nations) and to guide more comprehensive impact assessments of the ecological, social, health and economic impacts of major public policies and private sector developments. Specifically, to:
  - Identify health indicators for conditions plausibly related to ecological change for use within impact assessments and as early-warning or sentinel conditions to be monitored;
  - Revise the core set of indicators of health used in Canada to include indicators to measure key ecological determinants of health, the socio-ecological system and sentinel health conditions associated with ecological change;
  - Ensure that public health reports at all levels include indicators of ecological determinants of health in routine reports, and report specifically on them on a regular basis, reflecting local, regional, provincial, national, indigenous and global contexts; and
  - Assure that as much effort and profile are applied to the collection and publication of data on the state of the environment as on the state of the economy. This sustained activity will build capacity for full-cost accounting of ecological change throughout the economy and create knowledge to ensure when harm is done, the polluter pays.

Fund and support research into the ecological determinants of health:

- CIHR and other research funding bodies should make a significant and long-term commitment to funding research on the health impacts of ecological change, the relationship between the ecological and social determinants of health, and appropriate strategies and interventions for the prevention and mitigation of health impacts and adaptation to ecological change.
- CIHR should establish an Institute for Environment and Health, as a tri-council institute in conjunction with the Social Sciences and Humanities Research Council (SSHRC) and Natural Sciences and Engineering Research Council of Canada (NSERC), in order to more fully address the broader dimensions of a socio-ecological approach to population health.
- A dedicated fund should be established within the Canadian Global Health Research Program for research on the health impacts of anticipated ecological changes globally.
- Governments should re-invest substantially in Canada's capacity to monitor, undertake research, manage information, conduct impact assessments and report on ecological

change in Canada and globally. This will require investment in personnel, programs and technology.
- Research must be directed to the important tasks of knowledge translation and exchange, moving knowledge of ecological determinants of health into actions, policy and mechanisms to address these issues, and working in conjunction with relevant organizations to address this.

Establish a UN Commission on the Ecological Determinants of Health
- The UN should establish a Commission on the Ecological Determinants of Health to undertake work and continue the important investment in knowledge, similar to that of the Commission on the Social Determinants of Health.

Walk the talk: Environmentally responsible health care
- Public health organizations and their parent health care organizations should be members of the Canadian Coalition for Green Health Care and should apply the principles and practices of environmentally responsible health care, consistent with established national and international standards and codes of practice (e.g. LEED, ISO, etc.).
- The Cochrane Collaboration should be asked to undertake a review of the various green/sustainable health care initiatives.

Change social norms and values
- Develop and maintain a public dialogue on the Ecological Determinants of Health, because public participation is required to develop new values and social norms and to support broad national and international actions.
- Public health should work with interested individuals, organizations and communities to develop a shared vision of what a healthier, more just and sustainable future might look like, and how to achieve it, such as contained in The Earth Charter.[135]
- Public health should join others in working towards a fundamental shift in the values and social norms of the population in order to create change to address the emerging ecological crisis. To do this, public health organizations and practitioners need to listen to and learn from those already working toward alternative, more positive futures, and to foster alliances with other efforts that demonstrate socio-ecological approaches to the health of present and future generations.

Change the focus of development and the way it is measured
- Public health professionals and organizations must persistently argue for measurement of social development and progress, at all levels, that reflect the ecological determinants of health, sustainable health, wellbeing and human development, using the Canadian Index of Wellbeing or international alternatives such as the Genuine Progress Indicator, the Happy Planet Index, or Gross National Happiness.
- Public health organizations should incorporate measures of human and social development in health status reports, as well as advocating for such measures to be used in the wider governmental and societal context.
- "Health in All Policies" must be a major focus for public health, including to actively develop capacity to engage in intersectoral conversations that have implications for ecological and social determinants of health.

Strengthen ethical purchasing and investment policies
- Public health professionals and organizations should consider the ethical and ecological implications of their own purchasing and investment decisions, and develop ecological purchasing and investment policies including criteria to exclude receiving financial benefits from economic activities deemed to be the most harmful to local or global ecosystems.
- Public health organizations should partner with and accept funding only from industries that adhere to practices that will move us towards the sustainable, just and healthy future we seek. .
- Public health professionals and organizations must call for disinvestment, including by public pension funds, from ecologically harmful businesses.

Protect people and communities from harm and health inequity
- Public health practitioners and organizations should examine how to use public health legislation to address the health impacts of ecological change, and should request the Minister, Provincial Health Officer or other appropriate public health officials to initiate an inquiry or investigation where their Public Health Act requires or enables such an action.
- If the Public Health Act in a given jurisdiction does not require or enable public health officials to initiate an inquiry or investigation, public health practitioners and organizations should advocate for changes to the Act.

Protect people and communities from the adverse impacts of ecological change

- There are two main strategies: Reduce vulnerability and protect the vulnerable, and increase resilience and adaptation.
- The public health sector at all levels and the health care system in general must identify its own vulnerability with respect to its own mandate to protect and promote public health.
- Public health practitioners and organizations should expand their work with others to prevent, prepare for and respond to emergencies arising from ecological changes. This includes to:
- Identify the vulnerability of individuals and communities to increasing frequency and severity of floods, fires, storms, urban heat events and other climate-related events;
- Identify and protect the most vulnerable populations;
- Set up mechanisms to manage ecological decline; and
- Increase the resilience of the communities with which they work.

Work with others to establish policies and practices that create more ecologically sustainable and healthy societies and communities.

- Public health professionals and organizations need to support collaboration across government departments at all levels and across different sectors of society to help create a more just, sustainable and healthy society.
- Public health professionals and organizations must find allies and forge partnerships among those individuals and organizations in all levels and sectors of society that share our vision.
- Policies and practices in the public and private sectors should be examined from a population health perspective, as part of comprehensive impact assessments. Policies and practices that are consistent with improving or not harming the ecological determinants of health should be adopted or encouraged; those that would do harm must be amended or dropped.
- As a general principle, public health should support the transfer of public subsidies and tax incentives from economic activities that worsen the ecological crisis to those that improve ecological functions and resource sustainability.
- Public health organizations and professionals working at the local level should:
- Adopt an asset-based approach to community development around health and sustainability issues;
- Encourage and support existing sustainable community initiatives (e.g. Transition Towns, ecovillages, ecohousing applications, community gardens, and other related initiatives);
- Encourage and support linkages and collaboration between existing healthy community and sustainable community initiatives; and
- Work to establish healthy and sustainable community initiatives, in partnership with other key groups and organizations, including the efforts of municipal, regional and First Nations governments.

Founded in 1910, the Canadian Public Health Association (CPHA) is the independent voice for public health in Canada with links to the international community. As the only Canadian non-governmental organization focused exclusively on public health, CPHA is uniquely positioned to advise decision-makers about public health system reform and to guide initiatives to help safeguard the personal and community health of Canadians and people around the world. CPHA is a national, independent, not-for-profit, voluntary association. CPHA's members believe in universal and equitable access to the basic conditions which are necessary to achieve health for all.

Our Vision

A healthy and just world

Our Mission

CPHA's mission is to enhance the health of people in Canada and to contribute to a healthier and more equitable world.

www.cpha.ca

This is Exhibit "G" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.

Climate Change 2014
Synthesis Report
Summary for Policymakers

SPM

Introduction

This Synthesis Report is based on the reports of the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC), including relevant Special Reports. It provides an integrated view of climate change as the final part of the IPCC's Fifth Assessment Report (AR5).

This summary follows the structure of the longer report which addresses the following topics: Observed changes and their causes; Future climate change, risks and impacts; Future pathways for adaptation, mitigation and sustainable development; Adaptation and mitigation.

In the Synthesis Report, the certainty in key assessment findings is communicated as in the Working Group Reports and Special Reports. It is based on the author teams' evaluations of underlying scientific understanding and is expressed as a qualitative level of confidence (from *very low* to *very high*) and, when possible, probabilistically with a quantified likelihood (from *exceptionally unlikely* to *virtually certain*)[1]. Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers.

This report includes information relevant to Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC).

SPM 1. Observed Changes and their Causes

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. *{1}*

SPM 1.1 Observed changes in the climate system

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. *{1.1}*

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was *likely* the warmest 30-year period of the last 1400 years in the Northern Hemisphere, where such assessment is possible (*medium confidence*). The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 [0.65 to 1.06] °C[2] over the period 1880 to 2012, when multiple independently produced datasets exist (Figure SPM.1a). *{1.1.1, Figure 1.1}*

In addition to robust multi-decadal warming, the globally averaged surface temperature exhibits substantial decadal and interannual variability (Figure SPM.1a). Due to this natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends. As one example, the rate of warming over

[1] Each finding is grounded in an evaluation of underlying evidence and agreement. In many cases, a synthesis of evidence and agreement supports an assignment of confidence. The summary terms for evidence are: limited, medium or robust. For agreement, they are low, medium or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, e.g., *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, more unlikely than likely 0–<50%, extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., *very likely*. See for more details: Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe and F.W. Zwiers, 2010: Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland, 4 pp.

[2] Ranges in square brackets or following '±' are expected to have a 90% likelihood of including the value that is being estimated, unless otherwise stated.

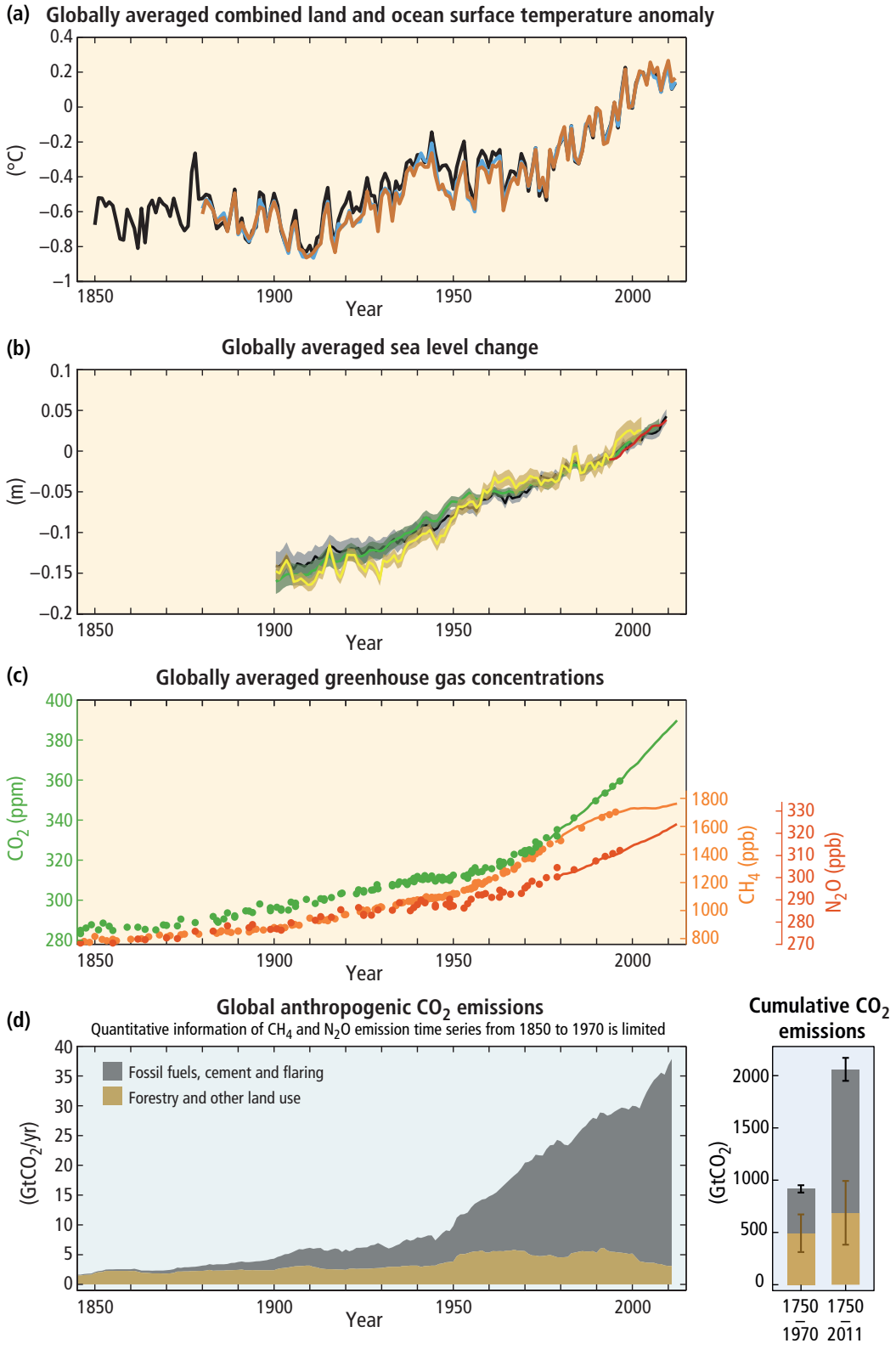

Figure SPM.1 | The complex relationship between the observations (panels a, b, c, yellow background) and the emissions (panel d, light blue background) is addressed in Section 1.2 and Topic 1. Observations and other indicators of a changing global climate system. Observations: **(a)** Annually and globally averaged combined land and ocean surface temperature anomalies relative to the average over the period 1986 to 2005. Colours indicate different data sets. **(b)** Annually and globally averaged sea level change relative to the average over the period 1986 to 2005 in the longest-running dataset. Colours indicate different data sets. All datasets are aligned to have the same value in 1993, the first year of satellite altimetry data (red). Where assessed, uncertainties are indicated by coloured shading. **(c)** Atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2, green), methane (CH_4, orange) and nitrous oxide (N_2O, red) determined from ice core data (dots) and from direct atmospheric measurements (lines). Indicators: **(d)** Global anthropogenic CO_2 emissions from forestry and other land use as well as from burning of fossil fuel, cement production and flaring. Cumulative emissions of CO_2 from these sources and their uncertainties are shown as bars and whiskers, respectively, on the right hand side. The global effects of the accumulation of CH_4 and N_2O emissions are shown in panel c. Greenhouse gas emission data from 1970 to 2010 are shown in Figure SPM.2. *{Figures 1.1, 1.3, 1.5}*

the past 15 years (1998–2012; 0.05 [–0.05 to 0.15] °C per decade), which begins with a strong El Niño, is smaller than the rate calculated since 1951 (1951–2012; 0.12 [0.08 to 0.14] °C per decade). *{1.1.1, Box 1.1}*

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (*high confidence*), with only about 1% stored in the atmosphere. On a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11 [0.09 to 0.13] °C per decade over the period 1971 to 2010. It is *virtually certain* that the upper ocean (0–700 m) warmed from 1971 to 2010, and it *likely* warmed between the 1870s and 1971. *{1.1.2, Figure 1.2}*

Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (*medium confidence* before and *high confidence* after 1951). For other latitudes, area-averaged long-term positive or negative trends have *low confidence*. Observations of changes in ocean surface salinity also provide indirect evidence for changes in the global water cycle over the ocean (*medium confidence*). It is *very likely* that regions of high salinity, where evaporation dominates, have become more saline, while regions of low salinity, where precipitation dominates, have become fresher since the 1950s. *{1.1.1, 1.1.2}*

Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1 (*high confidence*), corresponding to a 26% increase in acidity, measured as hydrogen ion concentration. *{1.1.2}*

Over the period 1992 to 2011, the Greenland and Antarctic ice sheets have been losing mass (*high confidence*), *likely* at a larger rate over 2002 to 2011. Glaciers have continued to shrink almost worldwide (*high confidence*). Northern Hemisphere spring snow cover has continued to decrease in extent (*high confidence*). There is *high confidence* that permafrost temperatures have increased in most regions since the early 1980s in response to increased surface temperature and changing snow cover. *{1.1.3}*

The annual mean Arctic sea-ice extent decreased over the period 1979 to 2012, with a rate that was *very likely* in the range 3.5 to 4.1% per decade. Arctic sea-ice extent has decreased in every season and in every successive decade since 1979, with the most rapid decrease in decadal mean extent in summer (*high confidence*). It is *very likely* that the annual mean Antarctic sea-ice extent increased in the range of 1.2 to 1.8% per decade between 1979 and 2012. However, there is *high confidence* that there are strong regional differences in Antarctica, with extent increasing in some regions and decreasing in others. *{1.1.3, Figure 1.1}*

Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m (Figure SPM.1b). The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). *{1.1.4, Figure 1.1}*

SPM 1.2 Causes of climate change

Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century. *{1.2, 1.3.1}*

Anthropogenic greenhouse gas (GHG) emissions since the pre-industrial era have driven large increases in the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Figure SPM.1c). Between 1750 and 2011, cumulative anthropogenic CO_2 emissions to the atmosphere were 2040 ± 310 $GtCO_2$. About 40% of these emissions have remained in the atmosphere (880 ± 35 $GtCO_2$); the rest was removed from the atmosphere and stored on land (in plants and soils) and in the ocean. The ocean has absorbed about 30% of the emitted anthropogenic CO_2, causing ocean acidification. About half of the anthropogenic CO_2 emissions between 1750 and 2011 have occurred in the last 40 years (*high confidence*) (Figure SPM.1d). *{1.2.1, 1.2.2}*

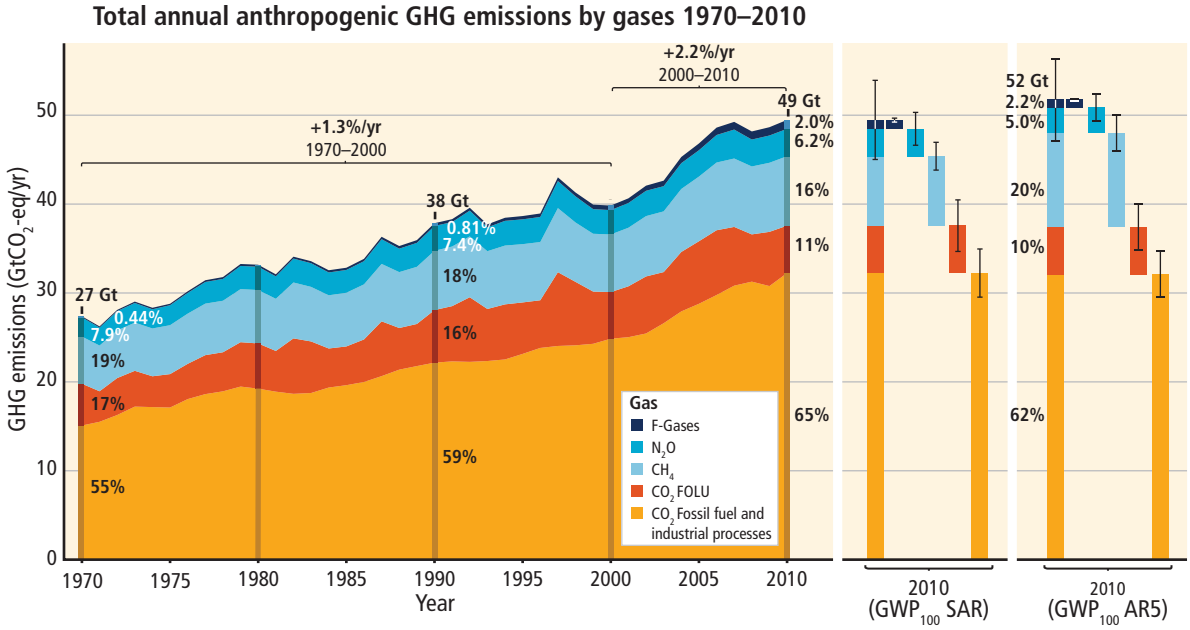

Figure SPM.2 | Total annual anthropogenic greenhouse gas (GHG) emissions (gigatonne of CO_2-equivalent per year, $GtCO_2$-eq/yr) for the period 1970 to 2010 by gases: CO_2 from fossil fuel combustion and industrial processes; CO_2 from Forestry and Other Land Use (FOLU); methane (CH_4); nitrous oxide (N_2O); fluorinated gases covered under the Kyoto Protocol (F-gases). Right hand side shows 2010 emissions, using alternatively CO_2-equivalent emission weightings based on IPCC Second Assessment Report (SAR) and AR5 values. Unless otherwise stated, CO_2-equivalent emissions in this report include the basket of Kyoto gases (CO_2, CH_4, N_2O as well as F-gases) calculated based on 100-year Global Warming Potential (GWP_{100}) values from the SAR (see Glossary). Using the most recent GWP_{100} values from the AR5 (right-hand bars) would result in higher total annual GHG emissions (52 $GtCO_2$-eq/yr) from an increased contribution of methane, but does not change the long-term trend significantly. *{Figure 1.6, Box 3.2}*

Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute increases between 2000 and 2010, despite a growing number of climate change mitigation policies. Anthropogenic GHG emissions in 2010 have reached 49 ± 4.5 $GtCO_2$-eq/yr [3]. Emissions of CO_2 from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emissions increase from 1970 to 2010, with a similar percentage contribution for the increase during the period 2000 to 2010 (*high confidence*) (Figure SPM.2). Globally, economic and population growth continued to be the most important drivers of increases in CO_2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has risen sharply. Increased use of coal has reversed the long-standing trend of gradual decarbonization (i.e., reducing the carbon intensity of energy) of the world's energy supply (*high confidence*). *{1.2.2}*

The evidence for human influence on the climate system has grown since the IPCC Fourth Assessment Report (AR4). It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic forcings together. The best estimate of the human-induced contribution to warming is similar to the observed warming over this period (Figure SPM.3). Anthropogenic forcings have *likely* made a substantial contribution to surface temperature increases since the mid-20th century over every continental region except Antarctica[4]. Anthropogenic influences have *likely* affected the global water cycle since 1960 and contributed to the retreat of glaciers since the 1960s and to the increased surface melting of the Greenland ice sheet since 1993. Anthropogenic influences have *very likely* contributed to Arctic sea-ice loss since 1979 and have *very likely* made a substantial contribution to increases in global upper ocean heat content (0–700 m) and to global mean sea level rise observed since the 1970s. *{1.3, Figure 1.10}*

[3] Greenhouse gas emissions are quantified as CO_2-equivalent ($GtCO_2$-eq) emissions using weightings based on the 100-year Global Warming Potentials, using IPCC Second Assessment Report values unless otherwise stated. *{Box 3.2}*

[4] For Antarctica, large observational uncertainties result in *low confidence* that anthropogenic forcings have contributed to the observed warming averaged over available stations.

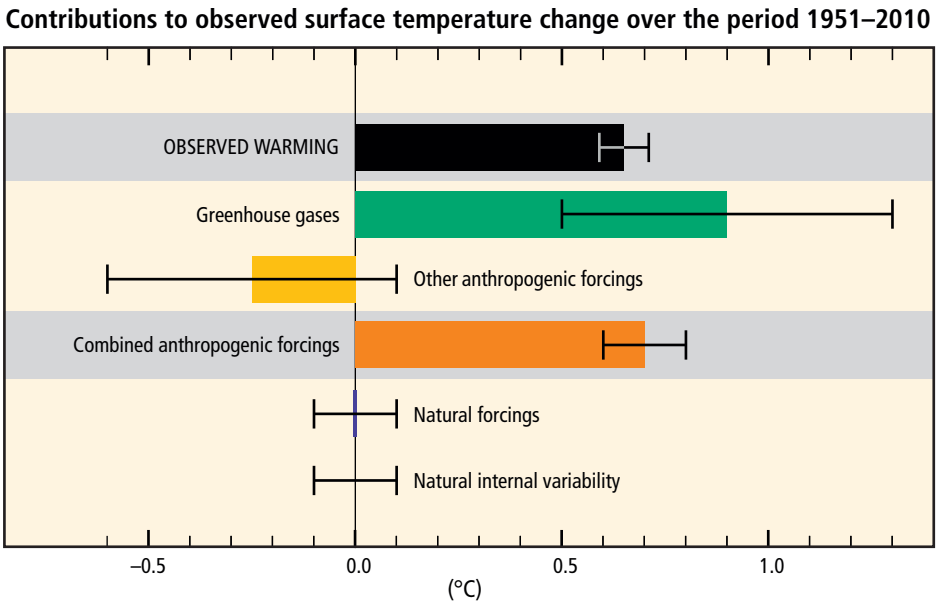

Figure SPM.3 | Assessed *likely* ranges (whiskers) and their mid-points (bars) for warming trends over the 1951–2010 period from well-mixed greenhouse gases, other anthropogenic forcings (including the cooling effect of aerosols and the effect of land use change), combined anthropogenic forcings, natural forcings and natural internal climate variability (which is the element of climate variability that arises spontaneously within the climate system even in the absence of forcings). The observed surface temperature change is shown in black, with the 5 to 95% uncertainty range due to observational uncertainty. The attributed warming ranges (colours) are based on observations combined with climate model simulations, in order to estimate the contribution of an individual external forcing to the observed warming. The contribution from the combined anthropogenic forcings can be estimated with less uncertainty than the contributions from greenhouse gases and from other anthropogenic forcings separately. This is because these two contributions partially compensate, resulting in a combined signal that is better constrained by observations. *{Figure 1.9}*

SPM 1.3 Impacts of climate change

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate. *{1.3.2}*

Evidence of observed climate change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to ongoing climate change (*high confidence*). Some impacts on human systems have also been attributed to climate change, with a major or minor contribution of climate change distinguishable from other influences (Figure SPM.4). Assessment of many studies covering a wide range of regions and crops shows that negative impacts of climate change on crop yields have been more common than positive impacts (*high confidence*). Some impacts of ocean acidification on marine organisms have been attributed to human influence (*medium confidence*). *{1.3.2}*

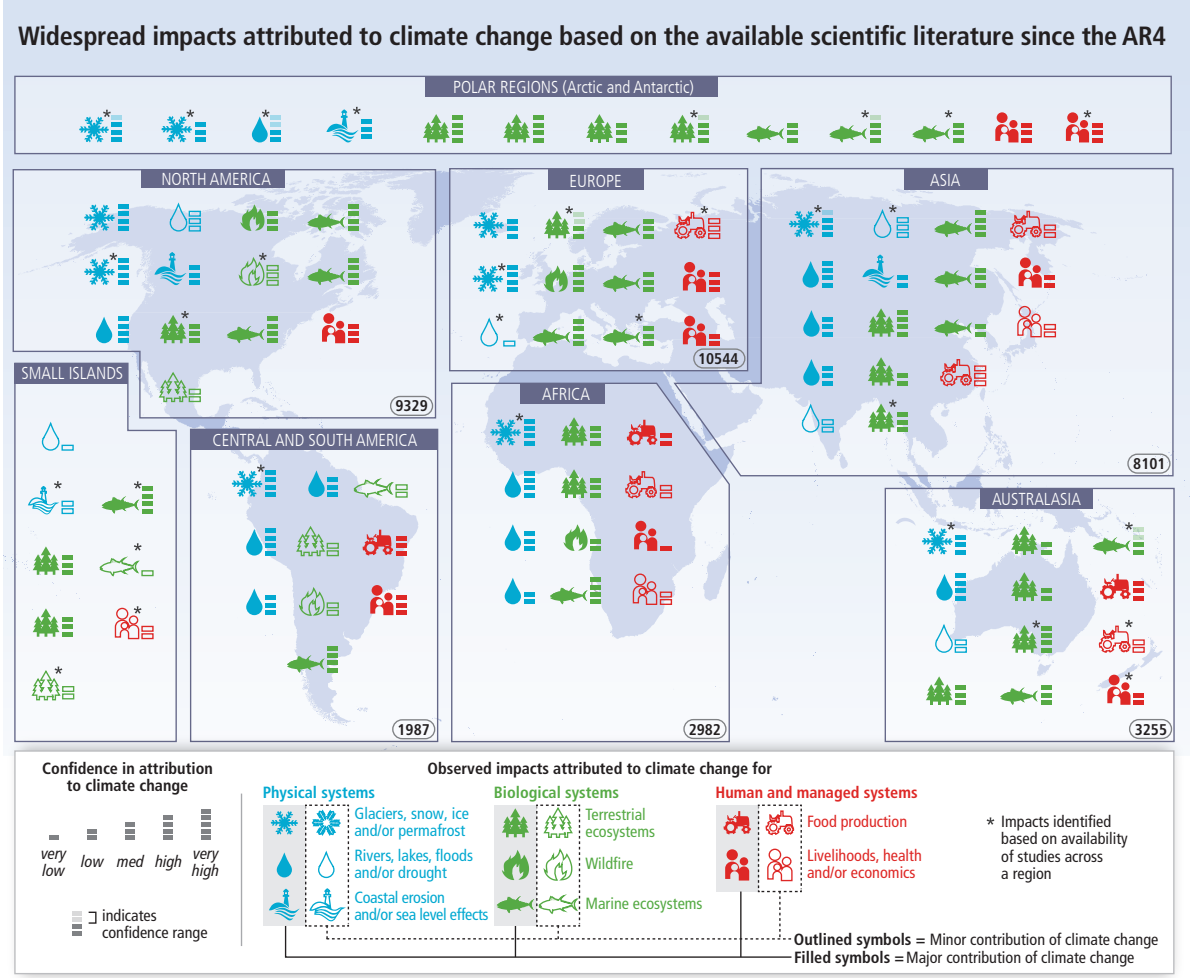

Figure SPM.4 | Based on the available scientific literature since the IPCC Fourth Assessment Report (AR4), there are substantially more impacts in recent decades now attributed to climate change. Attribution requires defined scientific evidence on the role of climate change. Absence from the map of additional impacts attributed to climate change does not imply that such impacts have not occurred. The publications supporting attributed impacts reflect a growing knowledge base, but publications are still limited for many regions, systems and processes, highlighting gaps in data and studies. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact and confidence in attribution. Each symbol refers to one or more entries in WGII Table SPM.A1, grouping related regional-scale impacts. Numbers in ovals indicate regional totals of climate change publications from 2001 to 2010, based on the Scopus bibliographic database for publications in English with individual countries mentioned in title, abstract or key words (as of July 2011). These numbers provide an overall measure of the available scientific literature on climate change across regions; they do not indicate the number of publications supporting attribution of climate change impacts in each region. Studies for polar regions and small islands are grouped with neighbouring continental regions. The inclusion of publications for assessment of attribution followed IPCC scientific evidence criteria defined in WGII Chapter 18. Publications considered in the attribution analyses come from a broader range of literature assessed in the WGII AR5. See WGII Table SPM.A1 for descriptions of the attributed impacts. *{Figure 1.11}*

SPM 1.4 Extreme events

Changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions. *{1.4}*

It is *very likely* that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. It is *likely* that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. It is

very likely that human influence has contributed to the observed global scale changes in the frequency and intensity of daily temperature extremes since the mid-20th century. It is *likely* that human influence has more than doubled the probability of occurrence of heat waves in some locations. There is *medium confidence* that the observed warming has increased heat-related human mortality and decreased cold-related human mortality in some regions. *{1.4}*

There are *likely* more land regions where the number of heavy precipitation events has increased than where it has decreased. Recent detection of increasing trends in extreme precipitation and discharge in some catchments implies greater risks of flooding at regional scale (*medium confidence*). It is *likely* that extreme sea levels (for example, as experienced in storm surges) have increased since 1970, being mainly a result of rising mean sea level. *{1.4}*

Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (*very high confidence*). *{1.4}*

SPM 2. Future Climate Changes, Risks and Impacts

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. *{2}*

SPM 2.1 Key drivers of future climate

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy. *{2.1}*

Anthropogenic GHG emissions are mainly driven by population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy. The Representative Concentration Pathways (RCPs), which are used for making projections based on these factors, describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5). Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP6.0 and RCP8.5 (Figure SPM.5a). RCP2.6 is representative of a scenario that aims to keep global warming *likely* below 2°C above pre-industrial temperatures. The RCPs are consistent with the wide range of scenarios in the literature as assessed by WGIII[5]. *{2.1, Box 2.2, 4.3}*

Multiple lines of evidence indicate a strong, consistent, almost linear relationship between cumulative CO_2 emissions and projected global temperature change to the year 2100 in both the RCPs and the wider set of mitigation scenarios analysed in WGIII (Figure SPM.5b). Any given level of warming is associated with a range of cumulative CO_2 emissions[6], and therefore, e.g., higher emissions in earlier decades imply lower emissions later. *{2.2.5, Table 2.2}*

[5] Roughly 300 baseline scenarios and 900 mitigation scenarios are categorized by CO_2-equivalent concentration (CO_2-eq) by 2100. The CO_2-eq includes the forcing due to all GHGs (including halogenated gases and tropospheric ozone), aerosols and albedo change.

[6] Quantification of this range of CO_2 emissions requires taking into account non-CO_2 drivers.

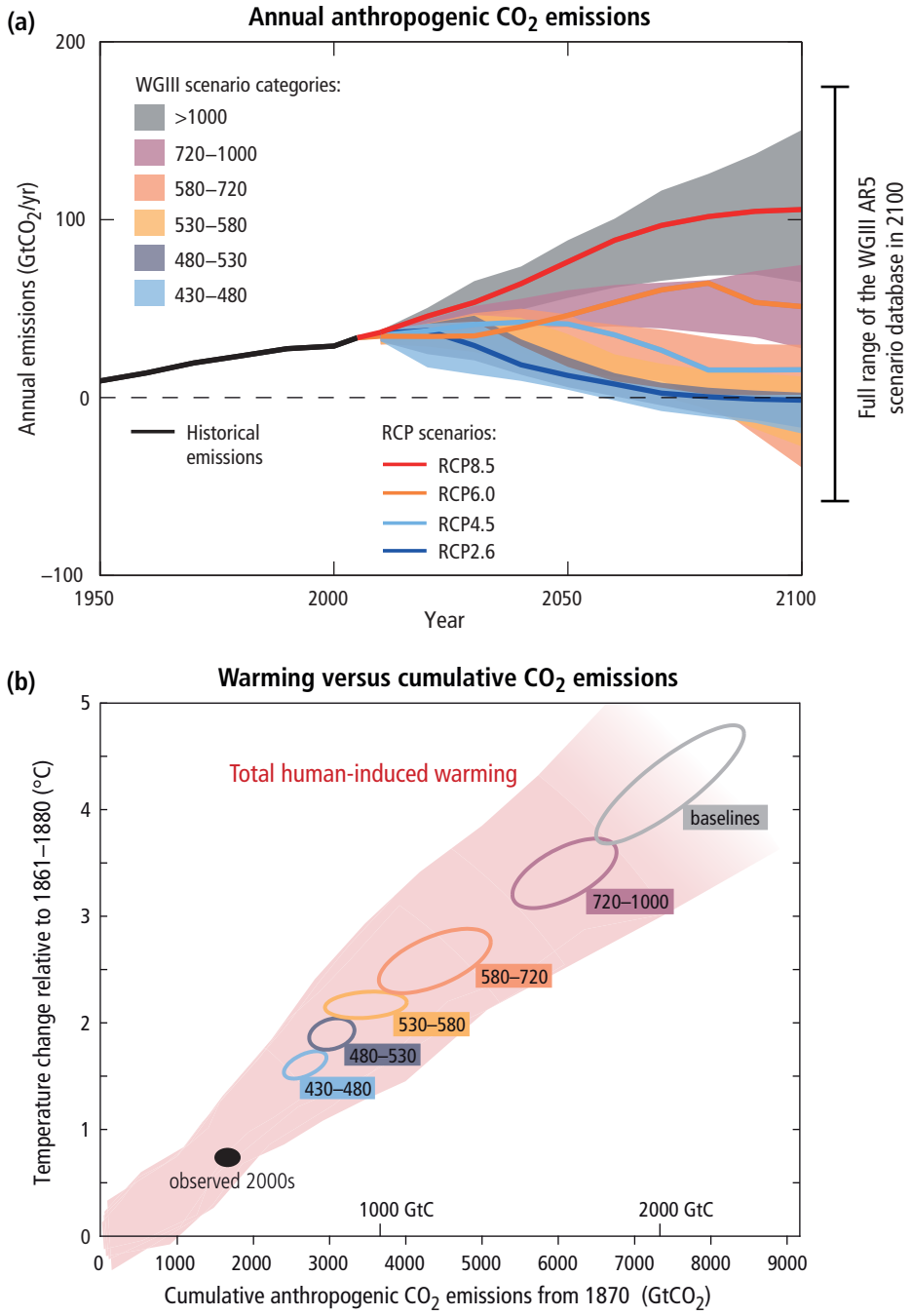

Figure SPM.5 | **(a)** Emissions of carbon dioxide (CO_2) alone in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in WGIII (coloured areas show 5 to 95% range). The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-eq concentration levels (in ppm) in 2100. The time series of other greenhouse gas emissions are shown in Box 2.2, Figure 1. **(b)** Global mean surface temperature increase at the time global CO_2 emissions reach a given net cumulative total, plotted as a function of that total, from various lines of evidence. Coloured plume shows the spread of past and future projections from a hierarchy of climate-carbon cycle models driven by historical emissions and the four RCPs over all times out to 2100, and fades with the decreasing number of available models. Ellipses show total anthropogenic warming in 2100 versus cumulative CO_2 emissions from 1870 to 2100 from a simple climate model (median climate response) under the scenario categories used in WGIII. The width of the ellipses in terms of temperature is caused by the impact of different scenarios for non-CO_2 climate drivers. The filled black ellipse shows observed emissions to 2005 and observed temperatures in the decade 2000–2009 with associated uncertainties. *{Box 2.2, Figure 1; Figure 2.3}*

Multi-model results show that limiting total human-induced warming to less than 2°C relative to the period 1861–1880 with a probability of >66%[7] would require cumulative CO_2 emissions from all anthropogenic sources since 1870 to remain below about 2900 $GtCO_2$ (with a range of 2550 to 3150 $GtCO_2$ depending on non-CO_2 drivers). About 1900 $GtCO_2$[8] had already been emitted by 2011. For additional context see Table 2.2. *{2.2.5}*

SPM 2.2 Projected changes in the climate system

Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is *very likely* that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. *{2.2}*

The projected changes in Section SPM 2.2 are for 2081–2100 relative to 1986–2005, unless otherwise indicated.

Future climate will depend on committed warming caused by past anthropogenic emissions, as well as future anthropogenic emissions and natural climate variability. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 is similar for the four RCPs and will *likely* be in the range 0.3°C to 0.7°C (*medium confidence*). This assumes that there will be no major volcanic eruptions or changes in some natural sources (e.g., CH_4 and N_2O), or unexpected changes in total solar irradiance. By mid-21st century, the magnitude of the projected climate change is substantially affected by the choice of emissions scenario. *{2.2.1, Table 2.1}*

Relative to 1850–1900, global surface temperature change for the end of the 21st century (2081–2100) is projected to *likely* exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (*high confidence*). Warming is *likely* to exceed 2°C for RCP6.0 and RCP8.5 (*high confidence*), *more likely than not* to exceed 2°C for RCP4.5 (*medium confidence*), but *unlikely* to exceed 2°C for RCP2.6 (*medium confidence*). *{2.2.1}*

The increase of global mean surface temperature by the end of the 21st century (2081–2100) relative to 1986–2005 is *likely* to be 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0 and 2.6°C to 4.8°C under RCP8.5[9]. The Arctic region will continue to warm more rapidly than the global mean (Figure SPM.6a, Figure SPM.7a). *{2.2.1, Figure 2.1, Figure 2.2, Table 2.1}*

It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean surface temperature increases. It is *very likely* that heat waves will occur with a higher frequency and longer duration. Occasional cold winter extremes will continue to occur. *{2.2.1}*

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[7] Corresponding figures for limiting warming to 2°C with a probability of >50% and >33% are 3000 $GtCO_2$ (range of 2900 to 3200 $GtCO_2$) and 3300 $GtCO_2$ (range of 2950 to 3800 $GtCO_2$) respectively. Higher or lower temperature limits would imply larger or lower cumulative emissions respectively.

[8] This corresponds to about two thirds of the 2900 $GtCO_2$ that would limit warming to less than 2°C with a probability of >66%; to about 63% of the total amount of 3000 $GtCO_2$ that would limit warming to less than 2°C with a probability of >50%; and to about 58% of the total amount of 3300 $GtCO_2$ that would limit warming to less than 2°C with a probability of >33%.

[9] The period 1986–2005 is approximately 0.61 [0.55 to 0.67] °C warmer than 1850–1900. *{2.2.1}*

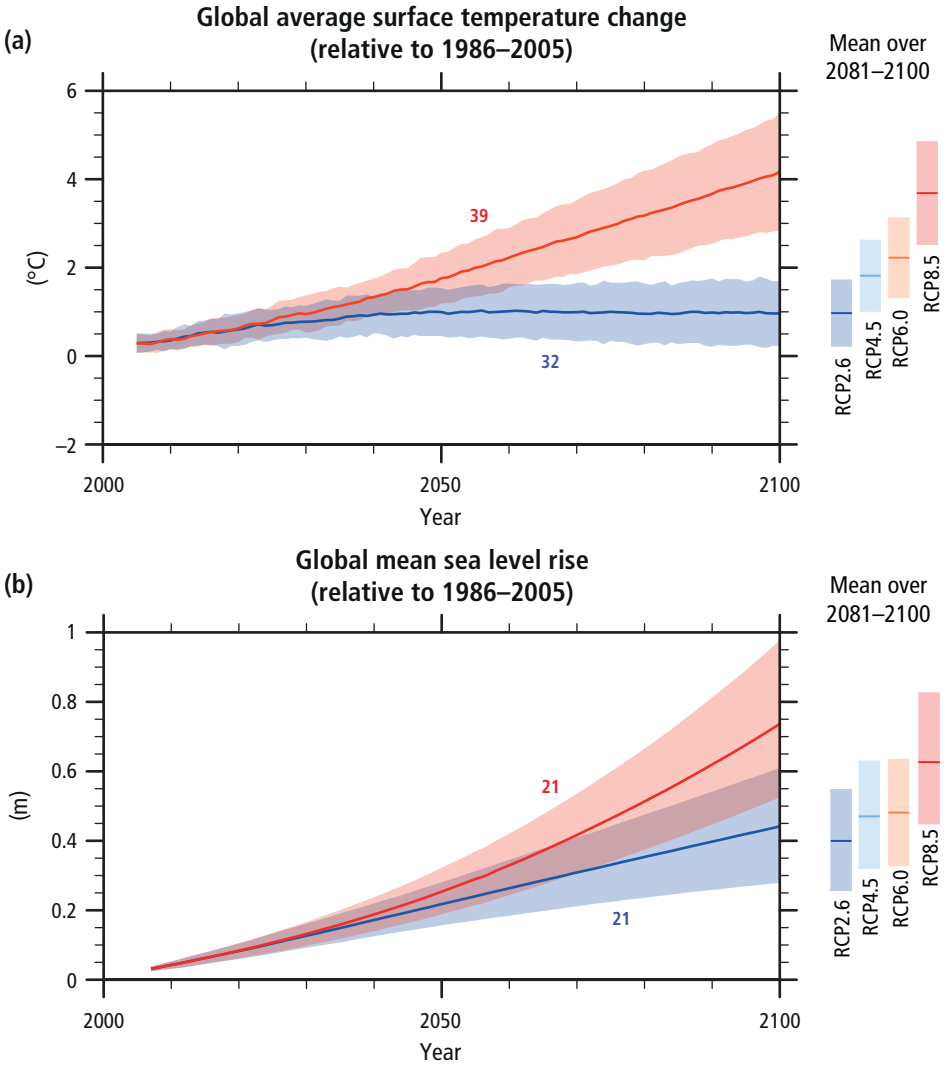

Figure SPM.6 | Global average surface temperature change **(a)** and global mean sea level rise[10] **(b)** from 2006 to 2100 as determined by multi-model simulations. All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars at the right hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated. *{2.2, Figure 2.1}*

Changes in precipitation will not be uniform. The high latitudes and the equatorial Pacific are *likely* to experience an increase in annual mean precipitation under the RCP8.5 scenario. In many mid-latitude and subtropical dry regions, mean precipitation will *likely* decrease, while in many mid-latitude wet regions, mean precipitation will *likely* increase under the RCP8.5 scenario (Figure SPM.7b). Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent. *{2.2.2, Figure 2.2}*

The global ocean will continue to warm during the 21st century, with the strongest warming projected for the surface in tropical and Northern Hemisphere subtropical regions (Figure SPM.7a). *{2.2.3, Figure 2.2}*

[10] Based on current understanding (from observations, physical understanding and modelling), only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. There is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century.

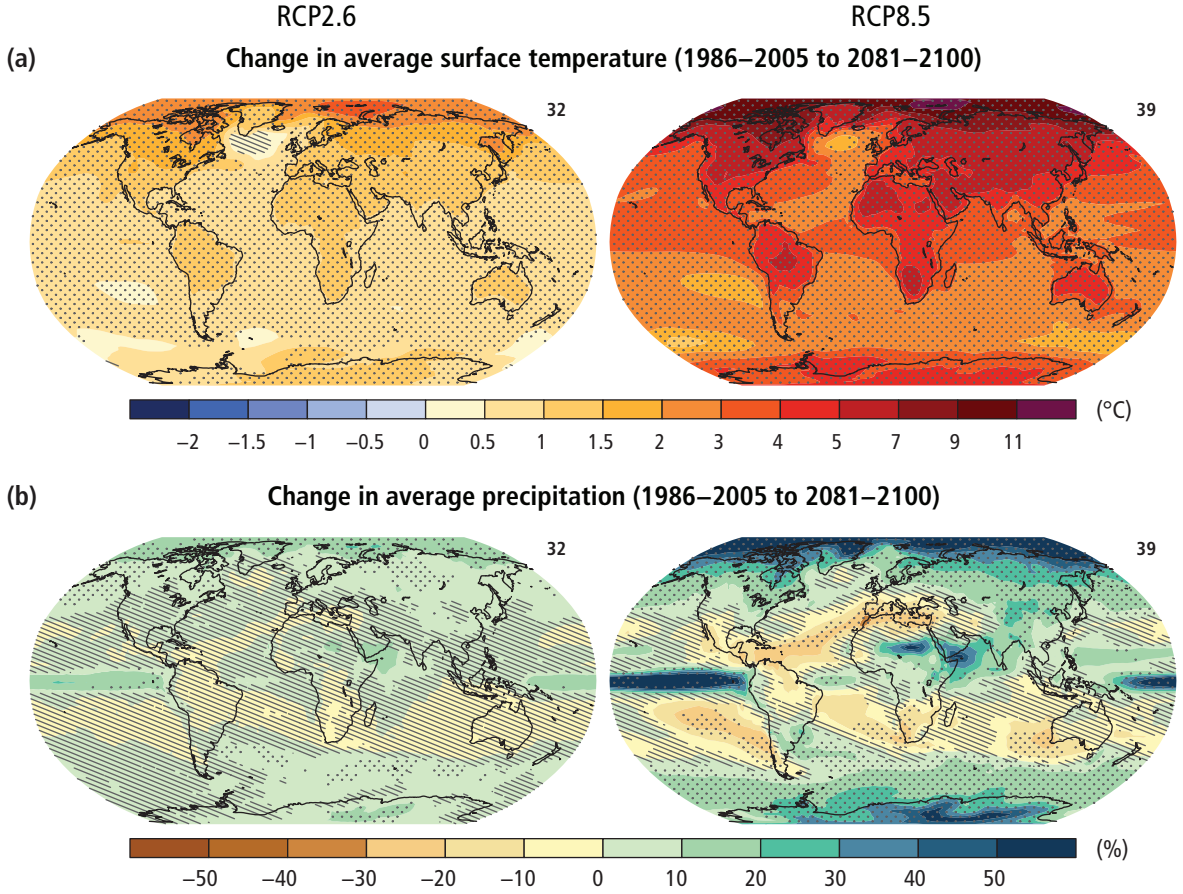

Figure SPM.7 | Change in average surface temperature **(a)** and change in average precipitation **(b)** based on multi-model mean projections for 2081–2100 relative to 1986–2005 under the RCP2.6 (left) and RCP8.5 (right) scenarios. The number of models used to calculate the multi-model mean is indicated in the upper right corner of each panel. Stippling (i.e., dots) shows regions where the projected change is large compared to natural internal variability and where at least 90% of models agree on the sign of change. Hatching (i.e., diagonal lines) shows regions where the projected change is less than one standard deviation of the natural internal variability. *{2.2, Figure 2.2}*

Earth System Models project a global increase in ocean acidification for all RCP scenarios by the end of the 21st century, with a slow recovery after mid-century under RCP2.6. The decrease in surface ocean pH is in the range of 0.06 to 0.07 (15 to 17% increase in acidity) for RCP2.6, 0.14 to 0.15 (38 to 41%) for RCP4.5, 0.20 to 0.21 (58 to 62%) for RCP6.0 and 0.30 to 0.32 (100 to 109%) for RCP8.5. *{2.2.4, Figure 2.1}*

Year-round reductions in Arctic sea ice are projected for all RCP scenarios. A nearly ice-free[11] Arctic Ocean in the summer sea-ice minimum in September before mid-century is *likely* for RCP8.5[12] (*medium confidence*). *{2.2.3, Figure 2.1}*

It is *virtually certain* that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases, with the area of permafrost near the surface (upper 3.5 m) projected to decrease by 37% (RCP2.6) to 81% (RCP8.5) for the multi-model average (*medium confidence*). *{2.2.3}*

The global glacier volume, excluding glaciers on the periphery of Antarctica (and excluding the Greenland and Antarctic ice sheets), is projected to decrease by 15 to 55% for RCP2.6 and by 35 to 85% for RCP8.5 (*medium confidence*). *{2.2.3}*

[11] When sea-ice extent is less than one million km^2 for at least five consecutive years.

[12] Based on an assessment of the subset of models that most closely reproduce the climatological mean state and 1979–2012 trend of the Arctic sea-ice extent.

There has been significant improvement in understanding and projection of sea level change since the AR4. Global mean sea level rise will continue during the 21st century, *very likely* at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6, and of 0.45 to 0.82 m for RCP8.5 (*medium confidence*)[10] (Figure SPM.6b). Sea level rise will not be uniform across regions. By the end of the 21st century, it is *very likely* that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience a sea level change within ±20% of the global mean. *{2.2.3}*

SPM 2.3 Future risks and impacts caused by a changing climate

Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development. *{2.3}*

Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems, including their ability to adapt. Rising rates and magnitudes of warming and other changes in the climate system, accompanied by ocean acidification, increase the risk of severe, pervasive and in some cases irreversible detrimental impacts. Some risks are particularly relevant for individual regions (Figure SPM.8), while others are global. The overall risks of future climate change impacts can be reduced by limiting the rate and magnitude of climate change, including ocean acidification. The precise levels of climate change sufficient to trigger abrupt and irreversible change remain uncertain, but the risk associated with crossing such thresholds increases with rising temperature (*medium confidence*). For risk assessment, it is important to evaluate the widest possible range of impacts, including low-probability outcomes with large consequences. *{1.5, 2.3, 2.4, 3.3, Box Introduction.1, Box 2.3, Box 2.4}*

A large fraction of species faces increased extinction risk due to climate change during and beyond the 21st century, especially as climate change interacts with other stressors (*high confidence*). Most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change in most landscapes; most small mammals and freshwater molluscs will not be able to keep up at the rates projected under RCP4.5 and above in flat landscapes in this century (*high confidence*). Future risk is indicated to be high by the observation that natural global climate change at rates lower than current anthropogenic climate change caused significant ecosystem shifts and species extinctions during the past millions of years. Marine organisms will face progressively lower oxygen levels and high rates and magnitudes of ocean acidification (*high confidence*), with associated risks exacerbated by rising ocean temperature extremes (*medium confidence*). Coral reefs and polar ecosystems are highly vulnerable. Coastal systems and low-lying areas are at risk from sea level rise, which will continue for centuries even if the global mean temperature is stabilized (*high confidence*). *{2.3, 2.4, Figure 2.5}*

Climate change is projected to undermine food security (Figure SPM.9). Due to projected climate change by the mid-21st century and beyond, global marine species redistribution and marine biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services (*high confidence*). For wheat, rice and maize in tropical and temperate regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late 20th century levels, although individual locations may benefit (*medium confidence*). Global temperature increases of ~4°C or more[13] above late 20th century levels, combined with increasing food demand, would pose large risks to food security globally (*high confidence*). Climate change is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions (*robust evidence*, *high agreement*), intensifying competition for water among sectors (*limited evidence*, *medium agreement*). *{2.3.1, 2.3.2}*

[13] Projected warming averaged over land is larger than global average warming for all RCP scenarios for the period 2081–2100 relative to 1986–2005. For regional projections, see Figure SPM.7. *{2.2}*

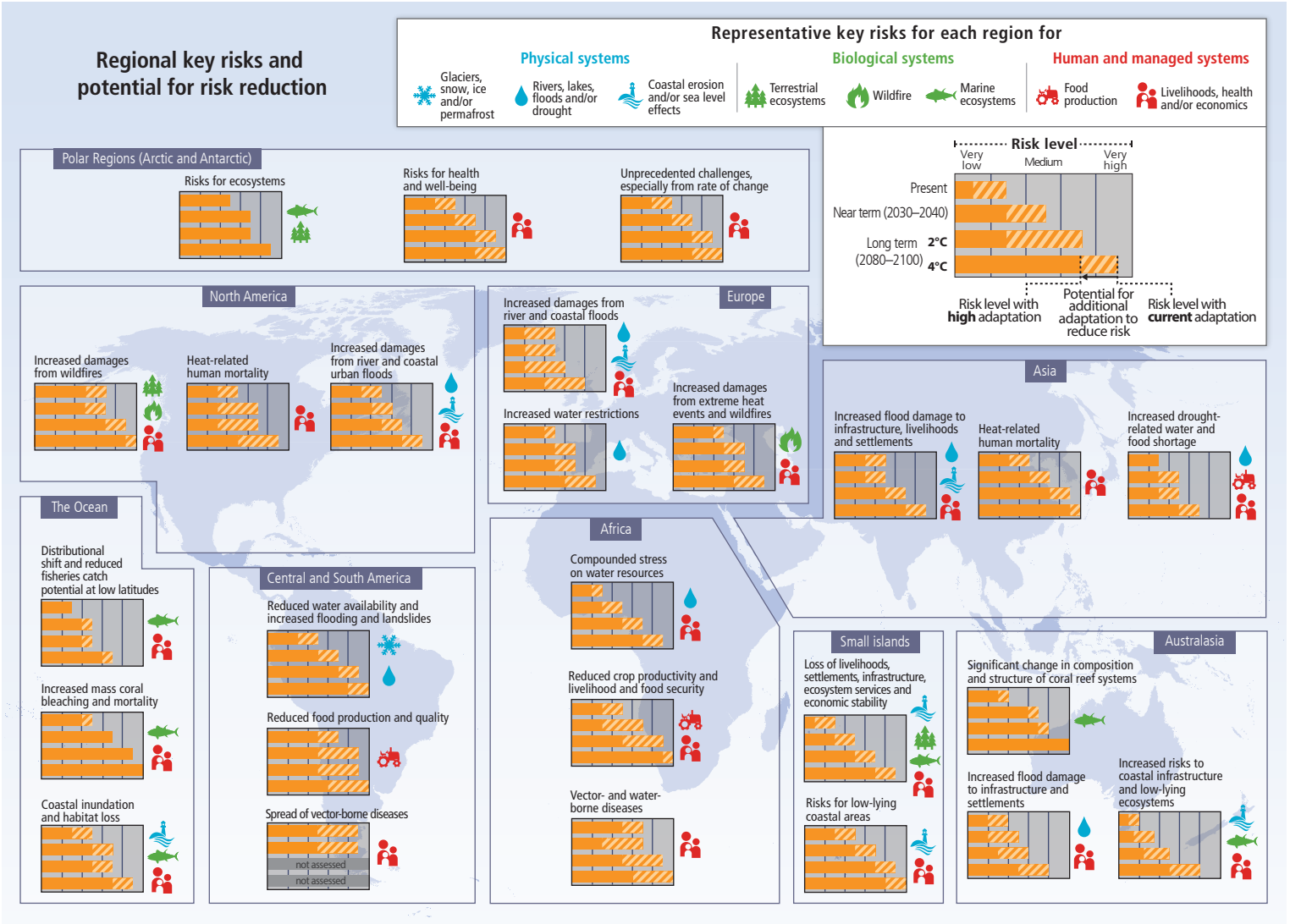

Figure SPM.8 | Representative key risks[14] for each region, including the potential for risk reduction through adaptation and mitigation, as well as limits to adaptation. Each key risk is assessed as very low, low, medium, high or very high. Risk levels are presented for three time frames: present, near term (here, for 2030–2040) and long term (here, for 2080–2100). In the near term, projected levels of global mean temperature increase do not diverge substantially across different emission scenarios. For the long term, risk levels are presented for two possible futures (2°C and 4°C global mean temperature increase above pre-industrial levels). For each timeframe, risk levels are indicated for a continuation of current adaptation and assuming high levels of current or future adaptation. Risk levels are not necessarily comparable, especially across regions. *{Figure 2.4}*

[14] Identification of key risks was based on expert judgment using the following specific criteria: large magnitude, high probability or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation.

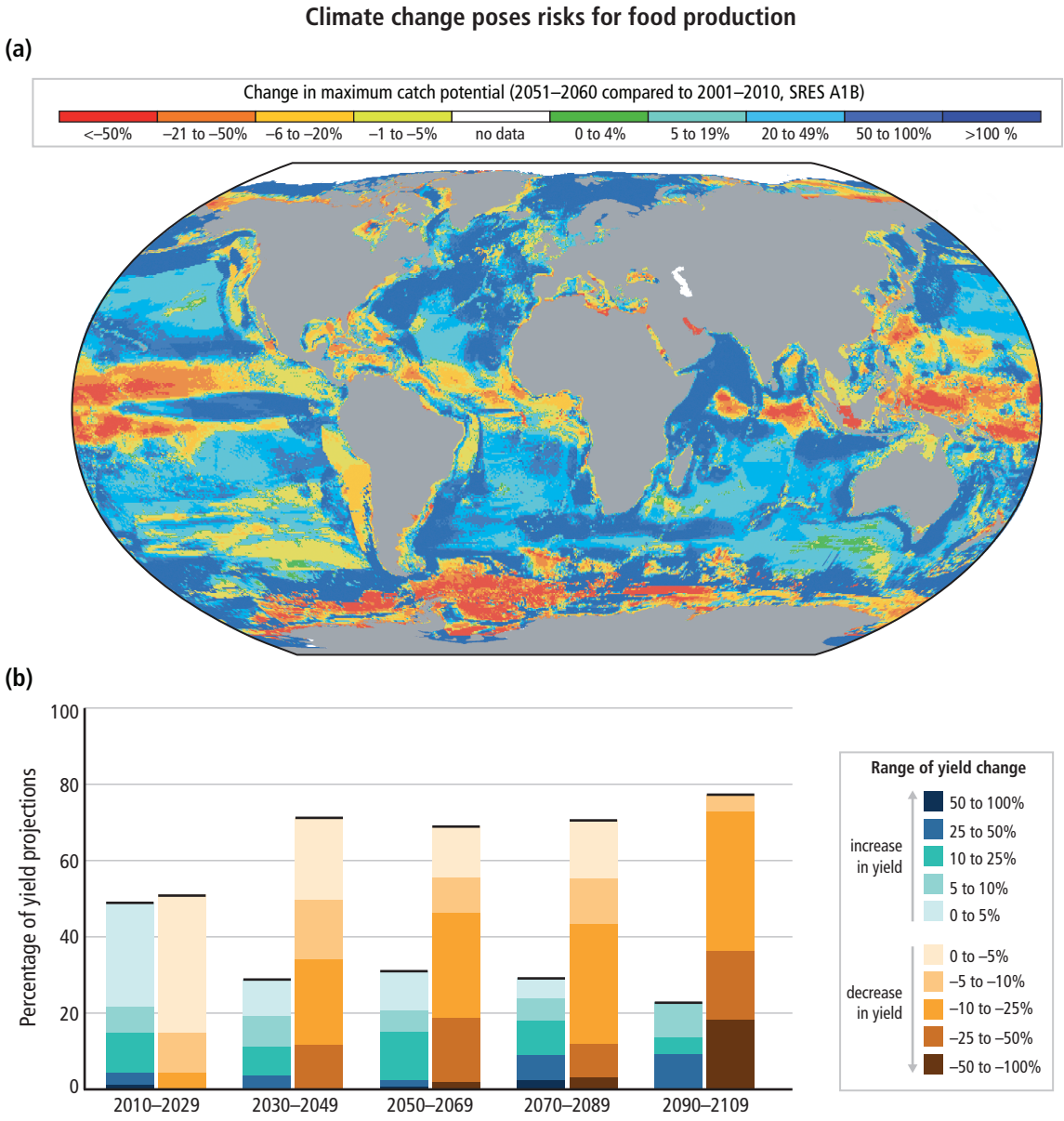

Figure SPM.9 | **(a)** Projected global redistribution of maximum catch potential of ~1000 exploited marine fish and invertebrate species. Projections compare the 10-year averages 2001–2010 and 2051–2060 using ocean conditions based on a single climate model under a moderate to high warming scenario, without analysis of potential impacts of overfishing or ocean acidification. **(b)** Summary of projected changes in crop yields (mostly wheat, maize, rice and soy), due to climate change over the 21st century. Data for each timeframe sum to 100%, indicating the percentage of projections showing yield increases versus decreases. The figure includes projections (based on 1090 data points) for different emission scenarios, for tropical and temperate regions and for adaptation and no-adaptation cases combined. Changes in crop yields are relative to late 20th century levels. *{Figure 2.6a, Figure 2.7}*

Until mid-century, projected climate change will impact human health mainly by exacerbating health problems that already exist (*very high confidence*). Throughout the 21st century, climate change is expected to lead to increases in ill-health in many regions and especially in developing countries with low income, as compared to a baseline without climate change (*high confidence*). By 2100 for RCP8.5, the combination of high temperature and humidity in some areas for parts of the year is expected to compromise common human activities, including growing food and working outdoors (*high confidence*). *{2.3.2}*

In urban areas climate change is projected to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surges (*very high confidence*). These risks are amplified for those lacking essential infrastructure and services or living in exposed areas. *{2.3.2}*

Rural areas are expected to experience major impacts on water availability and supply, food security, infrastructure and agricultural incomes, including shifts in the production areas of food and non-food crops around the world (*high confidence*). *{2.3.2}*

Aggregate economic losses accelerate with increasing temperature (*limited evidence, high agreement*), but global economic impacts from climate change are currently difficult to estimate. From a poverty perspective, climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security and prolong existing and create new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). International dimensions such as trade and relations among states are also important for understanding the risks of climate change at regional scales. *{2.3.2}*

Climate change is projected to increase displacement of people (*medium evidence, high agreement*). Populations that lack the resources for planned migration experience higher exposure to extreme weather events, particularly in developing countries with low income. Climate change can indirectly increase risks of violent conflicts by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (*medium confidence*). *{2.3.2}*

SPM 2.4 Climate change beyond 2100, irreversibility and abrupt changes

Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stopped. The risks of abrupt or irreversible changes increase as the magnitude of the warming increases. *{2.4}*

Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of net anthropogenic CO_2 emissions. A large fraction of anthropogenic climate change resulting from CO_2 emissions is irreversible on a multi-century to millennial timescale, except in the case of a large net removal of CO_2 from the atmosphere over a sustained period. *{2.4, Figure 2.8}*

Stabilization of global average surface temperature does not imply stabilization for all aspects of the climate system. Shifting biomes, soil carbon, ice sheets, ocean temperatures and associated sea level rise all have their own intrinsic long timescales which will result in changes lasting hundreds to thousands of years after global surface temperature is stabilized. *{2.1, 2.4}*

There is *high confidence* that ocean acidification will increase for centuries if CO_2 emissions continue, and will strongly affect marine ecosystems. *{2.4}*

It is *virtually certain* that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions. The threshold for the loss of the Greenland ice sheet over a millennium or more, and an associated sea level rise of up to 7 m, is greater than about 1°C (*low confidence*) but less than about 4°C (*medium confidence*) of global warming with respect to pre-industrial temperatures. Abrupt and irreversible ice loss from the Antarctic ice sheet is possible, but current evidence and understanding is insufficient to make a quantitative assessment. *{2.4}*

Magnitudes and rates of climate change associated with medium- to high-emission scenarios pose an increased risk of abrupt and irreversible regional-scale change in the composition, structure and function of marine, terrestrial and freshwater ecosystems, including wetlands (*medium confidence*). A reduction in permafrost extent is *virtually certain* with continued rise in global temperatures. *{2.4}*

SPM 3. Future Pathways for Adaptation, Mitigation and Sustainable Development

Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term and contribute to climate-resilient pathways for sustainable development. *{3.2, 3.3, 3.4}*

SPM 3.1 Foundations of decision-making about climate change

Effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments and diverse perceptions and responses to risk and uncertainty. *{3.1}*

Sustainable development and equity provide a basis for assessing climate policies. Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. Countries' past and future contributions to the accumulation of GHGs in the atmosphere are different, and countries also face varying challenges and circumstances and have different capacities to address mitigation and adaptation. Mitigation and adaptation raise issues of equity, justice and fairness. Many of those most vulnerable to climate change have contributed and contribute little to GHG emissions. Delaying mitigation shifts burdens from the present to the future, and insufficient adaptation responses to emerging impacts are already eroding the basis for sustainable development. Comprehensive strategies in response to climate change that are consistent with sustainable development take into account the co-benefits, adverse side effects and risks that may arise from both adaptation and mitigation options. *{3.1, 3.5, Box 3.4}*

The design of climate policy is influenced by how individuals and organizations perceive risks and uncertainties and take them into account. Methods of valuation from economic, social and ethical analysis are available to assist decision-making. These methods can take account of a wide range of possible impacts, including low-probability outcomes with large consequences. But they cannot identify a single best balance between mitigation, adaptation and residual climate impacts. *{3.1}*

Climate change has the characteristics of a collective action problem at the global scale, because most GHGs accumulate over time and mix globally, and emissions by any agent (e.g., individual, community, company, country) affect other agents. Effective mitigation will not be achieved if individual agents advance their own interests independently. Cooperative responses, including international cooperation, are therefore required to effectively mitigate GHG emissions and address other climate change issues. The effectiveness of adaptation can be enhanced through complementary actions across levels, including international cooperation. The evidence suggests that outcomes seen as equitable can lead to more effective cooperation. *{3.1}*

SPM 3.2 Climate change risks reduced by mitigation and adaptation

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally (*high confidence*). Mitigation involves some level of co-benefits and of risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts. *{3.2, 3.4}*

Mitigation and adaptation are complementary approaches for reducing risks of climate change impacts over different timescales (*high confidence*). Mitigation, in the near term and through the century, can substantially reduce climate change

impacts in the latter decades of the 21st century and beyond. Benefits from adaptation can already be realized in addressing current risks, and can be realized in the future for addressing emerging risks. *{3.2, 4.5}*

Five Reasons For Concern (RFCs) aggregate climate change risks and illustrate the implications of warming and of adaptation limits for people, economies and ecosystems across sectors and regions. The five RFCs are associated with: (1) Unique and threatened systems, (2) Extreme weather events, (3) Distribution of impacts, (4) Global aggregate impacts, and (5) Large-scale singular events. In this report, the RFCs provide information relevant to Article 2 of UNFCCC. *{Box 2.4}*

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally (*high confidence*) (Figure SPM.10). In most scenarios without additional mitigation efforts (those with 2100 atmospheric concentrations

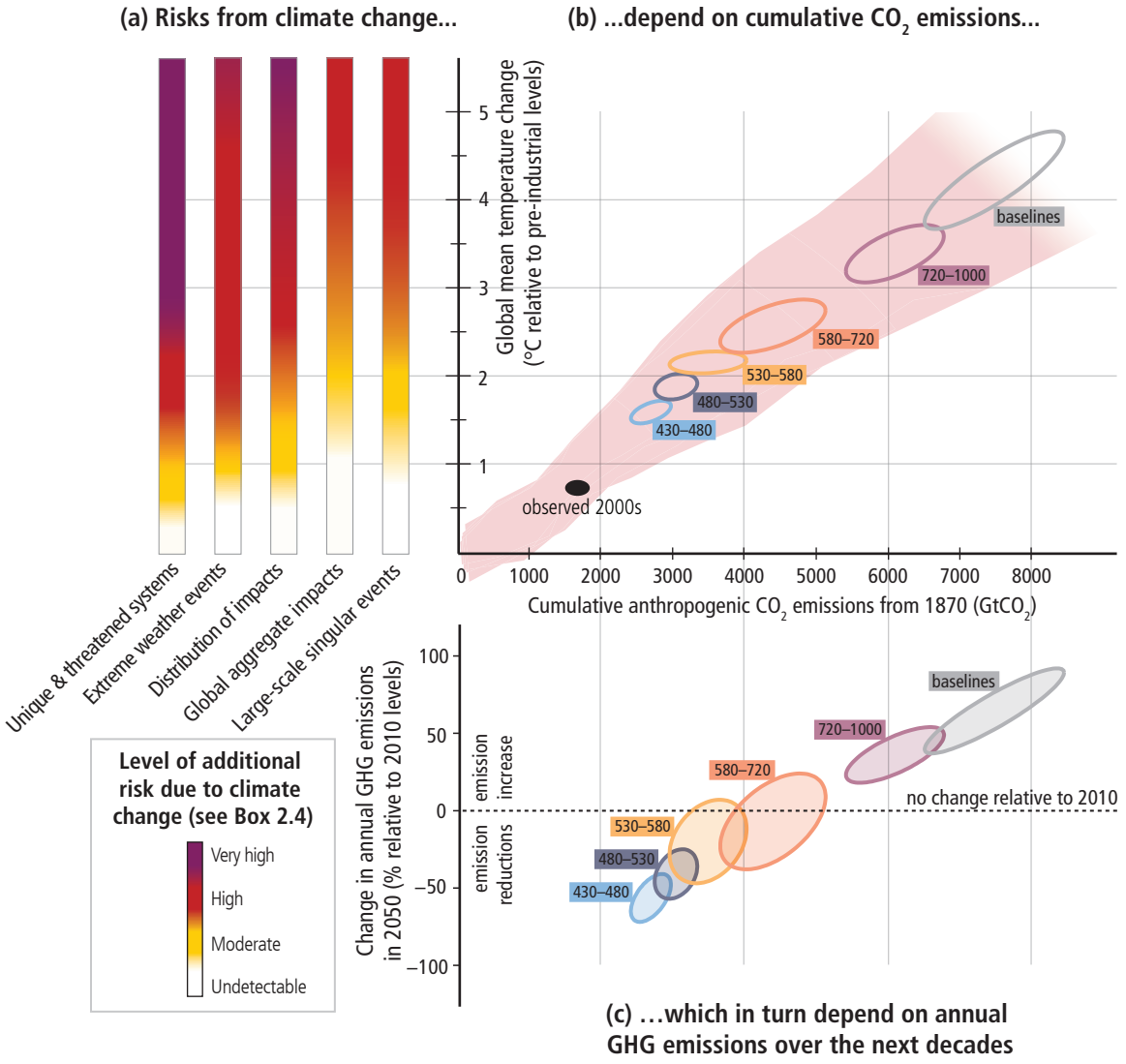

Figure SPM.10 | The relationship between risks from climate change, temperature change, cumulative carbon dioxide (CO_2) emissions and changes in annual greenhouse gas (GHG) emissions by 2050. Limiting risks across Reasons For Concern **(a)** would imply a limit for cumulative emissions of CO_2 **(b)** which would constrain annual GHG emissions over the next few decades **(c)**. **Panel a** reproduces the five Reasons For Concern *{Box 2.4}*. **Panel b** links temperature changes to cumulative CO_2 emissions (in $GtCO_2$) from 1870. They are based on Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations (pink plume) and on a simple climate model (median climate response in 2100), for the baselines and five mitigation scenario categories (six ellipses). Details are provided in Figure SPM.5. **Panel c** shows the relationship between the cumulative CO_2 emissions (in $GtCO_2$) of the scenario categories and their associated change in annual GHG emissions by 2050, expressed in percentage change (in percent $GtCO_2$-eq per year) relative to 2010. The ellipses correspond to the same scenario categories as in Panel b, and are built with a similar method (see details in Figure SPM.5). *{Figure 3.1}*

>1000 ppm CO_2-eq), warming is *more likely than not* to exceed 4°C above pre-industrial levels by 2100 (Table SPM.1). The risks associated with temperatures at or above 4°C include substantial species extinction, global and regional food insecurity, consequential constraints on common human activities and limited potential for adaptation in some cases (*high confidence*). Some risks of climate change, such as risks to unique and threatened systems and risks associated with extreme weather events, are moderate to high at temperatures 1°C to 2°C above pre-industrial levels. *{2.3, Figure 2.5, 3.2, 3.4, Box 2.4, Table SPM.1}*

Substantial cuts in GHG emissions over the next few decades can substantially reduce risks of climate change by limiting warming in the second half of the 21st century and beyond. Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Limiting risks across RFCs would imply a limit for cumulative emissions of CO_2. Such a limit would require that global net emissions of CO_2 eventually decrease to zero and would constrain annual emissions over the next few decades (Figure SPM.10) (*high confidence*). But some risks from climate damages are unavoidable, even with mitigation and adaptation. *{2.2.5, 3.2, 3.4}*

Mitigation involves some level of co-benefits and risks, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change. Inertia in the economic and climate system and the possibility of irreversible impacts from climate change increase the benefits from near-term mitigation efforts (*high confidence*). Delays in additional mitigation or constraints on technological options increase the longer-term mitigation costs to hold climate change risks at a given level (Table SPM.2). *{3.2, 3.4}*

SPM 3.3 Characteristics of adaptation pathways

Adaptation can reduce the risks of climate change impacts, but there are limits to its effectiveness, especially with greater magnitudes and rates of climate change. Taking a longer-term perspective, in the context of sustainable development, increases the likelihood that more immediate adaptation actions will also enhance future options and preparedness. *{3.3}*

Adaptation can contribute to the well-being of populations, the security of assets and the maintenance of ecosystem goods, functions and services now and in the future. Adaptation is place- and context-specific (*high confidence*). A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability (*high confidence*). Integration of adaptation into planning, including policy design, and decision-making can promote synergies with development and disaster risk reduction. Building adaptive capacity is crucial for effective selection and implementation of adaptation options (*robust evidence, high agreement*). *{3.3}*

Adaptation planning and implementation can be enhanced through complementary actions across levels, from individuals to governments (*high confidence*). National governments can coordinate adaptation efforts of local and sub-national governments, for example by protecting vulnerable groups, by supporting economic diversification and by providing information, policy and legal frameworks and financial support (*robust evidence*, *high agreement*). Local government and the private sector are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households and civil society and in managing risk information and financing (*medium evidence*, *high agreement*). *{3.3}*

Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts and expectations can benefit decision-making processes. Indigenous, local and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation. *{3.3}*

Constraints can interact to impede adaptation planning and implementation (*high confidence*). Common constraints on implementation arise from the following: limited financial and human resources; limited integration or coordination of governance; uncertainties about projected impacts; different perceptions of risks; competing values; absence of key adaptation leaders and advocates; and limited tools to monitor adaptation effectiveness. Another constraint includes insufficient research, monitoring, and observation and the finance to maintain them. *{3.3}*

Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits (*high confidence*). Limits to adaptation emerge from the interaction among climate change and biophysical and/or socio-economic constraints. Further, poor planning or implementation, overemphasizing short-term outcomes or failing to sufficiently anticipate consequences can result in maladaptation, increasing the vulnerability or exposure of the target group in the future or the vulnerability of other people, places or sectors (*medium evidence, high agreement*). Underestimating the complexity of adaptation as a social process can create unrealistic expectations about achieving intended adaptation outcomes. *{3.3}*

Significant co-benefits, synergies and trade-offs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions (*very high confidence*). Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, particularly at the intersections among water, energy, land use and biodiversity, but tools to understand and manage these interactions remain limited. Examples of actions with co-benefits include (i) improved energy efficiency and cleaner energy sources, leading to reduced emissions of health-damaging, climate-altering air pollutants; (ii) reduced energy and water consumption in urban areas through greening cities and recycling water; (iii) sustainable agriculture and forestry; and (iv) protection of ecosystems for carbon storage and other ecosystem services. *{3.3}*

Transformations in economic, social, technological and political decisions and actions can enhance adaptation and promote sustainable development (*high confidence*). At the national level, transformation is considered most effective when it reflects a country's own visions and approaches to achieving sustainable development in accordance with its national circumstances and priorities. Restricting adaptation responses to incremental changes to existing systems and structures, without considering transformational change, may increase costs and losses and miss opportunities. Planning and implementation of transformational adaptation could reflect strengthened, altered or aligned paradigms and may place new and increased demands on governance structures to reconcile different goals and visions for the future and to address possible equity and ethical implications. Adaptation pathways are enhanced by iterative learning, deliberative processes and innovation. *{3.3}*

SPM 3.4 Characteristics of mitigation pathways

There are multiple mitigation pathways that are *likely* to limit warming to below 2°C relative to pre-industrial levels. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO_2 and other long-lived greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges but on different timescales. *{3.4}*

Without additional efforts to reduce GHG emissions beyond those in place today, global emissions growth is expected to persist, driven by growth in global population and economic activities. Global mean surface temperature increases in 2100 in baseline scenarios—those without additional mitigation—range from 3.7°C to 4.8°C above the average for 1850–1900 for a median climate response. They range from 2.5°C to 7.8°C when including climate uncertainty (5th to 95th percentile range) (*high confidence*). *{3.4}*

Emissions scenarios leading to CO_2-equivalent concentrations in 2100 of about 450 ppm or lower are *likely* to maintain warming below 2°C over the 21st century relative to pre-industrial levels[15]. These scenarios are characterized by 40 to 70% global anthropogenic GHG emissions reductions by 2050 compared to 2010[16], and emissions levels near zero or below in 2100. Mitigation scenarios reaching concentration levels of about 500 ppm CO_2-eq by 2100 are *more likely than not* to limit temperature change to less than 2°C, unless they temporarily overshoot concentration levels of roughly 530 ppm CO_2-eq

[15] For comparison, the CO_2-eq concentration in 2011 is estimated to be 430 ppm (uncertainty range 340 to 520 ppm)

[16] This range differs from the range provided for a similar concentration category in the AR4 (50 to 85% lower than 2000 for CO_2 only). Reasons for this difference include that this report has assessed a substantially larger number of scenarios than in the AR4 and looks at all GHGs. In addition, a large proportion of the new scenarios include Carbon Dioxide Removal (CDR) technologies (see below). Other factors include the use of 2100 concentration levels instead of stabilization levels and the shift in reference year from 2000 to 2010.

before 2100, in which case they are *about as likely as not* to achieve that goal. In these 500 ppm CO_2-eq scenarios, global 2050 emissions levels are 25 to 55% lower than in 2010. Scenarios with higher emissions in 2050 are characterized by a greater reliance on Carbon Dioxide Removal (CDR) technologies beyond mid-century (and vice versa). Trajectories that are *likely* to limit warming to 3°C relative to pre-industrial levels reduce emissions less rapidly than those limiting warming to 2°C. A limited number of studies provide scenarios that are *more likely than not* to limit warming to 1.5°C by 2100; these scenarios are characterized by concentrations below 430 ppm CO_2-eq by 2100 and 2050 emission reduction between 70% and 95% below 2010. For a comprehensive overview of the characteristics of emissions scenarios, their CO_2-equivalent concentrations and their likelihood to keep warming to below a range of temperature levels, see Figure SPM.11 and Table SPM.1. *{3.4}*

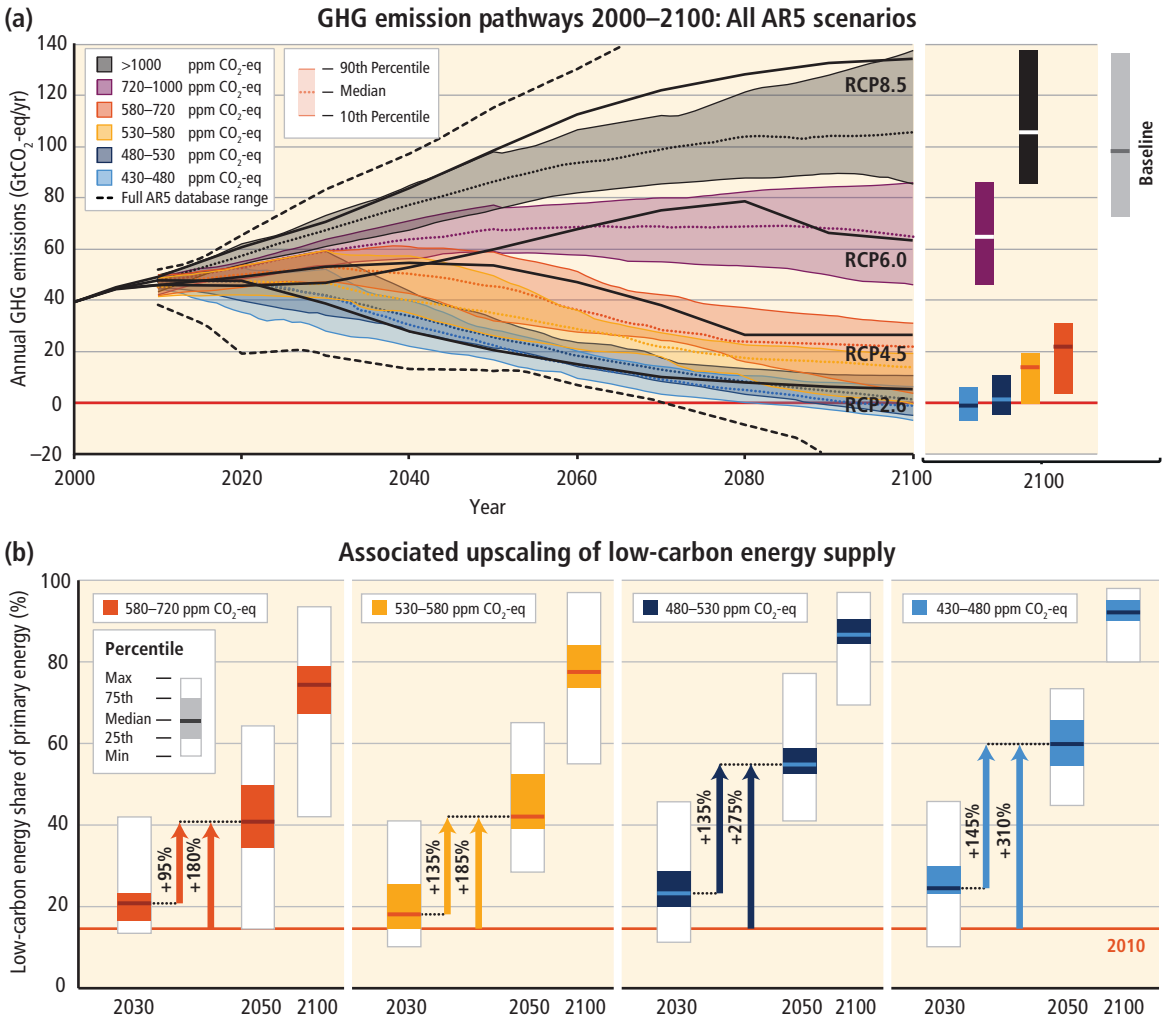

Figure SPM.11 | Global greenhouse gas emissions (gigatonne of CO_2-equivalent per year, $GtCO_2$-eq/yr) in baseline and mitigation scenarios for different long-term concentration levels **(a)** and associated upscaling requirements of low-carbon energy (% of primary energy) for 2030, 2050 and 2100 compared to 2010 levels in mitigation scenarios **(b)**. *{Figure 3.2}*

Table SPM.1 | Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters the 10th to 90th percentile of the scenarios is shown [a]. *{Table 3.1}*

CO_2-eq Concentrations in 2100 (ppm CO_2-eq) [f] Category label (conc. range)	Subcategories	Relative position of the RCPs [d]	Change in CO_2-eq emissions compared to 2010 (in %) [c]		Likelihood of staying below a specific temperature level over the 21st century (relative to 1850–1900) [d, e]			
			2050	2100	1.5°C	2°C	3°C	4°C
<430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2-eq [j]							
450 (430 to 480)	Total range [a, g]	RCP2.6	–72 to –41	–118 to –78	*More unlikely than likely*	*Likely*	*Likely*	*Likely*
500 (480 to 530)	No overshoot of 530 ppm CO_2-eq		–57 to –42	–107 to –73	*Unlikely*	*More likely than not*		
	Overshoot of 530 ppm CO_2-eq		–55 to –25	–114 to –90		*About as likely as not*		
550 (530 to 580)	No overshoot of 580 ppm CO_2-eq		–47 to –19	–81 to –59		*More unlikely than likely* [i]		
	Overshoot of 580 ppm CO_2-eq		–16 to 7	–183 to –86				
(580 to 650)	Total range	RCP4.5	–38 to 24	–134 to –50				
(650 to 720)	Total range		–11 to 17	–54 to –21		*Unlikely*	*More likely than not*	
(720 to 1000) [b]	Total range	RCP6.0	18 to 54	–7 to 72	*Unlikely* [h]		*More unlikely than likely*	
>1000 [b]	Total range	RCP8.5	52 to 95	74 to 178		*Unlikely* [h]	*Unlikely*	*More unlikely than likely*

Notes:

[a] The 'total range' for the 430 to 480 ppm CO_2-eq concentrations scenarios corresponds to the range of the 10th to 90th percentile of the subcategory of these scenarios shown in Table 6.3 of the Working Group III Report.

[b] Baseline scenarios fall into the >1000 and 720 to 1000 ppm CO_2-eq categories. The latter category also includes mitigation scenarios. The baseline scenarios in the latter category reach a temperature change of 2.5°C to 5.8°C above the average for 1850–1900 in 2100. Together with the baseline scenarios in the >1000 ppm CO_2-eq category, this leads to an overall 2100 temperature range of 2.5°C to 7.8°C (range based on median climate response: 3.7°C to 4.8°C) for baseline scenarios across both concentration categories.

[c] The global 2010 emissions are 31% above the 1990 emissions (consistent with the historic greenhouse gas emission estimates presented in this report). CO_2-eq emissions include the basket of Kyoto gases (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) as well as fluorinated gases).

[d] The assessment here involves a large number of scenarios published in the scientific literature and is thus not limited to the Representative Concentration Pathways (RCPs). To evaluate the CO_2-eq concentration and climate implications of these scenarios, the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) was used in a probabilistic mode. For a comparison between MAGICC model results and the outcomes of the models used in WGI, see WGI 12.4.1.2, 12.4.8 and WGIII 6.3.2.6.

[e] The assessment in this table is based on the probabilities calculated for the full ensemble of scenarios in WGIII AR5 using MAGICC and the assessment in WGI of the uncertainty of the temperature projections not covered by climate models. The statements are therefore consistent with the statements in WGI, which are based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) runs of the RCPs and the assessed uncertainties. Hence, the likelihood statements reflect different lines of evidence from both WGs. This WGI method was also applied for scenarios with intermediate concentration levels where no CMIP5 runs are available. The likelihood statements are indicative only *{WGIII 6.3}* and follow broadly the terms used by the WGI SPM for temperature projections: likely 66–100%, more likely than not >50–100%, about as likely as not 33–66%, and unlikely 0–33%. In addition the term more unlikely than likely 0–<50% is used.

[f] The CO_2-equivalent concentration (see Glossary) is calculated on the basis of the total forcing from a simple carbon cycle/climate model, MAGICC. The CO_2-equivalent concentration in 2011 is estimated to be 430 ppm (uncertainty range 340 to 520 ppm). This is based on the assessment of total anthropogenic radiative forcing for 2011 relative to 1750 in WGI, i.e., 2.3 W/m^2, uncertainty range 1.1 to 3.3 W/m^2.

[g] The vast majority of scenarios in this category overshoot the category boundary of 480 ppm CO_2-eq concentration.

[h] For scenarios in this category, no CMIP5 run or MAGICC realization stays below the respective temperature level. Still, an *unlikely* assignment is given to reflect uncertainties that may not be reflected by the current climate models.

[i] Scenarios in the 580 to 650 ppm CO_2-eq category include both overshoot scenarios and scenarios that do not exceed the concentration level at the high end of the category (e.g., RCP4.5). The latter type of scenarios, in general, have an assessed probability of *more unlikely than likely* to stay below the 2°C temperature level, while the former are mostly assessed to have an *unlikely* probability of staying below this level.

[j] In these scenarios, global CO_2-eq emissions in 2050 are between 70 to 95% below 2010 emissions, and they are between 110 to 120% below 2010 emissions in 2100.

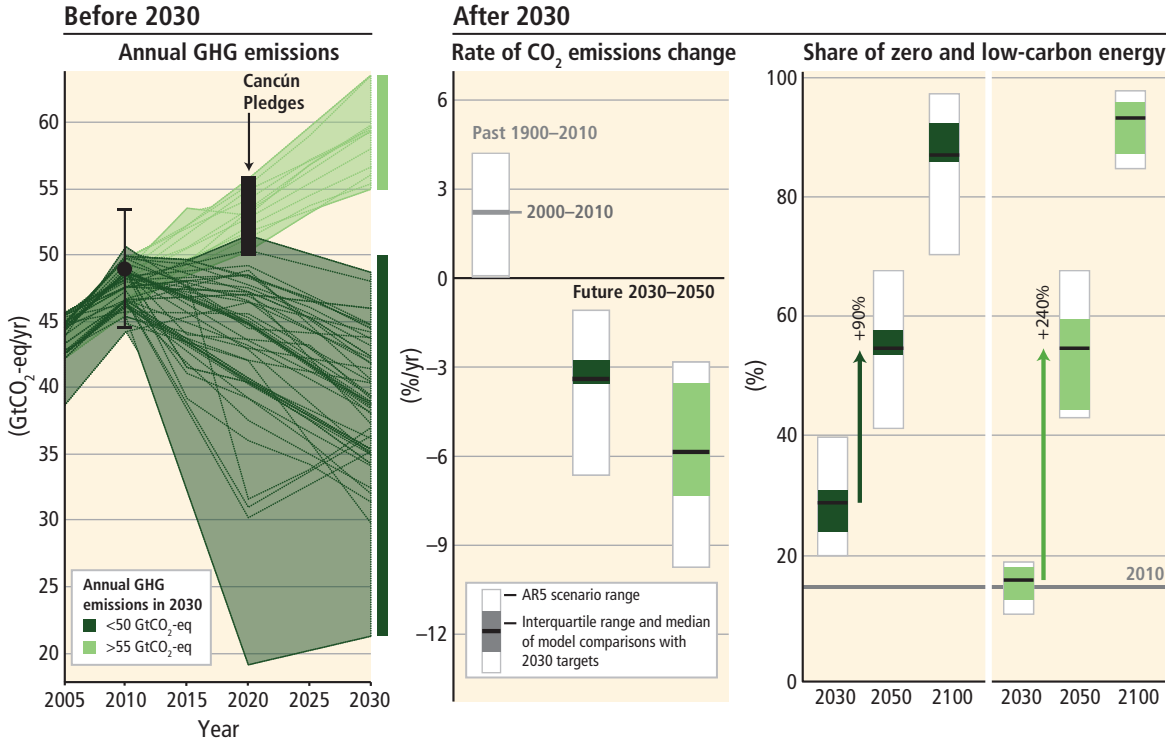

Figure SPM.12 | The implications of different 2030 greenhouse gas (GHG) emissions levels for the rate of carbon dioxide (CO_2) emissions reductions and low-carbon energy upscaling in mitigation scenarios that are at least *about as likely as not* to keep warming throughout the 21st century below 2°C relative to pre-industrial levels (2100 CO_2-equivalent concentrations of 430 to 530 ppm). The scenarios are grouped according to different emissions levels by 2030 (coloured in different shades of green). The left panel shows the pathways of GHG emissions (gigatonne of CO_2-equivalent per year, $GtCO_2$-eq/yr) leading to these 2030 levels. The black dot with whiskers gives historic GHG emission levels and associated uncertainties in 2010 as reported in Figure SPM.2. The black bar shows the estimated uncertainty range of GHG emissions implied by the Cancún Pledges. The middle panel denotes the average annual CO_2 emissions reduction rates for the period 2030–2050. It compares the median and interquartile range across scenarios from recent inter-model comparisons with explicit 2030 interim goals to the range of scenarios in the Scenario Database for WGIII AR5. Annual rates of historical emissions change (sustained over a period of 20 years) and the average annual CO_2 emission change between 2000 and 2010 are shown as well. The arrows in the right panel show the magnitude of zero and low-carbon energy supply upscaling from 2030 to 2050 subject to different 2030 GHG emissions levels. Zero- and low-carbon energy supply includes renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS) or bioenergy with CCS (BECCS). [Note: Only scenarios that apply the full, unconstrained mitigation technology portfolio of the underlying models (default technology assumption) are shown. Scenarios with large net negative global emissions (>20 $GtCO_2$-eq/yr), scenarios with exogenous carbon price assumptions and scenarios with 2010 emissions significantly outside the historical range are excluded.] *{Figure 3.3}*

Mitigation scenarios reaching about 450 ppm CO_2-eq in 2100 (consistent with a *likely* chance to keep warming below 2°C relative to pre-industrial levels) typically involve temporary overshoot[17] of atmospheric concentrations, as do many scenarios reaching about 500 ppm CO_2-eq to about 550 ppm CO_2-eq in 2100 (Table SPM.1). Depending on the level of overshoot, overshoot scenarios typically rely on the availability and widespread deployment of bioenergy with carbon dioxide capture and storage (BECCS) and afforestation in the second half of the century. The availability and scale of these and other CDR technologies and methods are uncertain and CDR technologies are, to varying degrees, associated with challenges and risks[18]. CDR is also prevalent in many scenarios without overshoot to compensate for residual emissions from sectors where mitigation is more expensive (*high confidence*). *{3.4, Box 3.3}*

Reducing emissions of non-CO_2 agents can be an important element of mitigation strategies. All current GHG emissions and other forcing agents affect the rate and magnitude of climate change over the next few decades, although long-term warming is mainly driven by CO_2 emissions. Emissions of non-CO_2 forcers are often expressed as 'CO_2-equivalent emissions', but the choice of metric to calculate these emissions, and the implications for the emphasis and timing of abatement of the various climate forcers, depends on application and policy context and contains value judgments. *{3.4, Box 3.2}*

[17] In concentration 'overshoot' scenarios, concentrations peak during the century and then decline.

[18] CDR methods have biogeochemical and technological limitations to their potential on the global scale. There is insufficient knowledge to quantify how much CO_2 emissions could be partially offset by CDR on a century timescale. CDR methods may carry side effects and long-term consequences on a global scale.

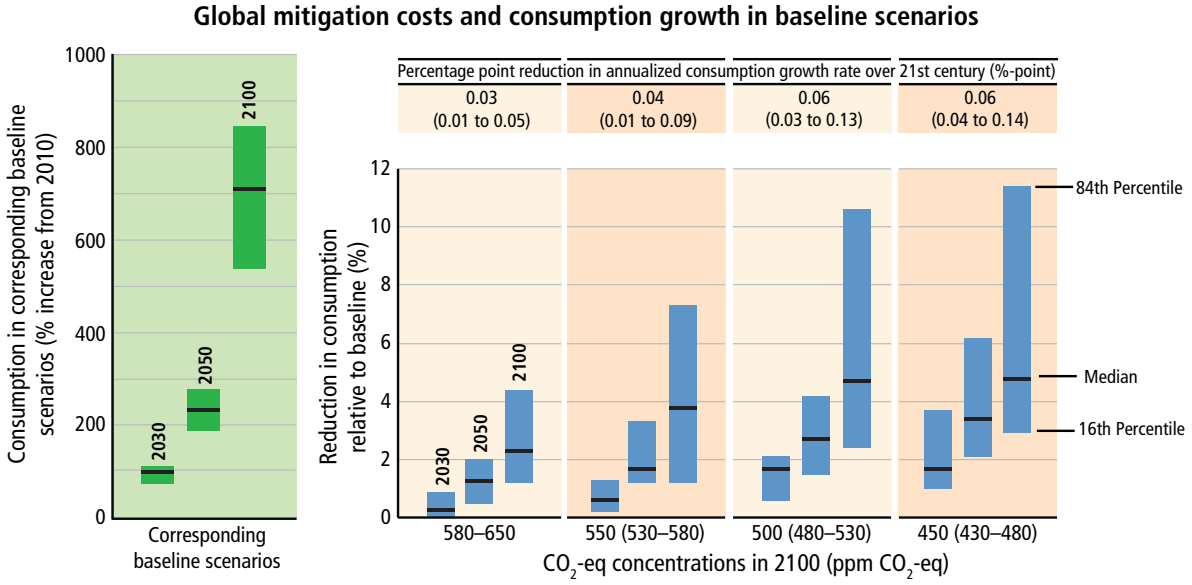

Figure SPM.13 | Global mitigation costs in cost-effective scenarios at different atmospheric concentrations levels in 2100. Cost-effective scenarios assume immediate mitigation in all countries and a single global carbon price, and impose no additional limitations on technology relative to the models' default technology assumptions. Consumption losses are shown relative to a baseline development without climate policy (left panel). The table at the top shows percentage points of annualized consumption growth reductions relative to consumption growth in the baseline of 1.6 to 3% per year (e.g., if the reduction is 0.06 percentage points per year due to mitigation, and baseline growth is 2.0% per year, then the growth rate with mitigation would be 1.94% per year). Cost estimates shown in this table do not consider the benefits of reduced climate change or co-benefits and adverse side effects of mitigation. Estimates at the high end of these cost ranges are from models that are relatively inflexible to achieve the deep emissions reductions required in the long run to meet these goals and/or include assumptions about market imperfections that would raise costs. *{Figure 3.4}*

Delaying additional mitigation to 2030 will substantially increase the challenges associated with limiting warming over the 21st century to below 2°C relative to pre-industrial levels. It will require substantially higher rates of emissions reductions from 2030 to 2050; a much more rapid scale-up of low-carbon energy over this period; a larger reliance on CDR in the long term; and higher transitional and long-term economic impacts. Estimated global emissions levels in 2020 based on the Cancún Pledges are not consistent with cost-effective mitigation trajectories that are at least *about as likely as not* to limit warming to below 2°C relative to pre-industrial levels, but they do not preclude the option to meet this goal (*high confidence*) (Figure SPM.12, Table SPM.2). *{3.4}*

Estimates of the aggregate economic costs of mitigation vary widely depending on methodologies and assumptions, but increase with the stringency of mitigation. Scenarios in which all countries of the world begin mitigation immediately, in which there is a single global carbon price, and in which all key technologies are available have been used as a cost-effective benchmark for estimating macro-economic mitigation costs (Figure SPM.13). Under these assumptions mitigation scenarios that are *likely* to limit warming to below 2°C through the 21st century relative to pre-industrial levels entail losses in global consumption—not including benefits of reduced climate change as well as co-benefits and adverse side effects of mitigation—of 1 to 4% (median: 1.7%) in 2030, 2 to 6% (median: 3.4%) in 2050 and 3 to 11% (median: 4.8%) in 2100 relative to consumption in baseline scenarios that grows anywhere from 300% to more than 900% over the century (Figure SPM.13). These numbers correspond to an annualized reduction of consumption growth by 0.04 to 0.14 (median: 0.06) percentage points over the century relative to annualized consumption growth in the baseline that is between 1.6 and 3% per year (*high confidence*). *{3.4}*

In the absence or under limited availability of mitigation technologies (such as bioenergy, CCS and their combination BECCS, nuclear, wind/solar), mitigation costs can increase substantially depending on the technology considered. Delaying additional mitigation increases mitigation costs in the medium to long term. Many models could not limit *likely* warming to below 2°C over the 21st century relative to pre-industrial levels if additional mitigation is considerably delayed. Many models could not limit *likely* warming to below 2°C if bioenergy, CCS and their combination (BECCS) are limited (*high confidence*) (Table SPM.2). *{3.4}*

Table SPM.2 | Increase in global mitigation costs due to either limited availability of specific technologies or delays in additional mitigation [a] relative to cost-effective scenarios [b]. The increase in costs is given for the median estimate and the 16th to 84th percentile range of the scenarios (in parentheses) [c]. In addition, the sample size of each scenario set is provided in the coloured symbols. The colours of the symbols indicate the fraction of models from systematic model comparison exercises that could successfully reach the targeted concentration level. *{Table 3.2}*

Mitigation cost increases in scenarios with limited availability of technologies [d] *[% increase in total discounted [e] mitigation costs (2015–2100) relative to default technology assumptions]*					**Mitigation cost increases due to delayed additional mitigation until 2030** *[% increase in mitigation costs relative to immediate mitigation]*	
2100 concentrations (ppm CO_2-eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy	medium term costs (2030–2050)	long term costs (2050–2100)
450 (430 to 480)	138% (29 to 297%) 4	7% (4 to 18%) 8	6% (2 to 29%) 8	64% (44 to 78%) 8	44% (2 to 78%) 29	37% (16 to 82%) 29
500 (480 to 530)	not available (n.a.)	n.a.	n.a.	n.a.		
550 (530 to 580)	39% (18 to 78%) 11	13% (2 to 23%) 10	8% (5 to 15%) 10	18% (4 to 66%) 12	15% (3 to 32%)	16% (5 to 24%)
580 to 650	n.a.	n.a.	n.a.	n.a.		

Symbol legend—fraction of models successful in producing scenarios (numbers indicate the number of successful models)

: all models successful

: between 80 and 100% of models successful

: between 50 and 80% of models successful

: less than 50% of models successful

Notes:

[a] Delayed mitigation scenarios are associated with greenhouse gas emission of more than 55 $GtCO_2$-eq in 2030, and the increase in mitigation costs is measured relative to cost-effective mitigation scenarios for the same long-term concentration level.

[b] Cost-effective scenarios assume immediate mitigation in all countries and a single global carbon price, and impose no additional limitations on technology relative to the models' default technology assumptions.

[c] The range is determined by the central scenarios encompassing the 16th to 84th percentile range of the scenario set. Only scenarios with a time horizon until 2100 are included. Some models that are included in the cost ranges for concentration levels above 530 ppm CO_2-eq in 2100 could not produce associated scenarios for concentration levels below 530 ppm CO_2-eq in 2100 with assumptions about limited availability of technologies and/or delayed additional mitigation.

[d] No CCS: carbon dioxide capture and storage is not included in these scenarios. Nuclear phase out: no addition of nuclear power plants beyond those under construction, and operation of existing plants until the end of their lifetime. Limited Solar/Wind: a maximum of 20% global electricity generation from solar and wind power in any year of these scenarios. Limited Bioenergy: a maximum of 100 EJ/yr modern bioenergy supply globally (modern bioenergy used for heat, power, combinations and industry was around 18 EJ/yr in 2008). EJ = Exajoule = 10^{18} Joule.

[e] Percentage increase of net present value of consumption losses in percent of baseline consumption (for scenarios from general equilibrium models) and abatement costs in percent of baseline gross domestic product (GDP, for scenarios from partial equilibrium models) for the period 2015–2100, discounted at 5% per year.

Mitigation scenarios reaching about 450 or 500 ppm CO_2-eq by 2100 show reduced costs for achieving air quality and energy security objectives, with significant co-benefits for human health, ecosystem impacts and sufficiency of resources and resilience of the energy system. *{4.4.2.2}*

Mitigation policy could devalue fossil fuel assets and reduce revenues for fossil fuel exporters, but differences between regions and fuels exist (*high confidence*). Most mitigation scenarios are associated with reduced revenues from coal and oil trade for major exporters (*high confidence*). The availability of CCS would reduce the adverse effects of mitigation on the value of fossil fuel assets (*medium confidence*). *{4.4.2.2}*

Solar Radiation Management (SRM) involves large-scale methods that seek to reduce the amount of absorbed solar energy in the climate system. SRM is untested and is not included in any of the mitigation scenarios. If it were deployed, SRM would

entail numerous uncertainties, side effects, risks and shortcomings and has particular governance and ethical implications. SRM would not reduce ocean acidification. If it were terminated, there is *high confidence* that surface temperatures would rise very rapidly impacting ecosystems susceptible to rapid rates of change. *{Box 3.3}*

SPM 4. Adaptation and Mitigation

Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives. *{4}*

SPM 4.1 Common enabling factors and constraints for adaptation and mitigation responses

Adaptation and mitigation responses are underpinned by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyle choices. *{4.1}*

Inertia in many aspects of the socio-economic system constrains adaptation and mitigation options (*medium evidence, high agreement*). Innovation and investments in environmentally sound infrastructure and technologies can reduce GHG emissions and enhance resilience to climate change (*very high confidence*). *{4.1}*

Vulnerability to climate change, GHG emissions and the capacity for adaptation and mitigation are strongly influenced by livelihoods, lifestyles, behaviour and culture (*medium evidence, medium agreement*). Also, the social acceptability and/or effectiveness of climate policies are influenced by the extent to which they incentivize or depend on regionally appropriate changes in lifestyles or behaviours. *{4.1}*

For many regions and sectors, enhanced capacities to mitigate and adapt are part of the foundation essential for managing climate change risks (*high confidence*). Improving institutions as well as coordination and cooperation in governance can help overcome regional constraints associated with mitigation, adaptation and disaster risk reduction (*very high confidence*). *{4.1}*

SPM 4.2 Response options for adaptation

Adaptation options exist in all sectors, but their context for implementation and potential to reduce climate-related risks differs across sectors and regions. Some adaptation responses involve significant co-benefits, synergies and trade-offs. Increasing climate change will increase challenges for many adaptation options. *{4.2}*

Adaptation experience is accumulating across regions in the public and private sectors and within communities. There is increasing recognition of the value of social (including local and indigenous), institutional, and ecosystem-based measures and of the extent of constraints to adaptation. Adaptation is becoming embedded in some planning processes, with more limited implementation of responses (*high confidence*). *{1.6, 4.2, 4.4.2.1}*

The need for adaptation along with associated challenges is expected to increase with climate change (*very high confidence*). Adaptation options exist in all sectors and regions, with diverse potential and approaches depending on their context in vulnerability reduction, disaster risk management or proactive adaptation planning (Table SPM.3). Effective strategies and actions consider the potential for co-benefits and opportunities within wider strategic goals and development plans. *{4.2}*

Table SPM.3 | Approaches for managing the risks of climate change through adaptation. These approaches should be considered overlapping rather than discrete, and they are often pursued simultaneously. Examples are presented in no specific order and can be relevant to more than one category. *{Table 4.2}*

Overlapping Approaches	Category	Examples
Vulnerability & Exposure Reduction through development, planning & practices including many low-regrets measures; **Adaptation** including incremental & transformational adjustments; **Transformation**	Human development	Improved access to education, nutrition, health facilities, energy, safe housing & settlement structures, & social support structures; Reduced gender inequality & marginalization in other forms.
	Poverty alleviation	Improved access to & control of local resources; Land tenure; Disaster risk reduction; Social safety nets & social protection; Insurance schemes.
	Livelihood security	Income, asset & livelihood diversification; Improved infrastructure; Access to technology & decision-making fora; Increased decision-making power; Changed cropping, livestock & aquaculture practices; Reliance on social networks.
	Disaster risk management	Early warning systems; Hazard & vulnerability mapping; Diversifying water resources; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements.
	Ecosystem management	Maintaining wetlands & urban green spaces; Coastal afforestation; Watershed & reservoir management; Reduction of other stressors on ecosystems & of habitat fragmentation; Maintenance of genetic diversity; Manipulation of disturbance regimes; Community-based natural resource management.
	Spatial or land-use planning	Provisioning of adequate housing, infrastructure & services; Managing development in flood prone & other high risk areas; Urban planning & upgrading programs; Land zoning laws; Easements; Protected areas.
	Structural/physical	***Engineered & built-environment options***: Sea walls & coastal protection structures; Flood levees; Water storage; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements; Floating houses; Power plant & electricity grid adjustments.
		Technological options: New crop & animal varieties; Indigenous, traditional & local knowledge, technologies & methods; Efficient irrigation; Water-saving technologies; Desalinisation; Conservation agriculture; Food storage & preservation facilities; Hazard & vulnerability mapping & monitoring; Early warning systems; Building insulation; Mechanical & passive cooling; Technology development, transfer & diffusion.
		Ecosystem-based options: Ecological restoration; Soil conservation; Afforestation & reforestation; Mangrove conservation & replanting; Green infrastructure (e.g., shade trees, green roofs); Controlling overfishing; Fisheries co-management; Assisted species migration & dispersal; Ecological corridors; Seed banks, gene banks & other *ex situ* conservation; Community-based natural resource management.
		Services: Social safety nets & social protection; Food banks & distribution of food surplus; Municipal services including water & sanitation; Vaccination programs; Essential public health services; Enhanced emergency medical services.
	Institutional	***Economic options***: Financial incentives; Insurance; Catastrophe bonds; Payments for ecosystem services; Pricing water to encourage universal provision and careful use; Microfinance; Disaster contingency funds; Cash transfers; Public-private partnerships.
		Laws & regulations: Land zoning laws; Building standards & practices; Easements; Water regulations & agreements; Laws to support disaster risk reduction; Laws to encourage insurance purchasing; Defined property rights & land tenure security; Protected areas; Fishing quotas; Patent pools & technology transfer.
		National & government policies & programs: National & regional adaptation plans including mainstreaming; Sub-national & local adaptation plans; Economic diversification; Urban upgrading programs; Municipal water management programs; Disaster planning & preparedness; Integrated water resource management; Integrated coastal zone management; Ecosystem-based management; Community-based adaptation.
	Social	***Educational options***: Awareness raising & integrating into education; Gender equity in education; Extension services; Sharing indigenous, traditional & local knowledge; Participatory action research & social learning; Knowledge-sharing & learning platforms.
		Informational options: Hazard & vulnerability mapping; Early warning & response systems; Systematic monitoring & remote sensing; Climate services; Use of indigenous climate observations; Participatory scenario development; Integrated assessments.
		Behavioural options: Household preparation & evacuation planning; Migration; Soil & water conservation; Storm drain clearance; Livelihood diversification; Changed cropping, livestock & aquaculture practices; Reliance on social networks.
	Spheres of change	***Practical***: Social & technical innovations, behavioural shifts, or institutional & managerial changes that produce substantial shifts in outcomes.
		Political: Political, social, cultural & ecological decisions & actions consistent with reducing vulnerability & risk & supporting adaptation, mitigation & sustainable development.
		Personal: Individual & collective assumptions, beliefs, values & worldviews influencing climate-change responses.

SPM 4.3 Response options for mitigation

Mitigation options are available in every major sector. Mitigation can be more cost-effective if using an integrated approach that combines measures to reduce energy use and the greenhouse gas intensity of end-use sectors, decarbonize energy supply, reduce net emissions and enhance carbon sinks in land-based sectors. *{4.3}*

Well-designed systemic and cross-sectoral mitigation strategies are more cost-effective in cutting emissions than a focus on individual technologies and sectors, with efforts in one sector affecting the need for mitigation in others (*medium confidence*). Mitigation measures intersect with other societal goals, creating the possibility of co-benefits or adverse side effects. These intersections, if well-managed, can strengthen the basis for undertaking climate action. *{4.3}*

Emissions ranges for baseline scenarios and mitigation scenarios that limit CO_2-equivalent concentrations to low levels (about 450 ppm CO_2-eq, *likely* to limit warming to 2°C above pre-industrial levels) are shown for different sectors and gases in Figure SPM.14. Key measures to achieve such mitigation goals include decarbonizing (i.e., reducing the carbon intensity of) electricity generation (*medium evidence, high agreement*) as well as efficiency enhancements and behavioural changes, in order to reduce energy demand compared to baseline scenarios without compromising development (*robust evidence, high agreement*). In scenarios reaching 450 ppm CO_2-eq concentrations by 2100, global CO_2 emissions from the energy supply sector are projected to decline over the next decade and are characterized by reductions of 90% or more below 2010 levels between 2040 and 2070. In the majority of low-concentration stabilization scenarios (about 450 to about 500 ppm CO_2-eq, at least *about as likely as not* to limit warming to 2°C above pre-industrial levels), the share of low-carbon electricity supply (comprising renewable energy (RE), nuclear and carbon dioxide capture and storage (CCS) including bioenergy with carbon dioxide capture and storage (BECCS)) increases from the current share of approximately 30% to more than 80% by 2050, and fossil fuel power generation without CCS is phased out almost entirely by 2100. *{4.3}*

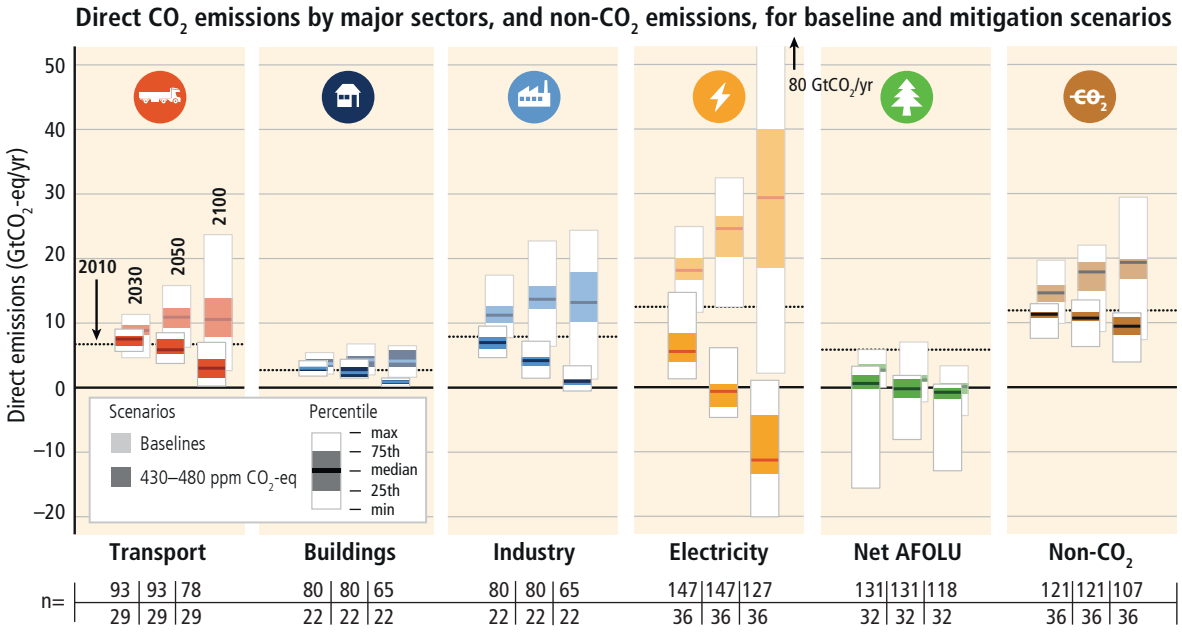

Figure SPM.14 | Carbon dioxide (CO_2) emissions by sector and total non-CO_2 greenhouse gases (Kyoto gases) across sectors in baseline (faded bars) and mitigation scenarios (solid colour bars) that reach about 450 (430 to 480) ppm CO_2-eq concentrations in 2100 (*likely* to limit warming to 2°C above pre-industrial levels). Mitigation in the end-use sectors leads also to indirect emissions reductions in the upstream energy supply sector. Direct emissions of the end-use sectors thus do not include the emission reduction potential at the supply-side due to, for example, reduced electricity demand. The numbers at the bottom of the graphs refer to the number of scenarios included in the range (upper row: baseline scenarios; lower row: mitigation scenarios), which differs across sectors and time due to different sectoral resolution and time horizon of models. Emissions ranges for mitigation scenarios include the full portfolio of mitigation options; many models cannot reach 450 ppm CO_2-eq concentration by 2100 in the absence of carbon dioxide capture and storage (CCS). Negative emissions in the electricity sector are due to the application of bioenergy with carbon dioxide capture and storage (BECCS). 'Net' agriculture, forestry and other land use (AFOLU) emissions consider afforestation, reforestation as well as deforestation activities. *{4.3, Figure 4.1}*

Near-term reductions in energy demand are an important element of cost-effective mitigation strategies, provide more flexibility for reducing carbon intensity in the energy supply sector, hedge against related supply-side risks, avoid lock-in to carbon-intensive infrastructures, and are associated with important co-benefits. The most cost-effective mitigation options in forestry are afforestation, sustainable forest management and reducing deforestation, with large differences in their relative importance across regions; and in agriculture, cropland management, grazing land management and restoration of organic soils (*medium evidence, high agreement*). *{4.3, Figures 4.1, 4.2, Table 4.3}*

Behaviour, lifestyle and culture have a considerable influence on energy use and associated emissions, with high mitigation potential in some sectors, in particular when complementing technological and structural change (*medium evidence, medium agreement*). Emissions can be substantially lowered through changes in consumption patterns, adoption of energy savings measures, dietary change and reduction in food wastes. *{4.1, 4.3}*

SPM 4.4 Policy approaches for adaptation and mitigation, technology and finance

Effective adaptation and mitigation responses will depend on policies and measures across multiple scales: international, regional, national and sub-national. Policies across all scales supporting technology development, diffusion and transfer, as well as finance for responses to climate change, can complement and enhance the effectiveness of policies that directly promote adaptation and mitigation. *{4.4}*

International cooperation is critical for effective mitigation, even though mitigation can also have local co-benefits. Adaptation focuses primarily on local to national scale outcomes, but its effectiveness can be enhanced through coordination across governance scales, including international cooperation: *{3.1, 4.4.1}*

- The United Nations Framework Convention on Climate Change (UNFCCC) is the main multilateral forum focused on addressing climate change, with nearly universal participation. Other institutions organized at different levels of governance have resulted in diversifying international climate change cooperation. *{4.4.1}*

- The Kyoto Protocol offers lessons towards achieving the ultimate objective of the UNFCCC, particularly with respect to participation, implementation, flexibility mechanisms and environmental effectiveness (*medium evidence, low agreement*). *{4.4.1}*

- Policy linkages among regional, national and sub-national climate policies offer potential climate change mitigation benefits (*medium evidence, medium agreement*). Potential advantages include lower mitigation costs, decreased emission leakage and increased market liquidity. *{4.4.1}*

- International cooperation for supporting adaptation planning and implementation has received less attention historically than mitigation but is increasing and has assisted in the creation of adaptation strategies, plans and actions at the national, sub-national and local level (*high confidence*). *{4.4.1}*

There has been a considerable increase in national and sub-national plans and strategies on both adaptation and mitigation since the AR4, with an increased focus on policies designed to integrate multiple objectives, increase co-benefits and reduce adverse side effects (*high confidence*): *{4.4.2.1, 4.4.2.2}*

- National governments play key roles in adaptation planning and implementation (*robust evidence, high agreement*) through coordinating actions and providing frameworks and support. While local government and the private sector have different functions, which vary regionally, they are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households and civil society and in managing risk information and financing (*medium evidence, high agreement*). *{4.4.2.1}*

- Institutional dimensions of adaptation governance, including the integration of adaptation into planning and decision-making, play a key role in promoting the transition from planning to implementation of adaptation (*robust evidence,*

high agreement). Examples of institutional approaches to adaptation involving multiple actors include economic options (e.g., insurance, public-private partnerships), laws and regulations (e.g., land-zoning laws) and national and government policies and programmes (e.g., economic diversification). *{4.2, 4.4.2.1, Table SPM.3}*

- In principle, mechanisms that set a carbon price, including cap and trade systems and carbon taxes, can achieve mitigation in a cost-effective way but have been implemented with diverse effects due in part to national circumstances as well as policy design. The short-run effects of cap and trade systems have been limited as a result of loose caps or caps that have not proved to be constraining (*limited evidence, medium agreement*). In some countries, tax-based policies specifically aimed at reducing GHG emissions—alongside technology and other policies—have helped to weaken the link between GHG emissions and GDP (*high confidence*). In addition, in a large group of countries, fuel taxes (although not necessarily designed for the purpose of mitigation) have had effects that are akin to sectoral carbon taxes. *{4.4.2.2}*

- Regulatory approaches and information measures are widely used and are often environmentally effective (*medium evidence, medium agreement*). Examples of regulatory approaches include energy efficiency standards; examples of information programmes include labelling programmes that can help consumers make better-informed decisions. *{4.4.2.2}*

- Sector-specific mitigation policies have been more widely used than economy-wide policies (*medium evidence, high agreement*). Sector-specific policies may be better suited to address sector-specific barriers or market failures and may be bundled in packages of complementary policies. Although theoretically more cost-effective, administrative and political barriers may make economy-wide policies harder to implement. Interactions between or among mitigation policies may be synergistic or may have no additive effect on reducing emissions. *{4.4.2.2}*

- Economic instruments in the form of subsidies may be applied across sectors, and include a variety of policy designs, such as tax rebates or exemptions, grants, loans and credit lines. An increasing number and variety of renewable energy (RE) policies including subsidies—motivated by many factors—have driven escalated growth of RE technologies in recent years. At the same time, reducing subsidies for GHG-related activities in various sectors can achieve emission reductions, depending on the social and economic context (*high confidence*). *{4.4.2.2}*

Co-benefits and adverse side effects of mitigation could affect achievement of other objectives such as those related to human health, food security, biodiversity, local environmental quality, energy access, livelihoods and equitable sustainable development. The potential for co-benefits for energy end-use measures outweighs the potential for adverse side effects whereas the evidence suggests this may not be the case for all energy supply and agriculture, forestry and other land use (AFOLU) measures. Some mitigation policies raise the prices for some energy services and could hamper the ability of societies to expand access to modern energy services to underserved populations (*low confidence*). These potential adverse side effects on energy access can be avoided with the adoption of complementary policies such as income tax rebates or other benefit transfer mechanisms (*medium confidence*). Whether or not side effects materialize, and to what extent side effects materialize, will be case- and site-specific, and depend on local circumstances and the scale, scope and pace of implementation. Many co-benefits and adverse side effects have not been well-quantified. *{4.3, 4.4.2.2, Box 3.4}*

Technology policy (development, diffusion and transfer) complements other mitigation policies across all scales, from international to sub-national; many adaptation efforts also critically rely on diffusion and transfer of technologies and management practices (*high confidence*). Policies exist to address market failures in R&D, but the effective use of technologies can also depend on capacities to adopt technologies appropriate to local circumstances. *{4.4.3}*

Substantial reductions in emissions would require large changes in investment patterns (*high confidence*). For mitigation scenarios that stabilize concentrations (without overshoot) in the range of 430 to 530 ppm CO_2-eq by 2100[19], annual investments in low carbon electricity supply and energy efficiency in key sectors (transport, industry and buildings) are projected in the scenarios to rise by several hundred billion dollars per year before 2030. Within appropriate enabling environments, the private sector, along with the public sector, can play important roles in financing mitigation and adaptation (*medium evidence, high agreement*). *{4.4.4}*

[19] This range comprises scenarios that reach 430 to 480 ppm CO_2-eq by 2100 (*likely* to limit warming to 2°C above pre-industrial levels) and scenarios that reach 480 to 530 ppm CO_2-eq by 2100 (without overshoot: *more likely than* not to limit warming to 2°C above pre-industrial levels).

Financial resources for adaptation have become available more slowly than for mitigation in both developed and developing countries. Limited evidence indicates that there is a gap between global adaptation needs and the funds available for adaptation (*medium confidence*). There is a need for better assessment of global adaptation costs, funding and investment. Potential synergies between international finance for disaster risk management and adaptation have not yet been fully realized (*high confidence*). *{4.4.4}*

SPM 4.5 Trade-offs, synergies and interactions with sustainable development

Climate change is a threat to sustainable development. Nonetheless, there are many opportunities to link mitigation, adaptation and the pursuit of other societal objectives through integrated responses (*high confidence*). Successful implementation relies on relevant tools, suitable governance structures and enhanced capacity to respond (*medium confidence*). *{3.5, 4.5}*

Climate change exacerbates other threats to social and natural systems, placing additional burdens particularly on the poor (*high confidence*). Aligning climate policy with sustainable development requires attention to both adaptation and mitigation (*high confidence*). Delaying global mitigation actions may reduce options for climate-resilient pathways and adaptation in the future. Opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded. Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, encompassing connections among human health, water, energy, land use and biodiversity (*medium evidence, high agreement*). *{3.1, 3.5, 4.5}*

Strategies and actions can be pursued now which will move towards climate-resilient pathways for sustainable development, while at the same time helping to improve livelihoods, social and economic well-being and effective environmental management. In some cases, economic diversification can be an important element of such strategies. The effectiveness of integrated responses can be enhanced by relevant tools, suitable governance structures and adequate institutional and human capacity (*medium confidence*). Integrated responses are especially relevant to energy planning and implementation; interactions among water, food, energy and biological carbon sequestration; and urban planning, which provides substantial opportunities for enhanced resilience, reduced emissions and more sustainable development (*medium confidence*). *{3.5, 4.4, 4.5}*

This is Exhibit "H" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.

ipcc
INTERGOVERNMENTAL PANEL ON climate change

GLOBAL WARMING OF 1.5 °C

an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Summary for Policymakers

This Summary for Policymakers was formally approved at the First Joint Session of Working Groups I, II and III of the IPCC and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018.

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Summary for Policymakers

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Date of Summary for Policymakers: 6 October 2018

Introduction

This report responds to the invitation for IPCC '... to provide a Special Report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways' contained in the Decision of the 21st Conference of Parties of the United Nations Framework Convention on Climate Change to adopt the Paris Agreement.[1]

The IPCC accepted the invitation in April 2016, deciding to prepare this Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

This Summary for Policy Makers (SPM) presents the key findings of the Special Report, based on the assessment of the available scientific, technical and socio-economic literature[2] relevant to global warming of 1.5°C and for the comparison between global warming of 1.5°C and 2°C above pre-industrial levels. The level of confidence associated with each key finding is reported using the IPCC calibrated language.[3] The underlying scientific basis of each key finding is indicated by references provided to chapter elements. In the SPM, knowledge gaps are identified associated with the underlying chapters of the report.

[1] Decision 1/CP.21, paragraph 21.

[2] The assessment covers literature accepted for publication by 15 May 2018.

[3] Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, more unlikely than likely 0–<50%, extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5.

A. Understanding Global Warming of 1.5°C[4]

A1. Human activities are estimated to have caused approximately 1.0°C of global warming[5] above pre-industrial levels, with a *likely* range of 0.8°C to 1.2°C. Global warming is *likely* to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. (*high confidence*) {1.2, Figure SPM.1}

A1.1. Reflecting the long-term warming trend since pre-industrial times, observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (*likely* between 0.75°C and 0.99°C)[6] higher than the average over the 1850–1900 period (*very high confidence*). Estimated anthropogenic global warming matches the level of observed warming to within ±20% (*likely* range). Estimated anthropogenic global warming is currently increasing at 0.2°C (*likely* between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (*high confidence*). {1.2.1, Table 1.1, 1.2.4}

A1.2. Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic. Warming is generally higher over land than over the ocean. (*high confidence*) {1.2.1, 1.2.2, Figure 1.1, Figure 1.3, 3.3.1, 3.3.2}

A1.3. Trends in intensity and frequency of some climate and weather extremes have been detected over time spans during which about 0.5°C of global warming occurred (*medium confidence*). This assessment is based on several lines of evidence, including attribution studies for changes in extremes since 1950. {3.3.1, 3.3.2, 3.3.3}

A.2. Warming from anthropogenic emissions from the pre-industrial period to the present will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts (*high confidence*), but these emissions alone are *unlikely* to cause global warming of 1.5°C (*medium confidence*) {1.2, 3.3, Figure 1.5, Figure SPM.1}

A2.1. Anthropogenic emissions (including greenhouse gases, aerosols and their precursors) up to the present are *unlikely* to cause further warming of more than 0.5°C over the next two to three decades (*high confidence*) or on a century time scale (*medium confidence*). {1.2.4, Figure 1.5}

[4] SPM BOX.1: Core Concepts

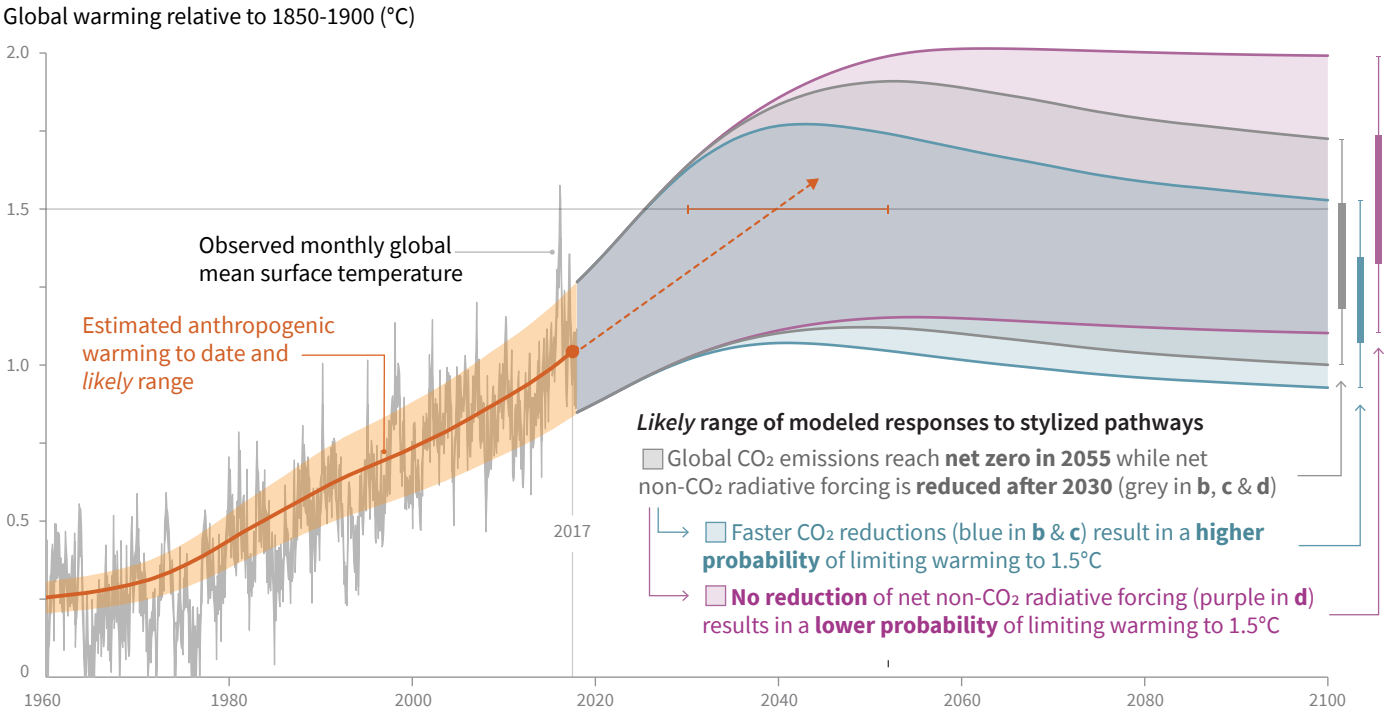
[5] Present level of global warming is defined as the average of a 30-year period centered on 2017 assuming the recent rate of warming continues.

[6] This range spans the four available peer-reviewed estimates of the observed GMST change and also accounts for additional uncertainty due to possible short-term natural variability. {1.2.1, Table 1.1}

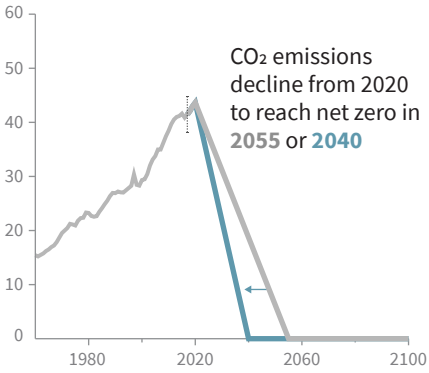
A2.2. Reaching and sustaining net-zero global anthropogenic CO_2 emissions and declining net non-CO_2 radiative forcing would halt anthropogenic global warming on multi-decadal timescales (*high confidence*). The maximum temperature reached is then determined by cumulative net global anthropogenic CO_2 emissions up to the time of net zero CO_2 emissions (*high confidence*) and the level of non-CO_2 radiative forcing in the decades prior to the time that maximum temperatures are reached (*medium confidence*). On longer timescales, sustained net negative global anthropogenic CO_2 emissions and/or further reductions in non-CO_2 radiative forcing may still be required to prevent further warming due to Earth system feedbacks and reverse ocean acidification (*medium confidence*) and will be required to minimise sea level rise (*high confidence*). {Cross-Chapter Box 2 in Chapter 1, 1.2.3, 1.2.4, Figure 1.4, 2.2.1, 2.2.2, 3.4.4.8, 3.4.5.1, 3.6.3.2}

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

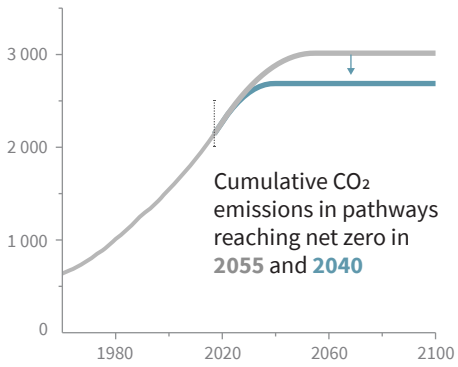
a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



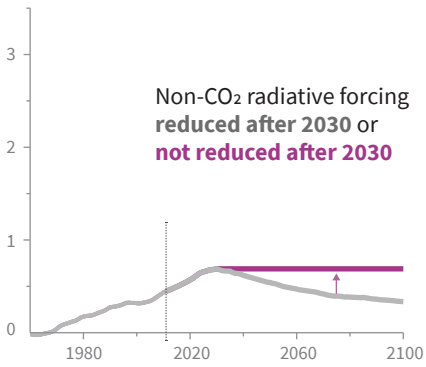
b) Stylized net global CO_2 emission pathways
Billion tonnes CO_2 per year ($GtCO_2$/yr)



c) Cumulative net CO_2 emissions
Billion tonnes CO_2 ($GtCO_2$)



d) Non-CO_2 radiative forcing pathways
Watts per square metre (W/m^2)



Faster immediate CO_2 emission reductions limit cumulative CO_2 emissions shown in panel **(c)**.

Maximum temperature rise is determined by cumulative net CO_2 emissions and net non-CO_2 radiative forcing due to methane, nitrous oxide, aerosols and other anthropogenic forcing agents.

Figure SPM.1: Panel a: Observed monthly global mean surface temperature (GMST) change grey line up to 2017, from the HadCRUT4, GISTEMP, Cowtan–Way, and NOAA datasets) and estimated anthropogenic global warming (solid orange line up to 2017, with orange shading indicating assessed *likely* range). Orange dashed arrow and horizontal orange error bar show respectively central estimate and *likely* range of the time at which 1.5°C is reached if the current rate of warming continues. The grey plume on the right of Panel a) shows the *likely* range of warming responses, computed with a simple climate model, to a stylized pathway (hypothetical future) in which net CO_2 emissions (grey line in panels b and c) decline in a straight line from 2020 to reach net zero in 2055 and net non-CO_2 radiative forcing (grey line in panel d) increases to 2030 and then declines. The blue plume in panel a) shows the response to faster CO_2 emissions reductions (blue line in panel b), reaching net zero in 2040, reducing cumulative CO_2 emissions (panel c). The purple plume shows the response to net CO_2 emissions declining to zero in 2055, with net non-CO_2 forcing remaining constant after 2030. The vertical error bars on right of panel a) show the *likely* ranges (thin lines) and central terciles (33rd – 66th percentiles, thick lines) of the estimated distribution of warming in 2100 under these three stylized pathways. Vertical dotted error bars in panels b, c and d show the *likely* range of historical annual and cumulative global net CO_2 emissions in 2017 (data from the Global Carbon Project) and of net non-CO_2 radiative forcing in 2011 from AR5, respectively. Vertical axes in panels c and d are scaled to represent approximately equal effects on GMST. {1.2.1, 1.2.3, 1.2.4, 2.3, Chapter 1 Figure 1.2 & Chapter 1 Supplementary Material, Cross-Chapter Box 2}

A3. Climate-related risks for natural and human systems are higher for global warming of 1.5°C than at present, but lower than at 2°C (*high confidence*). These risks depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options (*high confidence*) (Figure SPM.2). {1.3, 3.3, 3.4, 5.6}

A3.1. Impacts on natural and human systems from global warming have already been observed (*high confidence*). Many land and ocean ecosystems and some of the services they provide have already changed due to global warming (*high confidence*). {1.4, 3.4, 3.5, Figure SPM.2}

A3.2. Future climate-related risks depend on the rate, peak and duration of warming. In the aggregate they are larger if global warming exceeds 1.5°C before returning to that level by 2100 than if global warming gradually stabilizes at 1.5°C, especially if the peak temperature is high (e.g., about 2°C) (*high confidence*). Some impacts may be long-lasting or irreversible, such as the loss of some ecosystems (*high confidence*). {3.2, 3.4.4, 3.6.3, Cross-Chapter Box 8}

A3.3. Adaptation and mitigation are already occurring (*high confidence*). Future climate-related risks would be reduced by the upscaling and acceleration of far-reaching, multi-level and cross-sectoral climate mitigation and by both incremental and transformational adaptation (*high confidence*). {1.2, 1.3, Table 3.5, 4.2.2, Cross-Chapter Box 9 in Chapter 4, Box 4.2, Box 4.3, Box 4.6, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.4.1, 4.4.4, 4.4.5, 4.5.3}

B. Projected Climate Change, Potential Impacts and Associated Risks

B1. Climate models project robust[7] differences in regional climate characteristics between present-day and global warming of 1.5°C,[8] and between 1.5°C and 2°C.[8] These differences include increases in: mean temperature in most land and ocean regions (*high confidence*), hot extremes in most inhabited regions (*high confidence*), heavy precipitation in several regions (*medium confidence*), and the probability of drought and precipitation deficits in some regions (*medium confidence*). {3.3}

B1.1. Evidence from attributed changes in some climate and weather extremes for a global warming of about 0.5°C supports the assessment that an additional 0.5°C of warming compared to present is associated with further detectable changes in these extremes (*medium confidence*). Several regional changes in climate are assessed to occur with global warming up to 1.5°C compared to pre-industrial levels, including warming of extreme temperatures in many regions (*high confidence*), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (*high confidence*), and an increase in intensity or frequency of droughts in some regions (*medium confidence*). {3.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, Table 3.2}

B1.2. Temperature extremes on land are projected to warm more than GMST (*high confidence*): extreme hot days in mid-latitudes warm by up to about 3°C at global warming of 1.5°C and about

[7] Robust is here used to mean that at least two thirds of climate models show the same sign of changes at the grid point scale, and that differences in large regions are statistically significant.

[8] Projected changes in impacts between different levels of global warming are determined with respect to changes in global mean surface air temperature.

4°C at 2°C, and extreme cold nights in high latitudes warm by up to about 4.5°C at 1.5°C and about 6°C at 2°C (*high confidence*). The number of hot days is projected to increase in most land regions, with highest increases in the tropics (*high confidence*). {3.3.1, 3.3.2, Cross-Chapter Box 8 in Chapter 3}

B1.3. Risks from droughts and precipitation deficits are projected to be higher at 2°C compared to 1.5°C global warming in some regions (*medium confidence*). Risks from heavy precipitation events are projected to be higher at 2°C compared to 1.5°C global warming in several northern hemisphere high-latitude and/or high-elevation regions, eastern Asia and eastern North America (*medium confidence*). Heavy precipitation associated with tropical cyclones is projected to be higher at 2°C compared to 1.5°C global warming (*medium confidence*). There is generally *low confidence* in projected changes in heavy precipitation at 2°C compared to 1.5°C in other regions. Heavy precipitation when aggregated at global scale is projected to be higher at 2.0°C than at 1.5°C of global warming (*medium confidence*). As a consequence of heavy precipitation, the fraction of the global land area affected by flood hazards is projected to be larger at 2°C compared to 1.5°C of global warming (*medium confidence*). {3.3.1, 3.3.3, 3.3.4, 3.3.5, 3.3.6}

B2. By 2100, global mean sea level rise is projected to be around 0.1 metre lower with global warming of 1.5°C compared to 2°C (*medium confidence*). Sea level will continue to rise well beyond 2100 (*high confidence*), and the magnitude and rate of this rise depends on future emission pathways. A slower rate of sea level rise enables greater opportunities for adaptation in the human and ecological systems of small islands, low-lying coastal areas and deltas (*medium confidence*). {3.3, 3.4, 3.6 }

B2.1. Model-based projections of global mean sea level rise (relative to 1986-2005) suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5°C global warming, 0.1 m (0.04-0.16 m) less than for a global warming of 2°C (*medium confidence*). A reduction of 0.1 m in global sea level rise implies that up to 10 million fewer people would be exposed to related risks, based on population in the year 2010 and assuming no adaptation (*medium confidence*). {3.4.4, 3.4.5, 4.3.2}

B2.2. Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (*high confidence*). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-metre rise in sea level over hundreds to thousands of years. These instabilities could be triggered around 1.5°C to 2°C of global warming (*medium confidence*). {3.3.9, 3.4.5, 3.5.2, 3.6.3, Box 3.3, Figure SPM.2}

B2.3. Increasing warming amplifies the exposure of small islands, low-lying coastal areas and deltas to the risks associated with sea level rise for many human and ecological systems, including increased saltwater intrusion, flooding and damage to infrastructure (*high confidence*). Risks associated with sea level rise are higher at 2°C compared to 1.5°C. The slower rate of sea level rise at global warming of 1.5°C reduces these risks enabling greater opportunities for adaptation including managing and restoring natural coastal ecosystems, and infrastructure reinforcement (*medium confidence*). {3.4.5, Figure SPM.2, Box 3.5}

B3. On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5°C of global warming compared to 2°C. Limiting global warming to 1.5°C compared to 2°C is projected to lower the impacts on terrestrial, freshwater, and coastal ecosystems and to retain more of their services to humans (*high confidence*). (Figure SPM.2) {3.4, 3.5, Box 3.4, Box 4.2, Cross-Chapter Box 8 in Chapter 3}

B3.1. Of 105,000 species studied,[9] 6% of insects, 8% of plants and 4% of vertebrates are projected to lose over half of their climatically determined geographic range for global warming of 1.5°C, compared with 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C (*medium confidence*). Impacts associated with other biodiversity-related risks such as forest fires, and the spread of invasive species, are lower at 1.5°C compared to 2°C of global warming (*high confidence*). {3.4.3, 3.5.2}

B3.2. Approximately 4% (interquartile range 2–7%) of the global terrestrial land area is projected to undergo a transformation of ecosystems from one type to another at 1ºC of global warming, compared with 13% (interquartile range 8–20%) at 2°C (*medium confidence*). This indicates that the area at risk is projected to be approximately 50% lower at 1.5°C compared to 2°C (*medium confidence*). {3.4.3.1, 3.4.3.5}

B3.3. High-latitude tundra and boreal forests are particularly at risk of climate change-induced degradation and loss, with woody shrubs already encroaching into the tundra (*high confidence*) and will proceed with further warming. Limiting global warming to 1.5°C rather than 2°C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km^2 (*medium confidence*). {3.3.2, 3.4.3, 3.5.5}

B4. Limiting global warming to 1.5°C compared to 2ºC is projected to reduce increases in ocean temperature as well as associated increases in ocean acidity and decreases in ocean oxygen levels (*high confidence*). Consequently, limiting global warming to 1.5°C is projected to reduce risks to marine biodiversity, fisheries, and ecosystems, and their functions and services to humans, as illustrated by recent changes to Arctic sea ice and warm water coral reef ecosystems (*high confidence*). {3.3, 3.4, 3.5, Boxes 3.4, 3.5}

B4.1. There is *high confidence* that the probability of a sea-ice-free Arctic Ocean during summer is substantially lower at global warming of 1.5°C when compared to 2°C. With 1.5°C of global warming, one sea ice-free Arctic summer is projected per century. This likelihood is increased to at least one per decade with 2°C global warming. Effects of a temperature overshoot are reversible for Arctic sea ice cover on decadal time scales (*high confidence*). {3.3.8, 3.4.4.7}

B4.2. Global warming of 1.5°C is projected to shift the ranges of many marine species, to higher latitudes as well as increase the amount of damage to many ecosystems. It is also expected to drive the loss of coastal resources, and reduce the productivity of fisheries and aquaculture (especially at low latitudes). The risks of climate-induced impacts are projected to be higher at 2°C than those at global warming of 1.5°C (*high confidence*). Coral reefs, for example, are projected to decline by a further 70–90% at 1.5°C (*high confidence*) with larger losses (>99%) at 2ºC (*very high confidence*). The risk of irreversible loss of many marine and coastal ecosystems increases with global warming, especially at 2°C or more (*high confidence*). {3.4.4, Box 3.4}

B4.3. The level of ocean acidification due to increasing CO_2 concentrations associated with global warming of 1.5°C is projected to amplify the adverse effects of warming, and even further at 2°C,

[9] Consistent with earlier studies, illustrative numbers were adopted from one recent meta-study.

impacting the growth, development, calcification, survival, and thus abundance of a broad range of species, e.g., from algae to fish (*high confidence*). {3.3.10, 3.4.4}

B4.4. Impacts of climate change in the ocean are increasing risks to fisheries and aquaculture via impacts on the physiology, survivorship, habitat, reproduction, disease incidence, and risk of invasive species (*medium confidence)* but are projected to be less at 1.5ºC of global warming than at 2ºC. One global fishery model, for example, projected a decrease in global annual catch for marine fisheries of about 1.5 million tonnes for 1.5°C of global warming compared to a loss of more than 3 million tonnes for 2°C of global warming (*medium confidence*). {3.4.4, Box 3.4}

B5. Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. (Figure SPM.2) {3.4, 3.5, 5.2, Box 3.2, Box 3.3, Box 3.5, Box 3.6, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5, 5.2}

B5.1. Populations at disproportionately higher risk of adverse consequences of global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods (*high confidence*). Regions at disproportionately higher risk include Arctic ecosystems, dryland regions, small-island developing states, and least developed countries (*high confidence)*. Poverty and disadvantages are expected to increase in some populations as global warming increases; limiting global warming to 1.5°C, compared with 2°C, could reduce the number of people both exposed to climate-related risks and susceptible to poverty by up to several hundred million by 2050 (*medium confidence*). {3.4.10, 3.4.11, Box 3.5, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5, 4.2.2.2, 5.2.1, 5.2.2, 5.2.3, 5.6.3}

B5.2. Any increase in global warming is projected to affect human health, with primarily negative consequences (*high confidence*). Lower risks are projected at 1.5°C than at 2°C for heat-related morbidity and mortality (*very high confidence*) and for ozone-related mortality if emissions needed for ozone formation remain high (*high confidence)*. Urban heat islands often amplify the impacts of heatwaves in cities (*high confidence*). Risks from some vector-borne diseases, such as malaria and dengue fever, are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (*high confidence*). {3.4.7, 3.4.8, 3.5.5.8}

B5.3. Limiting warming to 1.5°C, compared with 2ºC, is projected to result in smaller net reductions in yields of maize, rice, wheat, and potentially other cereal crops, particularly in sub-Saharan Africa, Southeast Asia, and Central and South America; and in the CO_2 dependent, nutritional quality of rice and wheat (*high confidence*). Reductions in projected food availability are larger at 2ºC than at 1.5°C of global warming in the Sahel, southern Africa, the Mediterranean, central Europe, and the Amazon (*medium confidence*). Livestock are projected to be adversely affected with rising temperatures, depending on the extent of changes in feed quality, spread of diseases, and water resource availability (*high confidence*). {3.4.6, 3.5.4, 3.5.5, Box 3.1, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4}

B5.4. Depending on future socioeconomic conditions, limiting global warming to 1.5°C, compared to 2°C, may reduce the proportion of the world population exposed to a climate-change induced increase in water stress by up to 50%, although there is considerable variability between regions (*medium confidence*). Many small island developing states would experience lower water stress as a

result of projected changes in aridity when global warming is limited to 1.5°C, as compared to 2°C (*medium confidence*). {3.3.5, 3.4.2, 3.4.8, 3.5.5, Box 3.2, Box 3.5, Cross-Chapter Box 9 in Chapter 4}

B5.5. Risks to global aggregated economic growth due to climate change impacts are projected to be lower at 1.5°C than at 2°C by the end of this century[10] (*medium confidence*). This excludes the costs of mitigation, adaptation investments and the benefits of adaptation. Countries in the tropics and Southern Hemisphere subtropics are projected to experience the largest impacts on economic growth due to climate change should global warming increase from 1.5°C to 2 °C (*medium confidence*). {3.5.2, 3.5.3}

B5.6. Exposure to multiple and compound climate-related risks increases between 1.5°C and 2°C of global warming, with greater proportions of people both so exposed and susceptible to poverty in Africa and Asia (*high confidence*). For global warming from 1.5°C to 2°C, risks across energy, food, and water sectors could overlap spatially and temporally, creating new and exacerbating current hazards, exposures, and vulnerabilities that could affect increasing numbers of people and regions (*medium confidence*). {Box 3.5, 3.3.1, 3.4.5.3, 3.4.5.6, 3.4.11, 3.5.4.9}

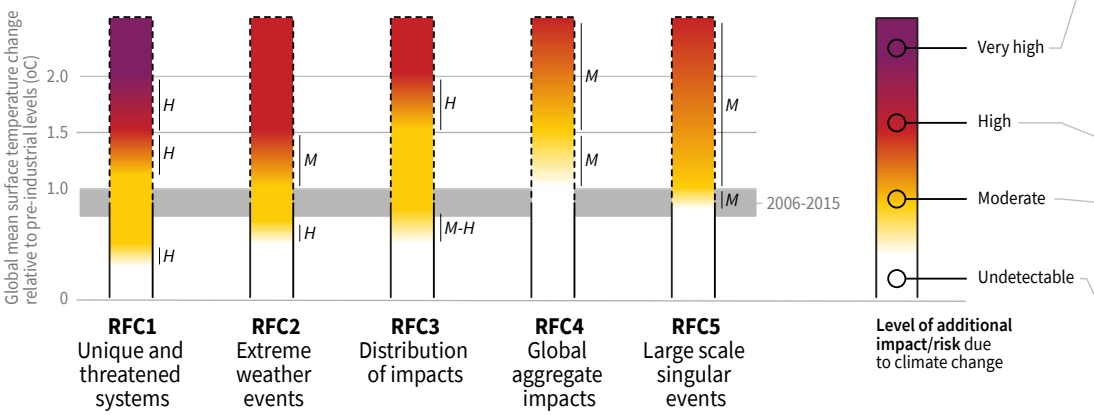
B5.7. There are multiple lines of evidence that since the AR5 the assessed levels of risk increased for four of the five Reasons for Concern (RFCs) for global warming to 2°C (*high confidence*). The risk transitions by degrees of global warming are now: from high to very high between 1.5°C and 2°C for RFC1 (Unique and threatened systems) (*high confidence*); from moderate to high risk between 1.0°C and 1.5°C for RFC2 (Extreme weather events) (*medium confidence*); from moderate to high risk between 1.5°C and 2°C for RFC3 (Distribution of impacts) (*high confidence*); from moderate to high risk between 1.5°C and 2.5°C for RFC4 (Global aggregate impacts) (*medium confidence*); and from moderate to high risk between 1°C and 2.5°C for RFC5 (Large-scale singular events) (*medium confidence*). (Figure SPM.2) {3.4.13; 3.5, 3.5.2}

[10] Here, impacts on economic growth refer to changes in GDP. Many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize.

How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems

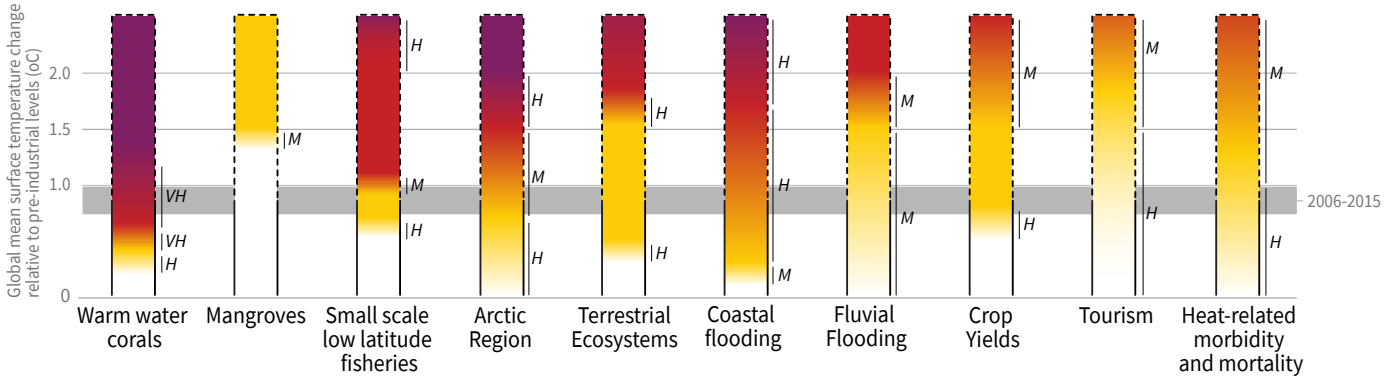
Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)



Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
Red indicates severe and widespread impacts/risks.
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.
White indicates that no impacts are detectable and attributable to climate change.

Impacts and risks for selected natural, managed and human systems



Confidence level for transition: *L*=Low, *M*=Medium, *H*=High and *VH*=Very high

Figure SPM.2: Five integrative reasons for concern (RFCs) provide a framework for summarizing key impacts and risks across sectors and regions, and were introduced in the IPCC Third Assessment Report. RFCs illustrate the implications of global warming for people, economies, and ecosystems. Impacts and/or risks for each RFC are based on assessment of the new literature that has appeared. As in the AR5, this literature was used to make expert judgments to assess the levels of global warming at which levels of impact and/or risk are undetectable, moderate, high or very high. The selection of impacts and risks to natural, managed and human systems in the lower panel is illustrative and is not intended to be fully comprehensive. **RFC1 Unique and threatened systems:** ecological and human systems that have restricted geographic ranges constrained by climate related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its indigenous people, mountain glaciers, and biodiversity hotspots. **RFC2 Extreme weather events**: risks/impacts to human health, livelihoods, assets, and ecosystems from extreme weather events such as heat waves, heavy rain, drought and associated wildfires, and coastal flooding. **RFC3 Distribution of impacts:** risks/impacts that disproportionately affect particular groups due to uneven distribution of physical climate change hazards, exposure or vulnerability. **RFC4 Global aggregate impacts:** global monetary damage, global scale degradation and loss of ecosystems and biodiversity. **RFC5 Large-scale singular events:** are relatively large, abrupt and sometimes irreversible changes in systems that are caused by global warming. Examples include disintegration of the Greenland and Antarctic ice sheets. {3.4, 3.5, 3.5.2.1, 3.5.2.2, 3.5.2.3, 3.5.2.4, 3.5.2.5, 5.4.1 5.5.3, 5.6.1, Box 3.4}

B6. Most adaptation needs will be lower for global warming of 1.5°C compared to 2°C (*high confidence*). There are a wide range of adaptation options that can reduce the risks of climate change (*high confidence*). There are limits to adaptation and adaptive capacity for some human and natural systems at global warming of 1.5°C, with associated losses (*medium confidence*). The number and availability of adaptation options vary by sector (*medium confidence*). {Table 3.5, 4.3, 4.5, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5}

B6.1. A wide range of adaptation options are available to reduce the risks to natural and managed ecosystems (e.g., ecosystem-based adaptation, ecosystem restoration and avoided degradation and deforestation, biodiversity management, sustainable aquaculture, and local knowledge and indigenous knowledge), the risks of sea level rise (e.g., coastal defence and hardening), and the risks to health, livelihoods, food, water, and economic growth, especially in rural landscapes (e.g., efficient irrigation, social safety nets, disaster risk management, risk spreading and sharing, community-based adaptation) and urban areas (e.g., green infrastructure, sustainable land use and planning, and sustainable water management) (*medium confidence*). {4.3.1, 4.3.2, 4.3.3, 4.3.5, 4.5.3, 4.5.4, 5.3.2, Box 4.2, Box 4.3, Box 4.6, Cross-Chapter Box 9 in Chapter 4}.

B6.2. Adaptation is expected to be more challenging for ecosystems, food and health systems at 2°C of global warming than for 1.5°C (*medium confidence*). Some vulnerable regions, including small islands and Least Developed Countries, are projected to experience high multiple interrelated climate risks even at global warming of 1.5°C (*high confidence*). {3.3.1, 3.4.5, Box 3.5, Table 3.5, Cross-Chapter Box 9 in Chapter 4, 5.6, Cross-Chapter Box 12 in Chapter 5, Box 5.3}

B6.3. Limits to adaptive capacity exist at 1.5°C of global warming, become more pronounced at higher levels of warming and vary by sector, with site-specific implications for vulnerable regions, ecosystems, and human health (*medium confidence*) {Cross-Chapter Box 12 in Chapter 5, Box 3.5, Table 3.5}

C. Emission Pathways and System Transitions Consistent with 1.5°C Global Warming

C1. In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). For limiting global warming to below 2°C[11] CO_2 emissions are projected to decline by about 20% by 2030 in most pathways (10–30% interquartile range) and reach net zero around 2075 (2065–2080 interquartile range). Non-CO_2 emissions in pathways that limit global warming to 1.5°C show deep reductions that are similar to those in pathways limiting warming to 2°C. (*high confidence*) (Figure SPM.3a) {2.1, 2.3, Table 2.4}

C1.1. CO_2 emissions reductions that limit global warming to 1.5°C with no or limited overshoot can involve different portfolios of mitigation measures, striking different balances between lowering energy and resource intensity, rate of decarbonization, and the reliance on carbon dioxide removal. Different portfolios face different implementation challenges, and potential synergies and trade-offs with sustainable development. (*high confidence*). (Figure SPM.3b) {2.3.2, 2.3.4, 2.4, 2.5.3}

[11] References to pathways limiting global warming to 2ºC are based on a 66% probability of staying below 2ºC.

C1.2. Modelled pathways that limit global warming to 1.5°C with no or limited overshoot involve deep reductions in emissions of methane and black carbon (35% or more of both by 2050 relative to 2010). These pathways also reduce most of the cooling aerosols, which partially offsets mitigation effects for two to three decades. Non-CO_2 emissions[12] can be reduced as a result of broad mitigation measures in the energy sector. In addition, targeted non-CO_2 mitigation measures can reduce nitrous oxide and methane from agriculture, methane from the waste sector, some sources of black carbon, and hydrofluorocarbons. High bioenergy demand can increase emissions of nitrous oxide in some 1.5°C pathways, highlighting the importance of appropriate management approaches. Improved air quality resulting from projected reductions in many non-CO_2 emissions provide direct and immediate population health benefits in all 1.5°C model pathways. (*high confidence*) (Figure SPM.3a) {2.2.1, 2.3.3, 2.4.4, 2.5.3, 4.3.6, 5.4.2}

C1.3. Limiting global warming requires limiting the total cumulative global anthropogenic emissions of CO_2 since the preindustrial period, i.e. staying within a total carbon budget (*high confidence*).[13] By the end of 2017, anthropogenic CO_2 emissions since the preindustrial period are estimated to have reduced the total carbon budget for 1.5°C by approximately 2200 ± 320 $GtCO_2$ (*medium confidence*). The associated remaining budget is being depleted by current emissions of 42 ± 3 $GtCO_2$ per year (*high confidence*). The choice of the measure of global temperature affects the estimated remaining carbon budget. Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 $GtCO_2$ for a 50% probability of limiting warming to 1.5°C, and 420 $GtCO_2$ for a 66% probability (*medium confidence*).[14] Alternatively, using GMST gives estimates of 770 and 570 $GtCO_2$, for 50% and 66% probabilities,[15] respectively (*medium confidence*). Uncertainties in the size of these estimated remaining carbon budgets are substantial and depend on several factors. Uncertainties in the climate response to CO_2 and non-CO_2 emissions contribute ±400 $GtCO_2$ and the level of historic warming contributes ±250 $GtCO_2$ (*medium confidence*). Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 $GtCO_2$ over the course of this century and more thereafter (*medium confidence*). In addition, the level of non-CO_2 mitigation in the future could alter the remaining carbon budget by 250 $GtCO_2$ in either direction (*medium confidence*). {1.2.4, 2.2.2, 2.6.1, Table 2.2, Chapter 2 Supplementary Material}

C1.4. Solar radiation modification (SRM) measures are not included in any of the available assessed pathways. Although some SRM measures may be theoretically effective in reducing an overshoot, they face large uncertainties and knowledge gaps as well as substantial risks,

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[12] Non-CO_2 emissions included in this report are all anthropogenic emissions other than CO_2 that result in radiative forcing. These include short-lived climate forcers, such as methane, some fluorinated gases, ozone precursors, aerosols or aerosol precursors, such as black carbon and sulphur dioxide, respectively, as well as long-lived greenhouse gases, such as nitrous oxide or some fluorinated gases. The radiative forcing associated with non-CO_2 emissions and changes in surface albedo is referred to as non-CO_2 radiative forcing. {x.y}

[13] There is a clear scientific basis for a total carbon budget consistent with limiting global warming to 1.5°C. However, neither this total carbon budget nor the fraction of this budget taken up by past emissions were assessed in this report.

[14] Irrespective of the measure of global temperature used, updated understanding and further advances in methods have led to an increase in the estimated remaining carbon budget of about 300 $GtCO_2$ compared to AR5. (*medium confidence*) {x.y}

[15] These estimates use observed GMST to 2006–2015 and estimate future temperature changes using near surface air temperatures.

institutional and social constraints to deployment related to governance, ethics, and impacts on sustainable development. They also do not mitigate ocean acidification. (*medium confidence*). {4.3.8, Cross-Chapter Box 10 in Chapter 4}

Global emissions pathway characteristics

General characteristics of the evolution of anthropogenic net emissions of CO_2, and total emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals. Reductions in net emissions can be achieved through different portfolios of mitigation measures illustrated in Figure SPM3B.

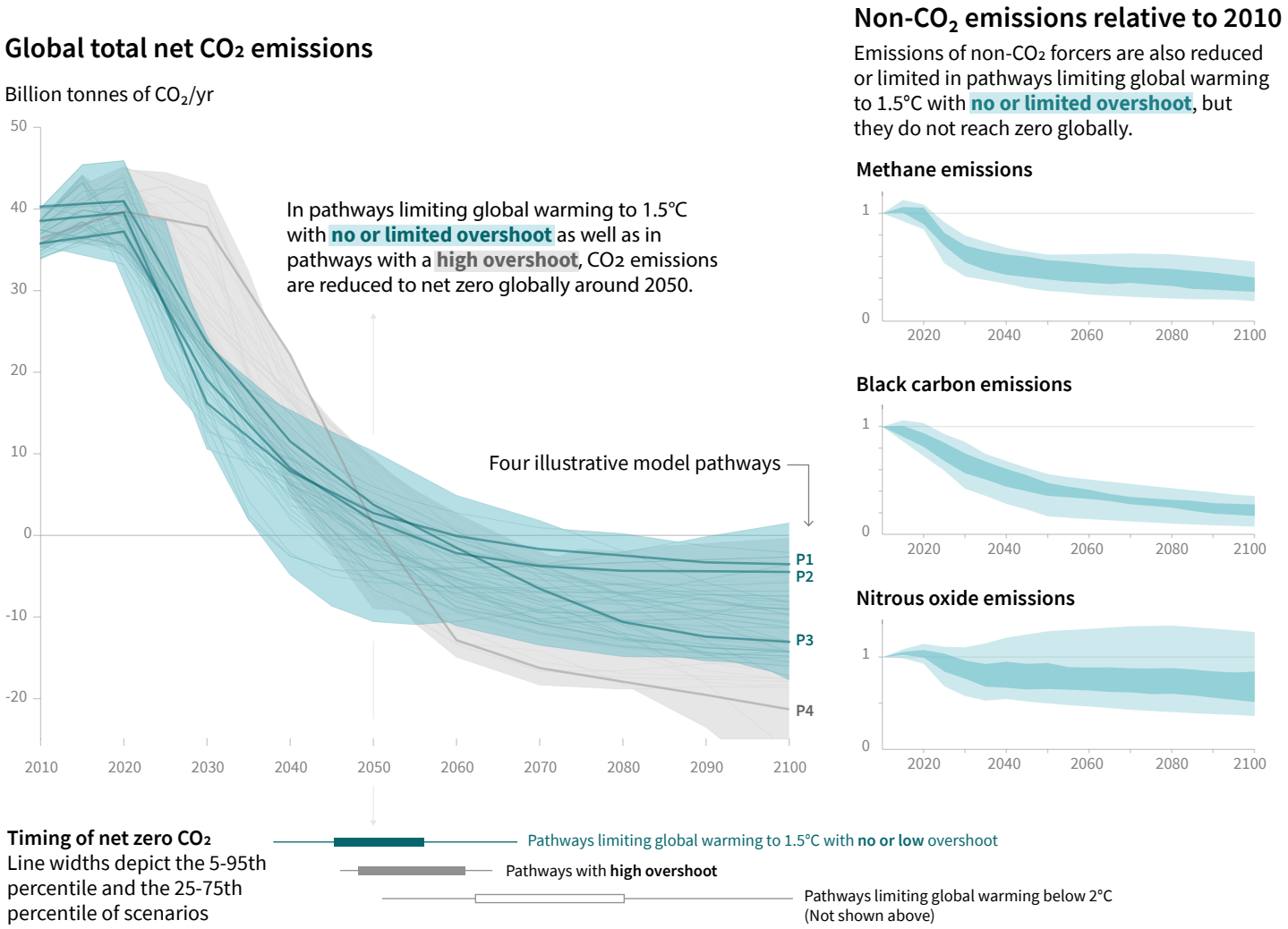
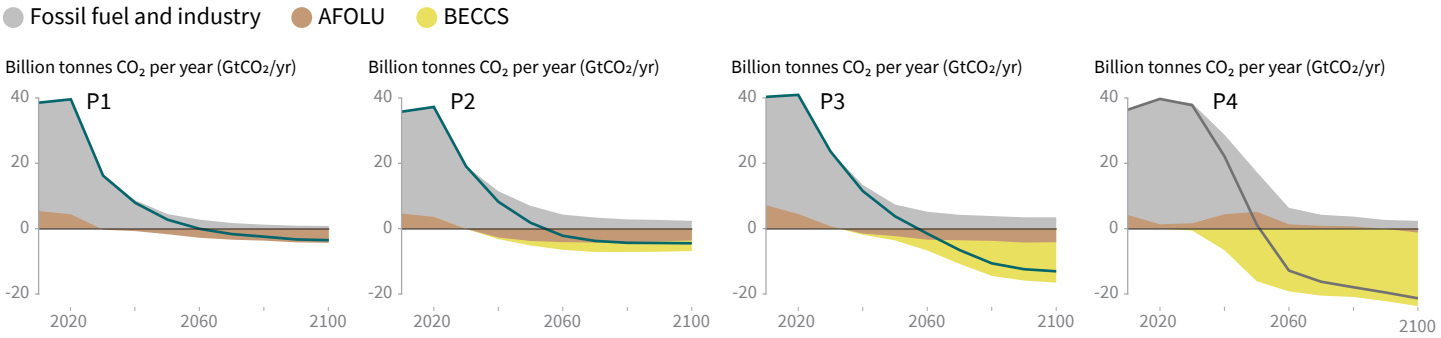


Figure SPM.3a: Global emissions pathway characteristics. The main panel shows global net anthropogenic CO_2 emissions in pathways limiting global warming to 1.5°C with no or limited (less than 0.1°C) overshoot and pathways with higher overshoot. The shaded area shows the full range for pathways analysed in this report. The panels on the right show non-CO_2 emissions ranges for three compounds with large historical forcing and a substantial portion of emissions coming from sources distinct from those central to CO_2 mitigation. Shaded areas in these panels show the 5–95% (light shading) and interquartile (dark shading) ranges of pathways limiting global warming to 1.5°C with no or limited overshoot. Box and whiskers at the bottom of the figure show the timing of pathways reaching global net zero CO_2 emission levels, and a comparison with pathways limiting global warming to 2°C with at least 66% probability. Four illustrative model pathways are highlighted in the main panel and are labelled P1, P2, P3 and P4, corresponding to the LED, S1, S2, and S5 pathways assessed in Chapter 2. Descriptions and characteristics of these pathways are available in Figure SPM3b. {2.1, 2.2, 2.3, Figure 2.5, Figure 2.10, Figure 2.11}

Characteristics of four illustrative model pathways

Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limit global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for the emissions and several other pathway characteristics.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and he althy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or low overshoot	No or low overshoot	No or low overshoot	High overshoot	No or low overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-59,-40)
└ in 2050 (% rel to 2010)	-93	-95	-91	-97	(-104,-91)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-55,-38)
└ in 2050 (% rel to 2010)	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12, 7)
└ in 2050 (% rel to 2010)	-32	2	21	44	(-11, 22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47, 65)
└ in 2050 (%)	77	81	63	70	(69, 87)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
└ in 2050 (% rel to 2010)	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
└ in 2050 (% rel to 2010)	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
└ in 2050 (% rel to 2010)	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
└ in 2050 (% rel to 2010)	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
└ in 2050 (% rel to 2010)	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(243,438)
└ in 2050 (% rel to 2010)	832	1327	878	1137	(575,1300)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550, 1017)
└ of which BECCS ($GtCO_2$)	0	151	414	1191	(364, 662)
Land area of bioenergy crops in 2050 (million hectare)	22	93	283	724	(151, 320)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-46,-23)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,4)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on SAR GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change*

Figure SPM.3b: Characteristics of four illustrative model pathways in relation to global warming of 1.5°C introduced in Figure SPM3a. These pathways were selected to show a range of potential mitigation approaches and vary widely in their projected energy and land use, as well as their assumptions about future socioeconomic developments, including economic and population growth, equity and sustainability. A breakdown of the global net anthropogenic CO_2 emissions into the contributions in terms of CO_2 emissions from fossil fuel and industry, agriculture, forestry and other land use (AFOLU), and bioenergy with carbon capture and storage (BECCS) is shown. AFOLU estimates reported here are not necessarily comparable with countries' estimates. Further characteristics for each of these pathways are listed below each pathway. These pathways illustrate relative global differences in mitigation strategies, but do not represent central estimates, national strategies, and do not indicate requirements. For comparison, the right-most column shows the interquartile ranges across pathways with no or limited overshoot of 1.5°C. Pathways P1, P2, P3 and P4, correspond to the LED, S1, S2, and S5 pathways assessed in Chapter 2. (Figure SPM.3a) {2.2.1, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.4.1, 2.4.2, 2.4.4, 2.5.3, Figure 2.5, Figure 2.6, Figure 2.9, Figure 2.10, Figure 2.11, Figure 2.14, Figure 2.15, Figure 2.16, Figure 2.17, Figure 2.24, Figure 2.25, Table 2.4, Table 2.6, Table 2.7, Table 2.9, Table 4.1}

C2. Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (*high confidence*). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (*medium confidence*). {2.3, 2.4, 2.5, 4.2, 4.3, 4.4, 4.5}

C2.1. Pathways that limit global warming to 1.5°C with no or limited overshoot show system changes that are more rapid and pronounced over the next two decades than in 2°C pathways (*high confidence*). The rates of system changes associated with limiting global warming to 1.5°C with no or limited overshoot have occurred in the past within specific sectors, technologies and spatial contexts, but there is no documented historic precedent for their scale (*medium confidence*). {2.3.3, 2.3.4, 2.4, 2.5, 4.2.1, 4.2.2, Cross-Chapter Box 11 in Chapter 4}

C2.2. In energy systems, modelled global pathways (considered in the literature) limiting global warming to 1.5°C with no or limited overshoot (for more details see Figure SPM.3b), generally meet energy service demand with lower energy use, including through enhanced energy efficiency, and show faster electrification of energy end use compared to 2°C (*high confidence*). In 1.5°C pathways with no or limited overshoot, low-emission energy sources are projected to have a higher share, compared with 2°C pathways, particularly before 2050 (*high confidence*). In 1.5°C pathways with no or limited overshoot, renewables are projected to supply 70–85% (interquartile range) of electricity in 2050 (*high confidence*). In electricity generation, shares of nuclear and fossil fuels with carbon dioxide capture and storage (CCS) are modelled to increase in most 1.5°C pathways with no or limited overshoot. In modelled 1.5°C pathways with limited or no overshoot, the use of CCS would allow the electricity generation share of gas to be approximately 8% (3–11% interquartile range) of global electricity in 2050, while the use of coal shows a steep reduction in all pathways and would be reduced to close to 0% (0–2%) of electricity (*high confidence*). While acknowledging the challenges, and differences between the options and national circumstances, political, economic, social and technical feasibility of solar energy, wind energy and electricity storage technologies have substantially improved over the past few years (*high confidence*). These improvements signal a potential system transition in electricity generation (Figure SPM.3b) {2.4.1, 2.4.2, Figure 2.1, Table 2.6, Table 2.7, Cross-Chapter Box 6 in Chapter 3, 4.2.1, 4.3.1, 4.3.3, 4.5.2}

C2.3. CO_2 emissions from industry in pathways limiting global warming to 1.5°C with no or limited overshoot are projected to be about 75–90% (interquartile range) lower in 2050 relative to 2010, as compared to 50–80% for global warming of 2°C (*medium confidence*). Such reductions can be achieved through combinations of new and existing technologies and practices, including electrification, hydrogen, sustainable bio-based feedstocks, product substitution, and carbon capture, utilization and storage (CCUS). These options are technically proven at various scales but their large-scale deployment may be limited by economic, financial, human capacity and institutional constraints in specific contexts, and specific characteristics of large-scale industrial installations. In industry, emissions reductions by energy and process efficiency by themselves are insufficient for limiting warming to 1.5°C with no or limited overshoot (*high confidence*). {2.4.3, 4.2.1, Table 4.1, Table 4.3, 4.3.3, 4.3.4, 4.5.2}

C2.4. The urban and infrastructure system transition consistent with limiting global warming to 1.5°C with no or limited overshoot would imply, for example, changes in land and urban planning practices, as well as deeper emissions reductions in transport and buildings compared to pathways that limit global warming below 2°C (see 2.4.3; 4.3.3; 4.2.1) (*medium confidence*). Technical

measures and practices enabling deep emissions reductions include various energy efficiency options. In pathways limiting global warming to 1.5°C with no or limited overshoot, the electricity share of energy demand in buildings would be about 55–75% in 2050 compared to 50–70% in 2050 for 2°C global warming (*medium confidence*). In the transport sector, the share of low-emission final energy would rise from less than 5% in 2020 to about 35–65% in 2050 compared to 25–45% for 2°C global warming (*medium confidence*). Economic, institutional and socio-cultural barriers may inhibit these urban and infrastructure system transitions, depending on national, regional and local circumstances, capabilities and the availability of capital (*high confidence*). {2.3.4, 2.4.3, 4.2.1, Table 4.1, 4.3.3, 4.5.2}.

C2.5. Transitions in global and regional land use are found in all pathways limiting global warming to 1.5°C with no or limited overshoot, but their scale depends on the pursued mitigation portfolio. Model pathways that limit global warming to 1.5°C with no or limited overshoot project the conversion of 0.5–8 million km^2 of pasture and 0–5 million km^2 of non-pasture agricultural land for food and feed crops into 1–7 million km^2 for energy crops and a 1 million km^2 reduction to 10 million km^2 increase in forests by 2050 relative to 2010 (*medium confidence*).[16] Land use transitions of similar magnitude can be observed in modelled 2°C pathways (*medium confidence*). Such large transitions pose profound challenges for sustainable management of the various demands on land for human settlements, food, livestock feed, fibre, bioenergy, carbon storage, biodiversity and other ecosystem services (*high confidence*). Mitigation options limiting the demand for land include sustainable intensification of land use practices, ecosystem restoration and changes towards less resource-intensive diets (*high confidence*). The implementation of land-based mitigation options would require overcoming socio-economic, institutional, technological, financing and environmental barriers that differ across regions (*high confidence*). {2.4.4, Figure 2.24, 4.3.2, 4.5.2, Cross-Chapter Box 7 in Chapter 3}

C2.6 Total annual average energy-related mitigation investment for the period 2015 to 2050 in pathways limiting warming to 1.5°C is estimated to be around 900 billion USD2015 (range of 180 billion to 1800 billion USD2015 across six models[17]). This corresponds to total annual average energy supply investments of 1600 to 3800 billion USD2015 and total annual average energy demand investments of 700 to 1000 billion USD2015 for the period 2015 to 2050, and an increase in total energy-related investments of about 12% (range of 3% to 23%) in 1.5°C pathways relative to 2°C pathways. Average annual investment in low-carbon energy technologies and energy efficiency are upscaled by roughly a factor of five (range of factor of 4 to 5) by 2050 compared to 2015 (*medium confidence*). {2.5.2, Box 4.8, Figure 2.27}

C2.7. Modelled pathways limiting global warming to 1.5°C with no or limited overshoot project a wide range of global average discounted marginal abatement costs over the 21st century. They are roughly 3-4 times higher than in pathways limiting global warming to below 2°C (*high confidence*). The economic literature distinguishes marginal abatement costs from total mitigation costs in the economy. The literature on total mitigation costs of 1.5°C mitigation pathways is limited and was not assessed in this report. Knowledge gaps remain in the integrated assessment of the economy wide costs and benefits of mitigation in line with pathways limiting warming to 1.5°C. {2.5.2; 2.6; Figure 2.26}

[16] The projected land use changes presented are not deployed to their upper limits simultaneously in a single pathway.

[17] Including two pathways limiting warming to 1.5°C with no or limited overshoot and four pathways with high overshoot.

C3. All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak (*high confidence*). CDR deployment of several hundreds of $GtCO_2$ is subject to multiple feasibility and sustainability constraints (*high confidence*). Significant near-term emissions reductions and measures to lower energy and land demand can limit CDR deployment to a few hundred $GtCO_2$ without reliance on bioenergy with carbon capture and storage (BECCS) (*high confidence*). {2.3, 2.4, 3.6.2, 4.3, 5.4}

C3.1. Existing and potential CDR measures include afforestation and reforestation, land restoration and soil carbon sequestration, BECCS, direct air carbon capture and storage (DACCS), enhanced weathering and ocean alkalinization. These differ widely in terms of maturity, potentials, costs, risks, co-benefits and trade-offs (*high confidence*). To date, only a few published pathways include CDR measures other than afforestation and BECCS. {2.3.4, 3.6.2, 4.3.2, 4.3.7}

C3.2. In pathways limiting global warming to 1.5°C with limited or no overshoot, BECCS deployment is projected to range from 0–1, 0–8, and 0–16 $GtCO_2\ yr^{-1}$ in 2030, 2050, and 2100, respectively, while agriculture, forestry and land-use (AFOLU) related CDR measures are projected to remove 0–5, 1–11, and 1–5 $GtCO_2\ yr^{-1}$ in these years (*medium confidence*). The upper end of these deployment ranges by mid-century exceeds the BECCS potential of up to 5 $GtCO_2\ yr^{-1}$ and afforestation potential of up to 3.6 $GtCO_2\ yr^{-1}$ assessed based on recent literature (*medium confidence*). Some pathways avoid BECCS deployment completely through demand-side measures and greater reliance on AFOLU-related CDR measures (*medium confidence*). The use of bioenergy can be as high or even higher when BECCS is excluded compared to when it is included due to its potential for replacing fossil fuels across sectors (*high confidence*). (Figure SPM.3b) {2.3.3, 2.3.4, 2.4.2, 3.6.2, 4.3.1, 4.2.3, 4.3.2, 4.3.7, 4.4.3, Table 2.4}

C3.3. Pathways that overshoot 1.5°C of global warming rely on CDR exceeding residual CO_2 emissions later in the century to return to below 1.5°C by 2100, with larger overshoots requiring greater amounts of CDR (Figure SPM.3b). (*high confidence*). Limitations on the speed, scale, and societal acceptability of CDR deployment hence determine the ability to return global warming to below 1.5°C following an overshoot. Carbon cycle and climate system understanding is still limited about the effectiveness of net negative emissions to reduce temperatures after they peak (*high confidence*). {2.2, 2.3.4, 2.3.5, 2.6, 4.3.7, 4.5.2, Table 4.11}

C3.4. Most current and potential CDR measures could have significant impacts on land, energy, water, or nutrients if deployed at large scale (*high confidence*). Afforestation and bioenergy may compete with other land uses and may have significant impacts on agricultural and food systems, biodiversity and other ecosystem functions and services (*high confidence*). Effective governance is needed to limit such trade-offs and ensure permanence of carbon removal in terrestrial, geological and ocean reservoirs (*high confidence*). Feasibility and sustainability of CDR use could be enhanced by a portfolio of options deployed at substantial, but lesser scales, rather than a single option at very large scale (*high confidence*). (Figure SPM.3b). {2.3.4, 2.4.4, 2.5.3, 2.6, 3.6.2, 4.3.2, 4.3.7, 4.5.2, 5.4.1, 5.4.2; Cross-Chapter Boxes 7 and 8 in Chapter 3, Table 4.11, Table 5.3, Figure 5.3}

C3.5. Some AFOLU-related CDR measures such as restoration of natural ecosystems and soil carbon sequestration could provide co-benefits such as improved biodiversity, soil quality, and local

food security. If deployed at large scale, they would require governance systems enabling sustainable land management to conserve and protect land carbon stocks and other ecosystem functions and services (*medium confidence*). (Figure SPM.4) {2.3.3, 2.3.4, 2.4.2, 2.4.4, 3.6.2, 5.4.1, Cross-Chapter Boxes 3 in Chapter 1 and 7 in Chapter 3, 4.3.2, 4.3.7, 4.4.1, 4.5.2, Table 2.4}

D. Strengthening the Global Response in the Context of Sustainable Development and Efforts to Eradicate Poverty

D1. Estimates of the global emissions outcome of current nationally stated mitigation ambitions as submitted under the Paris Agreement would lead to global greenhouse gas emissions[18] in 2030 of 52–58 $GtCO_2eq\ yr^{-1}$ (*medium confidence)*. Pathways reflecting these ambitions would not limit global warming to 1.5°C, even if supplemented by very challenging increases in the scale and ambition of emissions reductions after 2030 (*high confidence*). Avoiding overshoot and reliance on future large-scale deployment of carbon dioxide removal (CDR) can only be achieved if global CO_2 emissions start to decline well before 2030 (*high confidence*). {1.2, 2.3, 3.3, 3.4, 4.2, 4.4, Cross-Chapter Box 11 in Chapter 4}

D1.1. Pathways that limit global warming to 1.5°C with no or limited overshoot show clear emission reductions by 2030 (*high confidence*). All but one show a decline in global greenhouse gas emissions to below 35 $GtCO_2eq\ yr^{-1}$ in 2030, and half of available pathways fall within the 25–30 $GtCO_2eq\ yr^{-1}$ range (interquartile range), a 40–50% reduction from 2010 levels (*high confidence*). Pathways reflecting current nationally stated mitigation ambition until 2030 are broadly consistent with cost-effective pathways that result in a global warming of about 3°C by 2100, with warming continuing afterwards (*medium confidence*). {2.3.3, 2.3.5, Cross-Chapter Box 11 in Chapter 4, 5.5.3.2}

D1.2. Overshoot trajectories result in higher impacts and associated challenges compared to pathways that limit global warming to 1.5°C with no or limited overshoot (*high confidence*). Reversing warming after an overshoot of 0.2°C or larger during this century would require upscaling and deployment of CDR at rates and volumes that might not be achievable given considerable implementation challenges (*medium confidence*). {1.3.3, 2.3.4, 2.3.5, 2.5.1, 3.3, 4.3.7, Cross-Chapter Box 8 in Chapter 3, Cross-Chapter Box 11 in Chapter 4}

D1.3. The lower the emissions in 2030, the lower the challenge in limiting global warming to 1.5°C after 2030 with no or limited overshoot (*high confidence*). The challenges from delayed actions to reduce greenhouse gas emissions include the risk of cost escalation, lock-in in carbon-emitting infrastructure, stranded assets, and reduced flexibility in future response options in the medium to long-term (*high confidence*). These may increase uneven distributional impacts between countries at different stages of development (*medium confidence*). {2.3.5, 4.4.5, 5.4.2}

D2. The avoided climate change impacts on sustainable development, eradication of poverty and reducing inequalities would be greater if global warming were limited to 1.5°C rather than 2°C, if mitigation and adaptation synergies are maximized while trade-offs are minimized (*high confidence*). {1.1, 1.4, 2.5, 3.3, 3.4, 5.2, Table 5.1}

[18] GHG emissions have been aggregated with 100-year GWP values as introduced in the IPCC Second Assessment Report

D2.1. Climate change impacts and responses are closely linked to sustainable development which balances social well-being, economic prosperity and environmental protection. The United Nations Sustainable Development Goals (SDGs), adopted in 2015, provide an established framework for assessing the links between global warming of 1.5°C or 2°C and development goals that include poverty eradication, reducing inequalities, and climate action (*high confidence*) {Cross-Chapter Box 4 in Chapter 1, 1.4, 5.1}

D2.2. The consideration of ethics and equity can help address the uneven distribution of adverse impacts associated with 1.5°C and higher levels of global warming, as well as those from mitigation and adaptation, particularly for poor and disadvantaged populations, in all societies (*high confidence*). {1.1.1, 1.1.2, 1.4.3, 2.5.3, 3.4.10, 5.1, 5.2, 5.3. 5.4, Cross-Chapter Box 4 in Chapter 1, Cross-Chapter Boxes 6 and 8 in Chapter 3, and Cross-Chapter Box 12 in Chapter 5}

D2.3. Mitigation and adaptation consistent with limiting global warming to 1.5°C are underpinned by enabling conditions, assessed in SR1.5 across the geophysical, environmental-ecological, technological, economic, socio-cultural and institutional dimensions of feasibility. Strengthened multi-level governance, institutional capacity, policy instruments, technological innovation and transfer and mobilization of finance, and changes in human behaviour and lifestyles are enabling conditions that enhance the feasibility of mitigation and adaptation options for 1.5°C consistent systems transitions. *(high confidence*) {1.4, Cross-Chapter Box 3 in Chapter 1, 4.4, 4.5, 5.6}

D3. Adaptation options specific to national contexts, if carefully selected together with enabling conditions, will have benefits for sustainable development and poverty reduction with global warming of 1.5°C, although trade-offs are possible (*high confidence*). {1.4, 4.3, 4.5}

D3.1. Adaptation options that reduce the vulnerability of human and natural systems have many synergies with sustainable development, if well managed, such as ensuring food and water security, reducing disaster risks, improving health conditions, maintaining ecosystem services and reducing poverty and inequality (*high confidence*). Increasing investment in physical and social infrastructure is a key enabling condition to enhance the resilience and the adaptive capacities of societies. These benefits can occur in most regions with adaptation to 1.5°C of global warming (*high confidence*). {1.4.3, 4.2.2, 4.3.1, 4.3.2, 4.3.3, 4.3.5, 4.4.1, 4.4.3, 4.5.3, 5.3.1, 5.3.2}

D3.2. Adaptation to 1.5°C global warming can also result in trade–offs or maladaptations with adverse impacts for sustainable development. For example, if poorly designed or implemented, adaptation projects in a range of sectors can increase greenhouse gas emissions and water use, increase gender and social inequality, undermine health conditions, and encroach on natural ecosystems (*high confidence*). These trade-offs can be reduced by adaptations that include attention to poverty and sustainable development (*high confidence*). {4.3.2, 4.3.3, 4.5.4, 5.3.2; Cross-Chapter Boxes 6 and 7 in Chapter 3}

D3.3. A mix of adaptation and mitigation options to limit global warming to 1.5°C, implemented in a participatory and integrated manner, can enable rapid, systemic transitions in urban and rural areas (*high confidence*). These are most effective when aligned with economic and sustainable development, and when local and regional governments and decision makers are supported by national governments (*medium confidence*) {4.3.2, 4.3.3, 4.4.1, 4.4.2}

D3.4. Adaptation options that also mitigate emissions can provide synergies and cost savings in most sectors and system transitions, such as when land management reduces emissions and disaster

risk, or when low carbon buildings are also designed for efficient cooling. Trade-offs between mitigation and adaptation, when limiting global warming to 1.5°C, such as when bioenergy crops, reforestation or afforestation encroach on land needed for agricultural adaptation, can undermine food security, livelihoods, ecosystem functions and services and other aspects of sustainable development. (*high confidence*) {3.4.3, 4.3.2, 4.3.4, 4.4.1, 4.5.2, 4.5.3, 4.5.4}

D4. Mitigation options consistent with 1.5°C pathways are associated with multiple synergies and trade-offs across the Sustainable Development Goals (SDGs). While the total number of possible synergies exceeds the number of trade-offs, their net effect will depend on the pace and magnitude of changes, the composition of the mitigation portfolio and the management of the transition. *(high confidence*) (Figure SPM.4) {2.5, 4.5, 5.4}

D4.1. 1.5°C pathways have robust synergies particularly for the SDGs 3 (health), 7 (clean energy), 11 (cities and communities), 12 (responsible consumption and production), and 14 (oceans) (*very high confidence*). Some 1.5°C pathways show potential trade-offs with mitigation for SDGs 1 (poverty), 2 (hunger), 6 (water), and 7 (energy access), if not carefully managed (*high confidence*) (Figure SPM.4). {5.4.2; Figure 5.4, Cross-Chapter Boxes 7 and 8 in Chapter 3}

D4.2. 1.5°C pathways that include low energy demand (e.g., see P1 in Figure SPM.3a and SPM.3b), low material consumption, and low GHG-intensive food consumption have the most pronounced synergies and the lowest number of trade-offs with respect to sustainable development and the SDGs (*high confidence*). Such pathways would reduce dependence on CDR. In modelled pathways sustainable development, eradicating poverty and reducing inequality can support limiting warming to 1.5◦C. (*high confidence*) (Figure SPM.3b, Figure SPM.4) {2.4.3, 2.5.1, 2.5.3, Figure 2.4, Figure 2.28, 5.4.1, 5.4.2, Figure 5.4}

D4.3. 1.5°C and 2°C modelled pathways often rely on the deployment of large-scale land-related measures like afforestation and bioenergy supply, which, if poorly managed, can compete with food production and hence raise food security concerns (*high confidence*). The impacts of carbon dioxide removal (CDR) options on SDGs depend on the type of options and the scale of deployment (*high confidence*). If poorly implemented, CDR options such as BECCS and AFOLU options would lead to trade-offs. Context-relevant design and implementation requires considering people's needs, biodiversity, and other sustainable development dimensions (*very high confidence*). {Figure SPM.4, 5.4.1.3, Cross-Chapter Box 7 in Chapter 3}

D4.4. Mitigation consistent with 1.5°C pathways creates risks for sustainable development in regions with high dependency on fossil fuels for revenue and employment generation (*high confidence*). Policies that promote diversification of the economy and the energy sector can address the associated challenges (*high confidence*). {5.4.1.2, Box 5.2}

D4.5. Redistributive policies across sectors and populations that shield the poor and vulnerable can resolve trade-offs for a range of SDGs, particularly hunger, poverty and energy access. Investment needs for such complementary policies are only a small fraction of the overall mitigation investments in 1.5°C pathways. (*high confidence*) {2.4.3, 5.4.2, Figure 5.5}

Indicative linkages between mitigation options and sustainable development using SDGs (The linkages do not show costs and benefits)

Mitigation options deployed in each sector can be associated with potential positive effects (synergies) or negative effects (trade-offs) with the Sustainable Development Goals (SDGs). The degree to which this potential is realized will depend on the selected portfolio of mitigation options, mitigation policy design, and local circumstances and context. Particularly in the energy-demand sector, the potential for synergies is larger than for trade-offs. The bars group individually assessed options by level of confidence and take into account the relative strength of the assessed mitigation-SDG connections.

Length shows strength of connection

The overall **size of the coloured bars** depict **the relative** for synergies and trade-offs between the sectoral mitigation options and the SDGs.

Shades show level of confidence

The shades depict **the level of confidence** of the assessed potential for **Trade-offs** / **Synergies**.

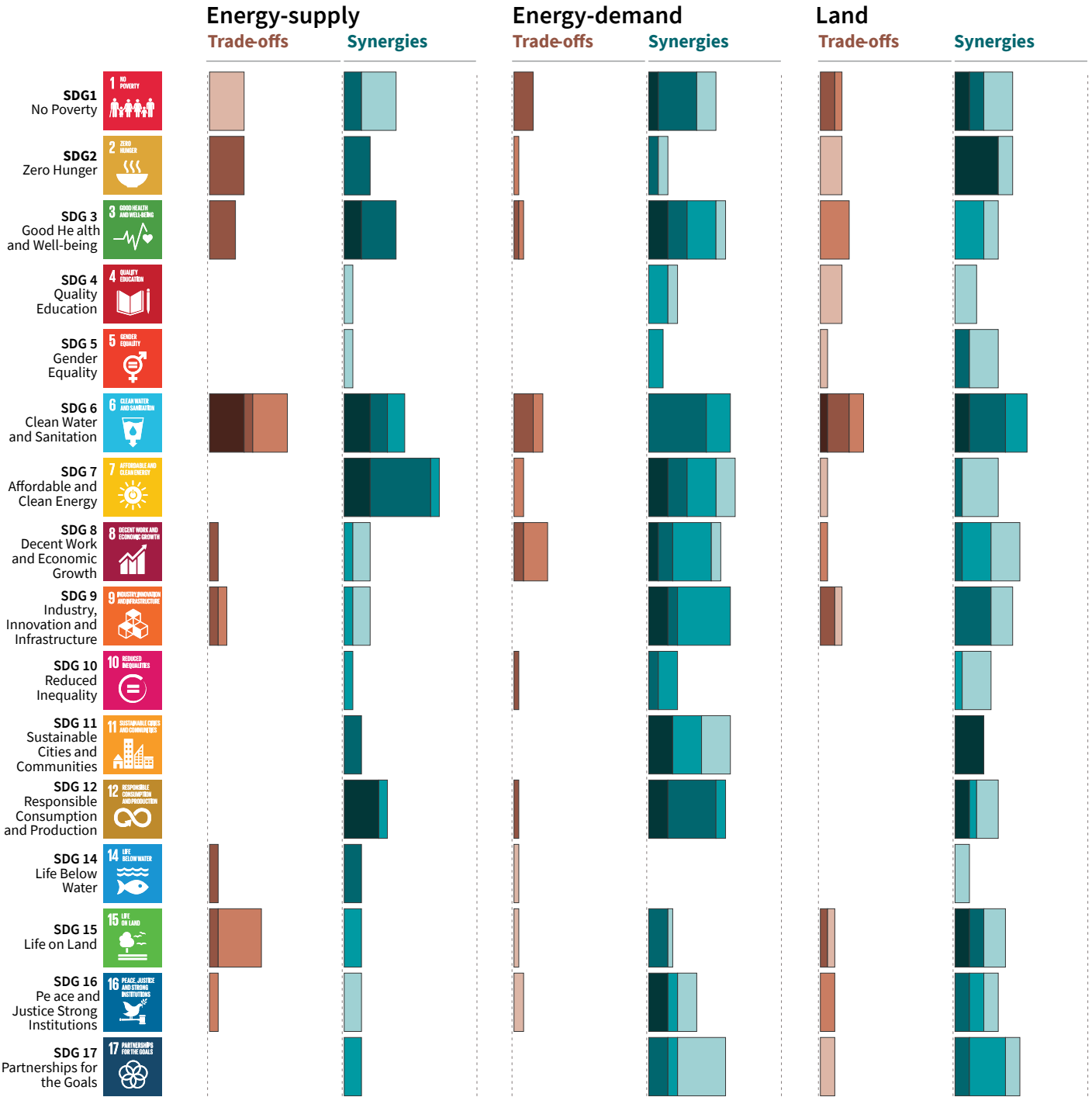


Figure SPM.4: Potential synergies and trade-offs between the sectoral portfolio of climate change mitigation options and the Sustainable Development Goals (SDGs). The SDGs serve as an analytical framework for the assessment of the different sustainable development dimensions, which extend beyond the time frame of the 2030 SDG targets. The assessment is based on literature on mitigation options that are considered relevant for 1.5ºC. The assessed strength of the SDG interactions is based on the qualitative and quantitative assessment of individual mitigation options listed in Table 5.2. For each mitigation option, the strength of the SDG-connection as well as the associated confidence of the underlying literature (shades of green and red) was assessed. The strength of positive connections (synergies) and negative connections (trade-offs) across all individual options within a sector (see Table 5.2) are aggregated into sectoral potentials for the whole mitigation portfolio. The (white) areas outside the bars, which indicate no interactions, have *low confidence* due to the uncertainty and limited number of studies exploring indirect effects. The strength of the connection considers only the effect of mitigation and does not include benefits of avoided impacts. SDG 13 (climate action) is not listed because mitigation is being considered in terms of interactions with SDGs and not vice versa. The bars denote the strength of the connection, and do not consider the strength of the impact on the SDGs. The energy demand sector comprises behavioural responses, fuel switching and efficiency options in the transport, industry and building sector as well as carbon capture options in the industry sector. Options assessed in the energy supply sector comprise biomass and non-biomass renewables, nuclear, CCS with bio-energy, and CCS with fossil fuels. Options in the land sector comprise agricultural and forest options, sustainable diets & reduced food waste, soil sequestration, livestock & manure management, reduced deforestation, afforestation & reforestation, responsible sourcing. In addition to this figure, options in the ocean sector are discussed in the underlying report. {5.4, Table 5.2, Figure 5.2}

Statement for knowledge gap:
Information about the net impacts of mitigation on sustainable development in 1.5°C pathways is available only for a limited number of SDGs and mitigation options. Only a limited number of studies have assessed the benefits of avoided climate change impacts of 1.5°C pathways for the SDGs, and the co-effects of adaptation for mitigation and the SDGs. The assessment of the indicative mitigation potentials in Figure SPM.4 is a step further from AR5 towards a more comprehensive and integrated assessment in the future.

D5. Limiting the risks from global warming of 1.5°C in the context of sustainable development and poverty eradication implies system transitions that can be enabled by an increase of adaptation and mitigation investments, policy instruments, the acceleration of technological innovation and behaviour changes (*high confidence*). {2.3, 2.4, 2.5, 3.2, 4.2, 4.4, 4.5, 5.2, 5.5, 5.6}

D5.1. Directing finance towards investment in infrastructure for mitigation and adaptation could provide additional resources. This could involve the mobilization of private funds by institutional investors, asset managers and development or investment banks, as well as the provision of public funds. Government policies that lower the risk of low-emission and adaptation investments can facilitate the mobilization of private funds and enhance the effectiveness of other public policies. Studies indicate a number of challenges including access to finance and mobilisation of funds (*high confidence*) {2.5.2, 4.4.5}

D5.2. Adaptation finance consistent with global warming of 1.5°C is difficult to quantify and compare with 2°C. Knowledge gaps include insufficient data to calculate specific climate resilience-enhancing investments, from the provision of currently underinvested basic infrastructure. Estimates of the costs of adaptation might be lower at global warming of 1.5°C than for 2°C. Adaptation needs have typically been supported by public sector sources such as national and subnational government budgets, and in developing countries together with support from development assistance, multilateral development banks, and UNFCCC channels (*medium confidence*). More recently there is a growing understanding of the scale and increase in NGO and private funding in some regions (*medium confidence*). Barriers include the scale of adaptation financing, limited capacity and access to adaptation finance (*medium confidence*).{4.4.5, 4.6}

D5.3. Global model pathways limiting global warming to 1.5°C are projected to involve the annual average investment needs in the energy system of around 2.4 trillion USD2010 between 2016 and 2035 representing about 2.5% of the world GDP (*medium confidence*). {2.5.2, 4.4.5, Box 4.8}

D5.4. Policy tools can help mobilise incremental resources, including through shifting global investments and savings and through market and non-market based instruments as well as accompanying measures to secure the equity of the transition, acknowledging the challenges related with implementation including those of energy costs, depreciation of assets and impacts on international competition, and utilizing the opportunities to maximize co-benefits (*high confidence*) {1.3.3, 2.3.4, 2.3.5, 2.5.1, 2.5.2, Cross-Chapter Box 8 in Chapter 3 and 11 in Chapter 4, 4.4.5, 5.5.2}

D5.5. The systems transitions consistent with adapting to and limiting global warming to 1.5°C include the widespread adoption of new and possibly disruptive technologies and practices and enhanced climate-driven innovation. These imply enhanced technological innovation capabilities, including in industry and finance. Both national innovation policies and international cooperation can contribute to the development, commercialization and widespread adoption of mitigation and adaptation technologies. Innovation policies may be more effective when they combine public support for research and development with policy mixes that provide incentives for technology diffusion. (*high confidence*) {4.4.4, 4.4.5}.

D5.6. Education, information, and community approaches, including those that are informed by Indigenous knowledge and local knowledge, can accelerate the wide scale behaviour changes consistent with adapting to and limiting global warming to 1.5°C. These approaches are more

effective when combined with other policies and tailored to the motivations, capabilities, and resources of specific actors and contexts (*high confidence*). Public acceptability can enable or inhibit the implementation of policies and measures to limit global warming to 1.5°C and to adapt to the consequences. Public acceptability depends on the individual's evaluation of expected policy consequences, the perceived fairness of the distribution of these consequences, and perceived fairness of decision procedures (*high confidence*). {1.1, 1.5, 4.3.5, 4.4.1, 4.4.3, Box 4.3, 5.5.3, 5.6.5}

D6. Sustainable development supports, and often enables, the fundamental societal and systems transitions and transformations that help limit global warming to 1.5°C. Such changes facilitate the pursuit of climate-resilient development pathways that achieve ambitious mitigation and adaptation in conjunction with poverty eradication and efforts to reduce inequalities *(high confidence)*. {Box 1.1, 1.4.3, Figure 5.1, 5.5.3, Box 5.3}

D6.1. Social justice and equity are core aspects of climate-resilient development pathways that aim to limit global warming to 1.5°C as they address challenges and inevitable trade-offs, widen opportunities, and ensure that options, visions, and values are deliberated, between and within countries and communities, without making the poor and disadvantaged worse off (*high confidence*). {5.5.2, 5.5.3, Box 5.3, Figure 5.1, Figure 5.6, Cross-Chapter Boxes 12 and 13 in Chapter 5}

D6.2. The potential for climate-resilient development pathways differs between and within regions and nations, due to different development contexts and systemic vulnerabilities (*very high confidence*). Efforts along such pathways to date have been limited (*medium confidence*) and enhanced efforts would involve strengthened and timely action from all countries and non-state actors (*high confidence*). {5.5.1, 5.5.3, Figure 5.1}

D6.3. Pathways that are consistent with sustainable development show fewer mitigation and adaptation challenges and are associated with lower mitigation costs. The large majority of modelling studies could not construct pathways characterized by lack of international cooperation, inequality and poverty that were able to limit global warming to 1.5°C. (*high confidence*) {2.3.1, 2.5.3, 5.5.2}

D7. Strengthening the capacities for climate action of national and sub-national authorities, civil society, the private sector, indigenous peoples and local communities can support the implementation of ambitious actions implied by limiting global warming to 1.5°C (*high confidence*). International cooperation can provide an enabling environment for this to be achieved in all countries and for all people, in the context of sustainable development. International cooperation is a critical enabler for developing countries and vulnerable regions (*high confidence*). {1.4, 2.3, 2.5, 4.2, 4.4, 4.5, 5.3, 5.4, 5.5, 5.6, 5, Box 4.1, Box 4.2, Box 4.7, Box 5.3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 13 in Chapter 5}

D7.1. Partnerships involving non-state public and private actors, institutional investors, the banking system, civil society and scientific institutions would facilitate actions and responses consistent with limiting global warming to 1.5°C (*very high confidence*). {1.4, 4.4.1, 4.2.2, 4.4.3, 4.4.5, 4.5.3, 5.4.1, 5.6.2, Box 5.3}.

D7.2. Cooperation on strengthened accountable multilevel governance that includes non-state actors such as industry, civil society and scientific institutions, coordinated sectoral and cross-sectoral

policies at various governance levels, gender-sensitive policies, finance including innovative financing and cooperation on technology development and transfer can ensure participation, transparency, capacity building, and learning among different players (*high confidence*). {2.5.2, 4.2.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.5.3, Cross-Chapter Box 9 in Chapter 4, 5.3.1, 4.4.5, 5.5.3, Cross-Chapter Box 13 in Chapter 5, 5.6.1, 5.6.3}

D7.3. International cooperation is a critical enabler for developing countries and vulnerable regions to strengthen their action for the implementation of 1.5°C-consistent climate responses, including through enhancing access to finance and technology and enhancing domestic capacities, taking into account national and local circumstances and needs (*high confidence*). {2.3.1, 4.4.1, 4.4.2, 4.4.4, 4.4.5, 5.4.1 5.5.3, 5.6.1, Box 4.1, Box 4.2, Box 4.7}.

D7.4. Collective efforts at all levels, in ways that reflect different circumstances and capabilities, in the pursuit of limiting global warming to 1.5ºC, taking into account equity as well as effectiveness, can facilitate strengthening the global response to climate change, achieving sustainable development and eradicating poverty (*high confidence*). {1.4.2, 2.3.1, 2.5.2, 4.2.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.3, 5.3.1, 5.4.1, 5.5.3, 5.6.1, 5.6.2, 5.6.3}

Box SPM 1: Core Concepts Central to this Special Report

Global mean surface temperature (GMST): Estimated global average of near-surface air temperatures over land and sea-ice, and sea surface temperatures over ice-free ocean regions, with changes normally expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperature over both land and oceans are also used.[19] {1.2.1.1}

Pre-industrial: The multi-century period prior to the onset of large-scale industrial activity around 1750. The reference period 1850–1900 is used to approximate pre-industrial GMST. {1.2.1.2}

Global warming: The estimated increase in GMST averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. {1.2.1}

Net zero CO_2 emissions: Net-zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period.

Carbon dioxide removal (CDR): Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

Total carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from the preindustrial period to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Remaining carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from a given start date to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Temperature overshoot: The temporary exceedance of a specified level of global warming.

Emission pathways: In this Summary for Policymakers, the modelled trajectories of global anthropogenic emissions over the 21st century are termed emission pathways. Emission pathways are classified by their temperature trajectory over the 21st century: pathways giving at least 50% probability based on current knowledge of limiting global warming to below 1.5°C are classified as 'no overshoot'; those limiting warming to below 1.6°C and returning to 1.5°C by 2100 are classified as '1.5°C limited-overshoot'; while those exceeding 1.6°C but still returning to 1.5°C by 2100 are classified as 'higher-overshoot'.

[19] Past IPCC reports, reflecting the literature, have used a variety of approximately equivalent metrics of GMST change.

Impacts: Effects of climate change on human and natural systems. Impacts can have beneficial or adverse outcomes for livelihoods, health and well-being, ecosystems and species, services, infrastructure, and economic, social and cultural assets.

Risk: The potential for adverse consequences from a climate-related hazard for human and natural systems, resulting from the interactions between the hazard and the vulnerability and exposure of the affected system. Risk integrates the likelihood of exposure to a hazard and the magnitude of its impact. Risk also can describe the potential for adverse consequences of adaptation or mitigation responses to climate change.

Climate-resilient development pathways (CRDPs): Trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transitions and transformations while reducing the threat of climate change through ambitious mitigation, adaptation, and climate resilience.

This is Exhibit "I" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

**Wudassie Semaneh Tamrat,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires May 1, 2020.**

IPCC Factsheet: How does the IPCC select its authors?

The role of the Intergovernmental Panel on Climate Change (IPCC) is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to the understanding of climate change, its impacts and future risks, and options for adaptation and mitigation.

Hundreds of leading experts in the different areas covered by IPCC reports volunteer their time and expertise as Coordinating Lead Authors and Lead Authors to produce these assessments. Many hundreds more are involved in drafting specific contributions as Contributing Authors and commenting on chapters as Expert Reviewers[1].

Following a call to governments and IPCC observer organisations for nominations and the submission of detailed CVs, authors are selected on the basis of their expertise. The composition of author teams aims to reflect a range of scientific, technical and socio-economic views and backgrounds. A comprehensive assessment requires author teams to include a mix of authors from different regions and from developed and developing countries to ensure that reports are not biased towards the perspective of any one country or group of countries and that questions of importance to particular regions are not overlooked.

The IPCC also seeks a balance of men and women, as well as between those experienced with working on IPCC reports and those new to the process, including younger scientists. Author teams may also include experts from industry and from non-profit organizations who bring a valuable perspective to the assessment.

Chapter teams comprise Coordinating Lead Authors, Lead Authors and Review Editors[2]. The Bureau of the relevant IPCC Working Group or Task Force selects scientists for these roles from nominations of experts from their respective countries by IPCC member governments and observer organizations or from other experts known through their publications and work.

Experts who are nominated by governments and observer organizations but not selected are encouraged to contribute to the report as Expert Reviewers. (See IPCC Factsheet – *How does the IPCC review process work?*)

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[1] The process for selecting authors is described in sections 4.3.1 and 4.3.2 of **Appendix A** to the **Principles Governing IPCC Work**, the **Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports**: http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a-final.pdf

[2] The roles of the different categories of authors are described in Annex 1 to **Appendix A** to the **Principles Governing IPCC Work**, the **Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports:** http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a-final.pdf

For the Fifth Assessment Report a total of 831 experts were originally selected as Coordinating Lead Authors, Lead Authors and Review Editors from 3,598 nominations across the three Working Groups (including some experts nominated for more than one Working Group). Author numbers may change slightly over the course of an assessment, for instance with the addition of an author with additional expertise or with a resignation due to health or time conflicts.

Coordinating Lead Authors and Lead Authors have collective responsibility for the contents of a chapter. They may enlist other experts as Contributing Authors to assist with their work. Contributing Authors, who number many hundreds, provide specific knowledge or expertise in a given area, and help ensure that the full range of views held in the scientific community is reflected in the report.

Balanced assessment of the full range of scientific views, protected from the influence of special interests, is supported through the method of author team selection, multiple rounds of review of each report, and IPCC's Conflict of Interest Policy[3].

[3] The **IPCC Conflict of Interest Policy** is here:
http://www.ipcc.ch/pdf/ipcc-principles/ipcc-conflict-of-interest.pdf

30 August 2013

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IPCC Factsheet: What literature does the IPCC assess?

The Assessment Reports and Special Reports produced by the Intergovernmental Panel on Climate Change (IPCC) cover a wide range of disciplines in fulfilling the IPCC's mandate of assessing scientific, technological and socio-economic information in order to provide policymakers with a clear view of the current state of scientific knowledge relevant to climate change.

The IPCC does not conduct its own research, run models or make measurements of climate or weather phenomena. Its role is to assess the scientific, technical and socio-economic literature relevant to understanding climate change, its impacts and future risks, and options for adaptation and mitigation. Author teams critically assess all such information from any source that is to be included in the report[1].

Author teams use calibrated uncertainty language to express a level of confidence in findings based on the strength of the scientific and technical evidence and the level of agreement in the scientific, technical and socio-economic literature[2].

At the beginning of the assessment process, each IPCC Working Group sets cut-off dates by which time literature has to be accepted for publication by scientific journals, if it is to be included in the current assessment. Cut-off dates ensure the assessment is as up to date as is practical while ensuring that author teams have sufficient time to fully evaluate all literature included in the assessment. For AR5 the cut-off dates were set so that literature has to be accepted for publication approximately two-three months before completion of the final draft.

Like other scientific publications, IPCC reports refer to cited material in the text with the full citations listed at the end of the relevant chapter so that readers can check the original sources. Copies of material that is cited in IPCC report drafts but not widely available are made available to reviewers upon request during the review period.

In the assessment process, emphasis is placed on the evaluation of all cited literature and of its sources. Contributions to IPCC reports take full advantage of peer-reviewed[3] and internationally available literature. Sources other than scientific journals also provide crucial information for a

1 The procedures for dealing with scientific literature are described in Annex 2 (page 17) to **Appendix A** to the **Principles Governing IPCC Work**, the **Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports**: http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a-final.pdf

2 See *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf

3 Peer review is the process by which scientists with relevant expertise critically evaluate the methods and conclusions of primary research papers or the balance and thoroughness of reviews and reports.

comprehensive assessment. Examples include reports from governments, industry and research institutions, international and other organizations, and conference proceedings. Information about certain experiences and practices in mitigation and adaptation activities in particular may be found in sources other than traditional scientific and technical journals. Such materials may utilize a wide range of quality-assurance mechanisms, including but not limited to formal peer review. Author teams using literature of this kind have a special responsibility to ensure its quality and validity.

The number of sources cited in the Fifth Assessment Report will total many thousands. This is an indication of the extensive literature base on which IPCC reports and their conclusions are built.

30 August 2013

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This is Exhibit "J" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat, a Commissioner, etc., Province of Ontario, while a Student-at-Law. Expires May 1, 2020.

Government of Canada | Gouvernement du Canada

2017 Canada

CANADA'S 7TH NATIONAL COMMUNICATION AND 3RD BIENNIAL REPORT

Canada's Seventh National Communication on Climate Change and Third Biennial Report—Actions to meet commitments under the United Nations Framework Convention on Climate Change

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Aussi disponible en français

Table of Contents—Canada's 7th National Communication and 3rd Biennial Report

Minister's Message

As Canada's Environment and Climate Change Minister, I am pleased to submit Canada's *7th National Communication* and *3rd Biennial Report* to the United Nations Framework Convention on Climate Change (UNFCCC).

In the two years since our last Biennial Report to the UNFCCC, Canada has taken significant steps to advance action on climate change and clean growth, both at home and abroad.

In December 2016, the Prime Minister and Provincial and Territorial Premiers adopted Canada's clean growth and climate plan to take ambitious action to fight climate change, build resilience to the changing climate, and drive clean economic growth. A landmark achievement, the Pan-Canadian Framework on Clean Growth and Climate Change is the first climate change plan in Canada's history to include joint and individual commitments by federal, provincial and territorial governments and to have been developed with input from Indigenous Peoples. The Pan-Canadian Framework outlines more than 50 concrete measures to reduce carbon pollution, help the country adapt to the impacts of a changing climate, foster clean technology solutions, and create good jobs that contribute to a stronger economy.

We have covered considerable ground since launching Canada's clean growth and climate plan just over one year ago. Now, we're starting to see results. Our plan includes a pan-Canadian approach to pricing carbon pollution, as well as measures to reduce emissions across all sectors of the economy that put Canada on the path to meet our Paris Agreement target to reduce emissions 30 percent below 2005 levels by 2030. We are determined to meet or exceed that 2030 goal.

Based on our updated greenhouse gas projections included in this report, we have taken great strides towards our target. But of course, much work remains. We have laid out a comprehensive plan for ourselves, and are now implementing it, along with an ambitious suite of policies, programs, regulations, and funding initiatives. The country has taken steps towards pricing carbon pollution: our approach requires carbon pricing across Canada in 2018. We are also advancing a number of additional measures that will take us the rest of the way to our target, in continued partnership with provinces and territories, and in consultation with stakeholders across sectors.

Despite global action to reduce emissions, adapting to the impacts of climate change will also be critical. In the past year, governments across Canada have taken steps to support communities most affected by impacts of climate change, such as fires, floods and extreme weather. Governments have also invested in climate solutions and clean growth. Their investments will help Canadians save money through the use of smarter energy solutions.

Indigenous Peoples are important environmental leaders in Canada. They are often among the most vulnerable to the effects of a changing climate. The Government of Canada is committed to ensuring that Canada's Indigenous Peoples are real partners in the country's transition to a low-carbon, climate resilient economy. That is why the Government of Canada is working with National Indigenous Organizations to support the implementation of the Pan-Canadian Framework and to advance broader clean growth and climate change priorities.

These and other domestic actions represent Canada's commitment to implementing the Paris Agreement and, much like processes under the UNFCCC, the Pan-Canadian Framework includes accountability and reporting mechanisms that will allow us to revisit our climate change measures and enhance our ambition over time.

The Government of Canada is supporting these

domestic actions with historic investments. In June 2017, we launched the Low Carbon Economy Fund to leverage investments in projects that will support clean growth and reduce greenhouse gas emissions from buildings, industries and forestry. The government is also investing billions in green infrastructure and public transit, and through the Canada Infrastructure Bank and green bonds from Export Development Canada, we are using innovative financing mechanisms to support climate investments and help new technologies become mainstream.

At the international level, Canada continues to demonstrate its strong commitment to global leadership on clean growth and climate change. Our country is working closely with its international partners on negotiations to implement the Paris Agreement under the UNFCCC. In advance of the 23rd Conference of the Parties (COP23), together with China and the European Union, Canada co-hosted a Ministerial on Climate Action, bringing together ministers and representatives from more than 30 major economies and other key players on international climate change.

In 2017, Canada also hosted a series of events on key issues under the UNFCCC. These included carbon markets, gender equality, and the engagement of Indigenous Peoples in international climate action. These complementary meetings informed the COP23 negotiations, where Canada was recognized for its leadership in helping to reach agreement on a UNFCCC Gender Action Plan and on the launch of the local communities and Indigenous Peoples' platform to enhance engagement of Indigenous Peoples on international climate action.

Canada remains committed to supporting countries that are most vulnerable to the impacts of climate change. We are delivering on a historic commitment to provide $2.65 billion in climate finance by 2020-21. Canada also recently doubled its funding to the UN Intergovernmental Panel on Climate Change (IPCC), and hosted hundreds of scientists supporting the IPCC at a Montréal conference in fall 2017.

We continue to work through other multilateral fora to advance action on climate change. For example, Canada has acted as a strong advocate for a global hydrofluorocarbon (HFC) phase-down under the Montreal Protocol. Canada also ratified the Kigali Amendment to the Protocol in November 2017, which commits countries to significantly reduce consumption and production of HFCs thereby minimizing their impact on climate change. We played a leadership role in encouraging the support of 21 other Parties to ratify the Kigali Amendment, helping bring it into force on January 1, 2019. Canada is also playing a lead role in Mission Innovation, a global initiative launched in 2015 by countries that have agreed to double national investment in clean energy innovation over five years while encouraging greater levels of private-sector investment in clean energy technologies.

In addition to multilateral work, Canada continues to advance climate action directly with its partners. For example, Canada worked in partnership with the United Kingdom recently to launch the Powering Past Coal Alliance, a global initiative to phase out traditional coal-fired electricity generation. In December 2017, Canada and five provinces joined with Mexico, Chile, Colombia, Costa Rica and two U.S. states to establish the Declaration on Carbon Markets in the Americas, which aims to enhance collaboration on carbon pricing systems and promote carbon markets throughout the Americas.

Canada understands that addressing climate change represents a significant economic opportunity. Those countries that pursue strong climate action will be best placed to compete in the clean growth century. Through reducing emissions and enhancing resilience, we can all work together to avoid the worst impacts of climate change and secure a safer, more prosperous future for our kids and grandkids.

I look forward to continued work with my domestic and international colleagues to make this future a reality.

Sincerely,
Catherine McKenna

CHAPTER 6

Vulnerability Assessment, Climate Change Impacts and Adaptation Measures

The impacts of climate change are being felt across Canada. Ongoing climate change poses significant risks to communities, public safety, health and well-being, the economy, and the natural environment. Mobilizing action on adaptation helps protect Canadians from climate change risks, build resilience, and ensure that society thrives in a changing climate.

Climate resilience is the ability to survive and prosper in the face of the new climate reality. Adaptation is key to achieving climate resilience, and is about making informed, forward looking decisions in response to climate change, in order to moderate harm or take advantage of new opportunities. Implementing effective adaptation measures saves lives, minimizes damage, and lowers costs over the long term for individuals, businesses, organizations, and governments.

Adapting to climate change impacts is a shared responsibility. Governments, communities, the private sector, academia, the non-profit sector, professional organizations, and individuals all have important roles to play in building resilience to climate change. In Canada, there is growing awareness of the impacts of climate change and the value of adaptation, and there are examples of initiatives being advanced across the country.

This chapter provides an overview of progress on adaptation in Canada since *Canada's 6th National Communication* (2014). It includes a brief overview of climate change impacts in Canada and outlines key programs, policies, strategies, and frameworks related to adaptation implemented domestically and internationally by federal, provincial, territorial, municipal, and Indigenous governments and Indigenous Peoples.

Key Developments since 2014

As described elsewhere in this report, Canada's First Ministers adopted the Vancouver Declaration on Clean Growth and Climate Change on March 3, 2016. Under the Vancouver Declaration, First Ministers committed to build on the momentum of the Paris Agreement by developing a concrete plan to achieve Canada's international commitments through a Pan-Canadian Framework on Clean Growth and Climate Change.

The Government of Canada became a signatory to the Paris Agreement on October 5, 2016, and committed to continuing to enhance its domestic adaptation activities and supporting international adaptation actions for developing countries.

The Pan-Canadian Framework on Clean Growth and Climate Change was adopted on December 9, 2016 by federal, provincial, and territorial governments.[a] The Pan-Canadian Framework sets out a collaborative plan for building resilience to climate change, encouraging clean economic growth, and reducing GHG emissions.

In 2016, the Government of Canada announced funding over five years (2016–2021) for seven federal departments and agencies to implement federal adaptation programming, and to integrate climate resilience into building design guides and codes.

Building on 2016 adaptation investments, in 2017 the Government of Canada announced funding over five years (2017–2022) for a suite of adaptation and climate resilience programs to protect communities and all Canadians from the risks associated with climate change. The Government of Canada also announced green infrastructure funding, a significant portion of which will help communities prepare for challenges that result from climate change. This includes significant investments in a Disaster Mitigation and Adaptation Fund to support large-scale national, provincial and municipal infrastructure projects that are resilient to the effects of a changing climate.

Provinces and territories have recognized the need to adapt either through stand-alone plans or strategies or as part of broader climate change plans or strategies and have made investments to support adaptation initiatives.

At the local level, cities and communities are actively planning for climate risks including, for example, through the development of adaptation strategies that inform city planning and infrastructure decisions and encourage action by homeowners and businesses.

Indigenous Peoples are also taking adaptation action, in the form of, for example, the development of community plans and hazard maps, and specific actions to maintain cultural practices and engage youth.

In the private sector, some companies are integrating climate considerations into their investment, planning, and operational decisions in order to improve their long-term resilience and competitiveness. Professional associations (e.g., engineers, planners, accountants, insurers, foresters) are working to inform and equip their members to be able to address a changing climate within their professional practice.

Banks are also beginning to engage in climate change risk reporting. Toronto-Dominion Bank and Royal Bank of Canada are among 14 of the world's leading banks to work with the United Nations Environment Programme Financial Initiative to develop better climate-risk assessments for financial institutions.

[a] Manitoba and Saskatchewan did not join the Pan-Canadian Framework at this time.

6.1 Climate Modelling, Projections, and Scenarios

Temperatures in Canada have been increasing at roughly double the average global rate, with average temperatures in Canada having already increased by 1.7°C since 1948.[1,2] Warming has been observed consistently across most of Canada, and across all seasons, but with stronger trends in the north and west, and in winter and spring.[3] Annual average precipitation has also changed in Canada with most of the country (particularly the North) having experienced an increase in precipitation since the mid-20th century. The strong regional and seasonal variability in precipitation is illustrated in Figure 6-1.

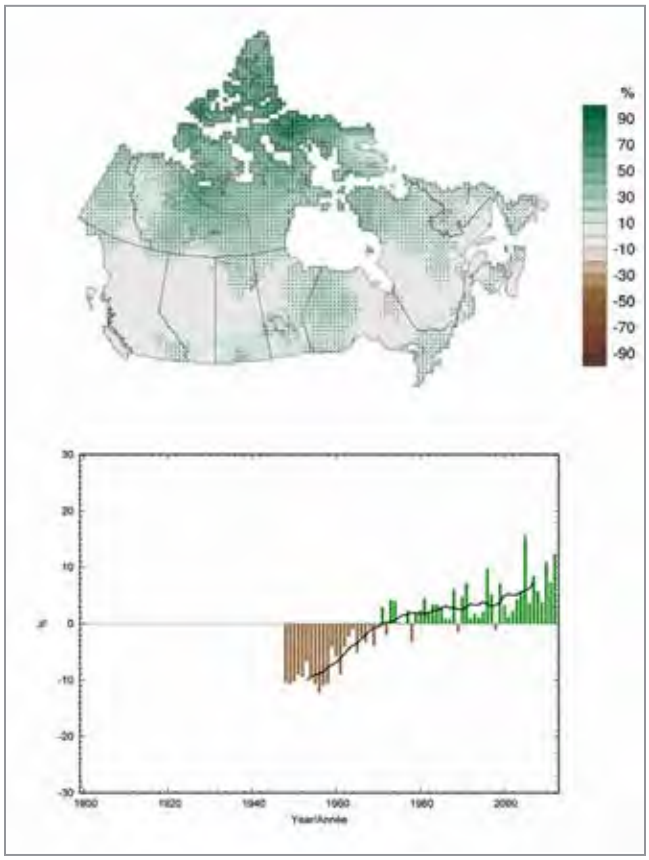

Figure 6-1: Annual total precipitation 1948–2012
The upper panel shows linear trends in annual total precipitation (expressed as per cent change relative to the local 1961–1990 climatology) for the period 1948–2012 for all of Canada. Grid squares with trends statistically significant at the 5% level are marked with a dot. Note that the distribution of observing stations over northern Canada is sparse. The bottom panel shows the time series and the 11-year moving average for Canada (Vincent et al., 2015[4]).

Future climate projections for Canada, fully consistent with those used in the IPCC Fifth Assessment Report (AR5), are developed by Environment and Climate Change Canada's Climate Research Division and made available to Canadians through the Climate Data and Scenarios website.

Continued amplification of warming at high latitudes compared to the global average is projected under all scenarios of future climate change; therefore, Canada's temperature will continue to warm at a faster rate than the world as a whole. Within Canada, climate change is not projected to be uniform, with both seasonal and geographic differences in rates of projected warming. The strongest warming is projected for winter and for northerly latitudes, a robust result consistent across all scenarios.

See Figure 6-2 for climate projections under a scenario based on a mid-range global GHG emissions scenario (e.g., Representative Concentration Pathway (RCP) 4.5).

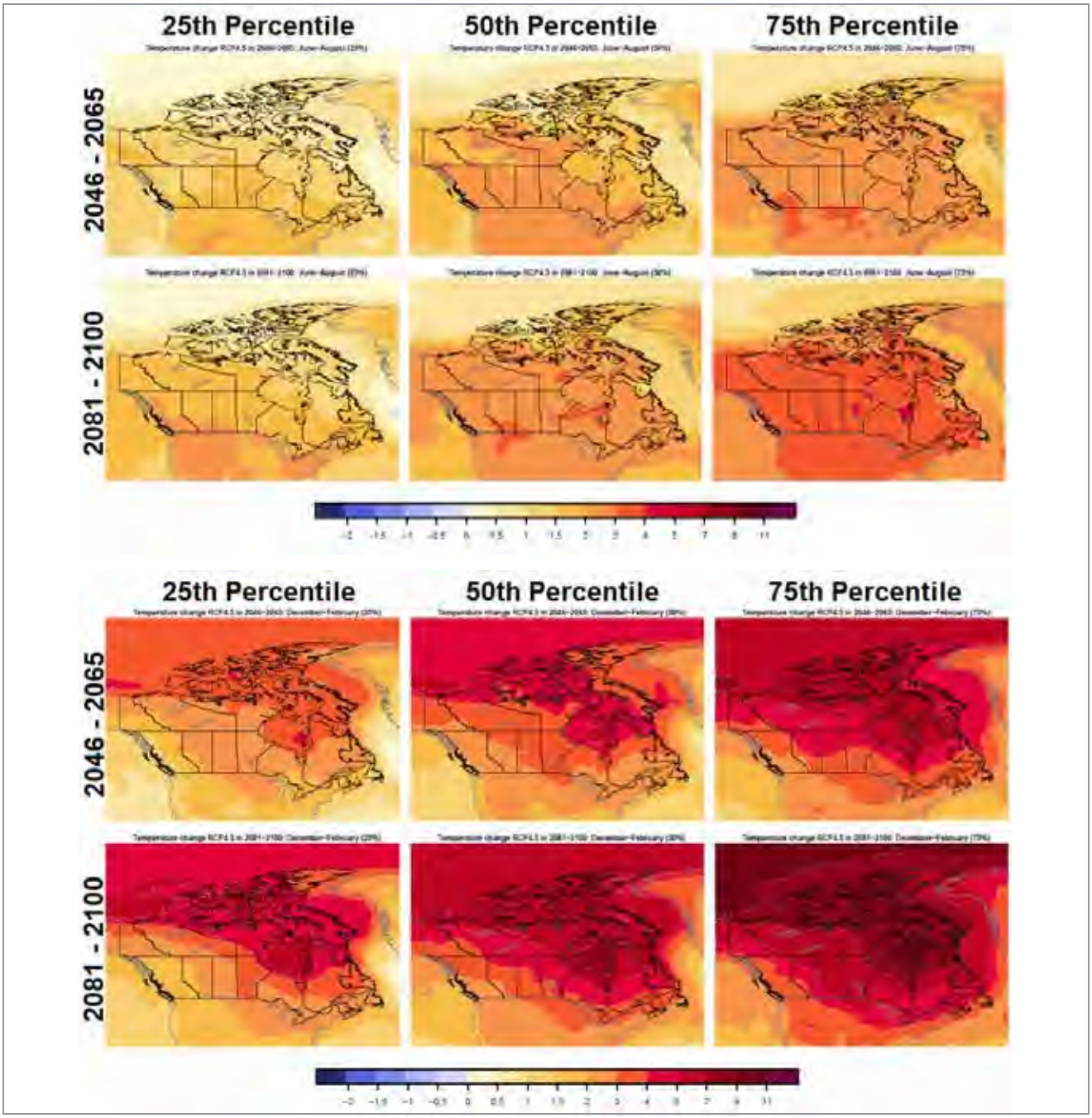

Figure 6-2: Temperature Change Projected by the CMIP5 Multi-Model Ensemble for the RCP4.5 Scenario; Summer and Winter

Maps of temperature change projected by the Coupled Model Intercomparison Project (CMIP5) multi-model ensemble for the RCP4.5 scenario, for summer (top frame, averaged over June–August) and winter (bottom frame, averaged over December-February). Change is computed relative to the 1986–2005 baseline period.[5] As in the IPCC Atlas (Annex 1, IPCC, 2013),[6] the top row shows results for the period 2046–2065, and the bottom row for 2081–2100. For each row the left panel shows the 25th percentile, the middle panel the 50th percentile (median), and the right panel the 75th percentile. The color scale indicates temperature change in °C with positive change (warming) indicated by yellow through red colors and cooling by blue colors, consistent with the color scale used in the IPCC AR5 Annex I.

Figure 6-3 below provides a projection of changes in summer and winter precipitation for Canada under a mid-range GHG emissions scenario (RCP4.5). Relative precipitation increases (% changes) are larger in the north and in winter versus summer.

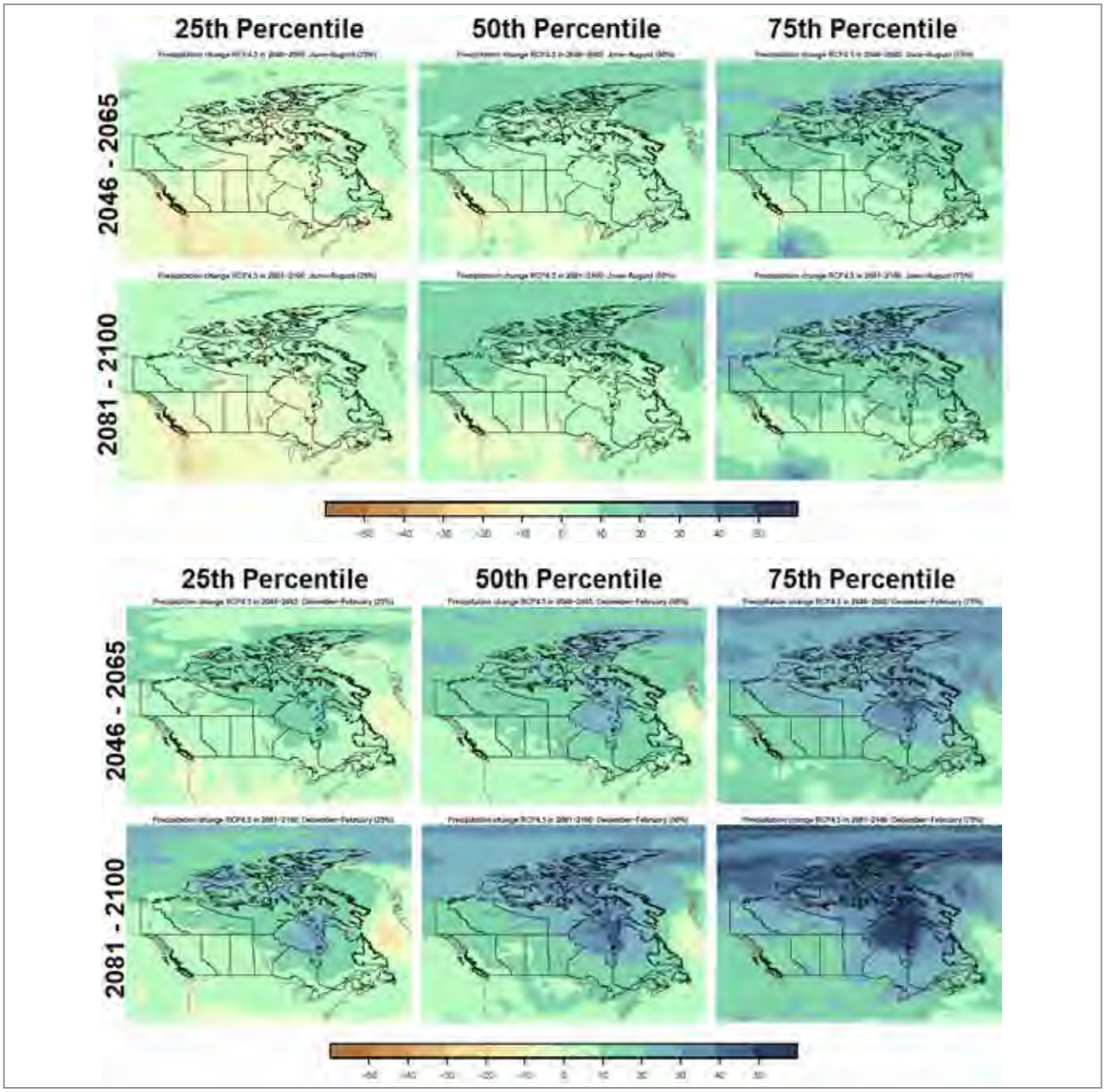

Figure 6-3: Precipitation Change Projected by the CMIP5 Multi-Model Ensemble for the RCP4.5 Scenario; Summer and Winter

Maps of precipitation change projected by the CMIP5 multi-model ensemble for the RCP4.5 scenario, for summer (top frame, averaged over June–August) and winter (top frame, averaged over December-February). Change is computed relative to the 1986–2005 baseline period.[7] As in the IPCC Atlas (Annex 1, IPCC, 2013),[8] the top row shows results for the period 2046–2065 and the bottom row for 2081–2100. For each row the left panel shows the 25th percentile, the middle panel the 50th percentile (median), and the right panel the 75th percentile. The colour scale indicates precipitation change in % with positive change (increased precipitation) indicated by green colours and decrease by yellow to brown colours, consistent with the colour scale used in the IPCC AR5 Annex I.

Overall, Canada can expect to continue to experience warmer temperatures and more rainfall across the country as a whole, although regional and seasonal variability will continue. Associated with these trends in average temperature and precipitation are projected increases in daily hot extremes and heavy rainfall events, and declines in snow and ice cover (see section 6.2.2.2 on Canada's North).[9] Sea level along many of Canada's coastlines will continue to rise, and this rise will be greatest in areas where the land is currently eroding, such as most of the Maritime Provinces. Warmer waters and ocean acidification are expected to become increasingly evident in most Canadian ocean waters over the next century.[10]

The impacts being observed are the result of historical emissions. Even with a successful transition to a carbon-neutral society, the impacts of changing temperature, precipitation, and the occurrence and severity of extreme events will continue to touch all regions, sectors, communities, and ecosystems for decades to come.

6.2 Assessment of Risk and Vulnerability to Climate Change Impacts

Knowledge of climate change impacts and the potential for associated risks is the foundation for organizations to protect assets and resources and to strengthen planning and decision-making. The development of programs, policies, and actions related to climate change impacts and adaptation are commonly informed by research and different types of assessments, including vulnerability, risk, and science assessments.

Since Canada's *6th National Communication*, more Canadian governments and communities have completed some form of climate change assessment focusing on their own organization or specific sector. These research and assessment activities have contributed to the development of decision-support tools and have revealed lessons learned that have supported the advancement of adaptation. While there has been no systematic attempt to conduct risk or vulnerability assessments across Canada, a number of individual initiatives employing a wide range of methodologies have been undertaken.

The consequences of climate change are evident across Canada, and include impacts to natural and built environments, as well as to the safety, health, socio-economic, and cultural well-being of Canadians. These impacts have high human and financial costs, and are already causing rapid and irreversible change in Canada's northern and coastal regions. These threats are often more acute for some Indigenous Peoples, who live closer to the land, with a strong socio-economic and spiritual connection to it. These changes have been well documented in several assessment reports (for example, *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, Canada's Marine Coasts in a Changing Climate, Climate Risks & Adaptation Practices for the Canadian Transportation Sector 2016)*.

This section outlines assessments conducted by federal, provincial, territorial, and municipal governments, and Indigenous Peoples and provides a brief summary of some impacts of concern identified by assessments, focusing on extreme events, northern and coastal regions, Indigenous Peoples, food and water security, health and well-being, and economic prosperity.

6.2.1 Assessments of Risk and Vulnerability to Climate Change

Assessments have been performed by the Government of Canada as a tool to further highlight the importance of understanding and addressing climate change impacts. These assessments are scientific reports that assess, critically analyze, and synthesize the growing knowledge base on the issue. Working with subject matter experts in government, universities, and non-government organizations, federal departments produce science assessments that are current, relevant, and accessible sources of information to help inform planning of policies, programs, and actions.

Fisheries and Oceans Canada completed four Large Aquatic Basin Risk Assessments covering the Pacific, Arctic, Atlantic Oceans and Canada's inland waters represented by the Lake Winnipeg and Great Lakes' drainage systems. Each large basin assessment included an analysis of climate trends and projections for the aquatic environment in order to help managers make strategic, climate-sensitive decisions about aquatic resource management activities and coastal infrastructure which are at risk to a changing climate.

Natural Resources Canada published a national-scale scientific assessment on the impacts of climate change in Canada in 2014, titled Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. This report was an update to the 2008 report, titled *From Impacts to Adaptation: Canada in a Changing Climate*. The updated report took a sector-based approach, and focused on natural resources (e.g., forestry, mining, and energy), food production, industry, biodiversity and protected areas, human health, and water and transportation infrastructure. This assessment illustrated how Canada's climate is changing and will continue to change, and how adaptation has been accepted as a necessary response to climate change, complementing global measures to reduce GHG emissions.

Natural Resources Canada also published a sectoral assessment focused on marine coasts in 2016, titled *Canada's Marine Coasts in a Changing Climate*. This assessment emphasized the impacts of climate change on Canada's coasts, and presented both the challenges and potential opportunities for coastal communities, ecosystems, and the economy as a result of these changes. The assessment highlighted a variety of adaptation measures that are being adopted in different coastal regions, such as presenting enhanced use of natural infrastructure as an alternative to hard coastal protection measures to reduce climate risks, and emphasized the importance of adaptation in ensuring the sustainability and continued prosperity of Canada and its coastal regions.

Transport Canada released a national-level assessment of climate risks and adaptation practices for the Canadian transportation sector in 2017, titled *Climate Risks & Adaptation Practices for the Canadian Transportation Sector 2016*. The report represents the state of knowledge on climate risks to the sector and identifies existing or potential adaptation measures to mitigate risks. The report is structured regionally, with a synthesis chapter that brings together knowledge relevant to each main mode of transportation (e.g., rail, marine, aviation, road), as well as a chapter specifically dedicated to urban transportation. The information will help decision-makers across the sector better understand potential climate risks and the actions that can be taken to mitigate them.

The Government of Canada also supports sectors, provinces, territories, and communities in conducting their own assessments. For example, through the AgriRisk Initiatives program, Agriculture and Agri-Food Canada is supporting the agriculture sector in developing regional climate vulnerability and opportunity assessments to evaluate potential climate change impacts on local agricultural production.

Together with the governments of the Northwest Territories and of Nunavut, the Government of Canada assessed infrastructure engineering vulnerabilities of three northern airports (Churchill Airport, Inuvik Airport and Cambridge Bay Airport), using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. The knowledge gained through these assessments is intended to inform asset management plans, investment plans, and other decision-making relevant to these assets.

The Government of Yukon is developing better methodologies for assessing the financial impacts of permafrost thaw, and experimenting with new approaches to building and maintaining infrastructure on permafrost-affected terrain. The territory has also performed risk and/or vulnerability assessments,

disaster resiliency planning, and is actively monitoring permafrost temperatures and identifying intervention opportunities to mitigate impacts with the help of the Yukon Permafrost Knowledge Network.

Assessments are often the first stage of municipal adaptation planning processes. For example, the municipality of Wawa, Ontario brought together varied stakeholders from across the community to come together and identify local climate change impacts. Using this information they then worked through a process of vulnerability and risk assessment and they will use the results to protect Wawa's community by integrating the identified climate risks into their broader *Emergency Preparedness Plan*.

Similarly, Calgary and Edmonton, Alberta, worked with the Prairie Climate Centre to create a series of publications for the public and government officials that explore how to build cities that are resilient to the impacts of climate change, drawing on lived experience and best practices. The reports touch on climate change and its local impacts on a number of sectors, including economics and finance, agriculture and food security, urban ecosystems, transportation, water supply, and electricity.

While important, assessments of adaptation planning in Indigenous and northern communities have occurred on a predominantly ad-hoc basis. Despite this the Government of Canada, as well as provincial, territorial and municipal governments, contribute to increasing northern and Indigenous Peoples' resilience to climate change by supporting them in the identification of high risk areas for climate change impacts. Indigenous and Northern Affairs Canada has provided financial support to communities to engage in a variety of planning activities including: gathering traditional knowledge, participating in regional planning activities, producing Indigenous-specific tools and guides and conducting vulnerability assessments and adaptation plans.

6.2.2 Climate Change Impacts

Assessments present the latest knowledge on climate change impacts and adaptation, and act as accessible sources of information to help inform planning of policies, programs, and actions.

6.2.2.1 Extreme Weather Events

Extreme weather events are a key concern for Canada and there is growing confidence that some types of extreme events will increase in frequency and/or intensity as the climate continues to warm.[11] Changes in temperature and precipitation patterns have made the wildfire season longer, while drought- and pest-stressed forests and rangelands are increasing the severity of wildland fires.[12] Sea level rise is increasing the extent of storm surge flooding.[13]

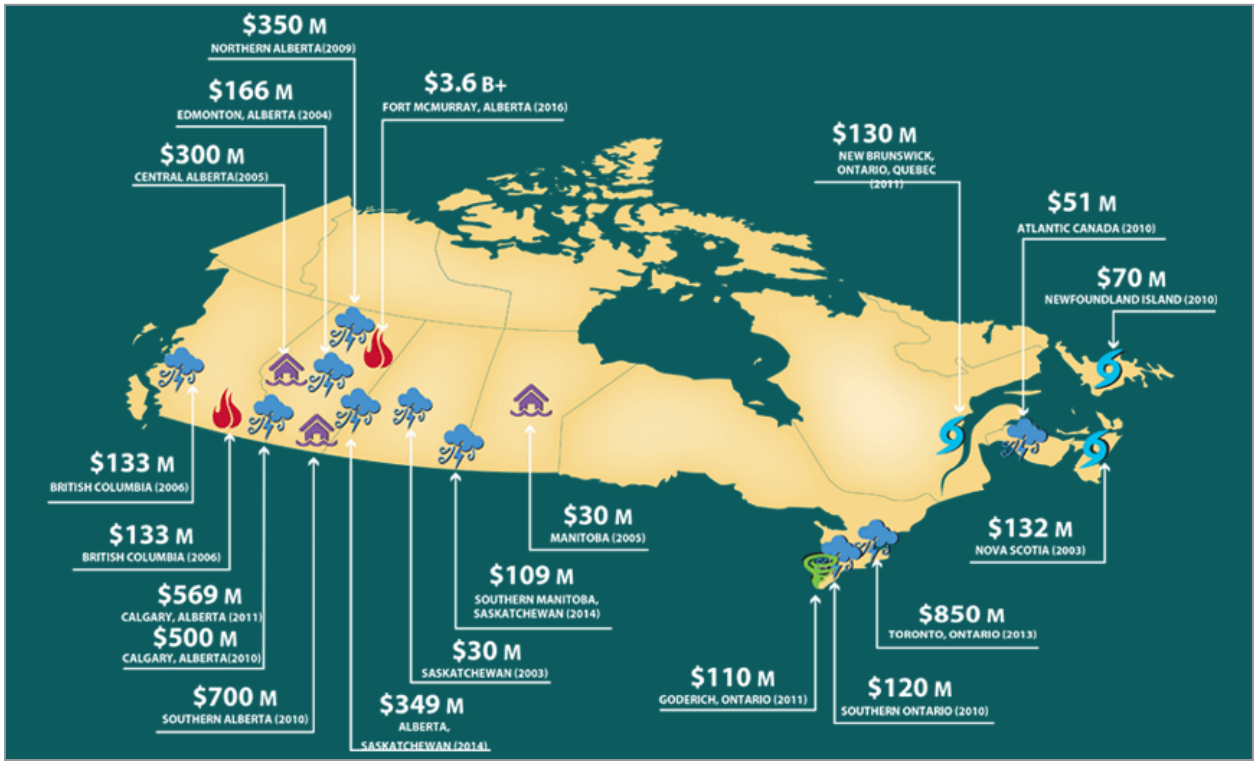

Figure 6-4: Insured Losses from Extreme Weather Events in Canada
Examples of insured losses from extreme weather events in Canada (Sources: Updated from Kovacs and Thistlethwaite, 2014[14])

Recent examples demonstrate the potentially devastating effects of these events and the vulnerability of communities to an increasing risk of climate-related extreme events. The 2016 Fort McMurray wildfire displaced 90,000 people, destroyed approximately 2,400 homes and other buildings, and caused disruptions in local economic activities. With insured losses in excess of $3.5 billion, this fire was the costliest insurable loss in Canada's history. In early May 2017, a strong and prolonged precipitation event caused historic floods in eastern Ontario and western Québec. The flooding caused thousands of people to evacuate their homes, and even more were affected by the flooding.[15] The response to the flooding required over 2,000 Canadian Armed Forces personnel to be deployed to assist in relief efforts.[16]

6.2.2.2 Canada's North

While Canada's temperature increases are outpacing the global average, temperatures are rising even faster in Canada's Arctic and northern areas. The rapid warming of Canada's North is leading to significant reductions in the extent of sea ice, accelerated permafrost thaw and loss of glaciers, and other ecosystem impacts.

The volume and coverage of sea ice have decreased significantly since observations began in 1979. A nearly-ice free summer is considered a strong possibility for the Arctic Ocean by the middle of the century although summer sea ice may persist longer in the Canadian Arctic Archipelago region, which will have wide ranging implications in Canada's North, as well as globally.[17] Northern Arctic ice shelves have undergone significant changes in the last 100 years, eroding from one large ice shelf that spanned the entire northwest coast of Ellesmere Island into three smaller ice shelves. Since 2005, the total remaining area of ice shelves has decreased by more than 50%.[18] Sea ice provides critical transportation in parts of the North, and its rapid loss is having a profound impact on communities that rely on ice to access hunting grounds and traditional sites, as well as on seasonal ice roads that provide access to food

and supplies from the south. As Simeonie Amagoalik, an Elder from Nunavut, recalls: "I used to go egg hunting but now it is too dangerous to travel by ice so I cannot go to the places that I used to go to. I think it is mainly the ice on the sea that has affected me the most."[19]

The loss of sea ice also alters animal ranges (e.g., seals, walruses, salmon, whales) and opens new pathways for disease (e.g., a seal-killing virus previously seen only in the Atlantic Ocean was found in a population of Pacific sea otters in Alaska). These impacts are especially felt by Indigenous Peoples that depend on these animals for sustenance and cultural survival. While reduced ice cover is increasing marine access to the North for resource development, shipping, and tourism, these activities bring with them new risks of accidents and spills, which put people and ecosystems at risk and place additional stress on limited search and rescue and disaster response capacity.

Warmer temperatures, along with other factors such as fire, increased rainfall, and erosion, are causing permafrost to degrade. The loss of permafrost is causing irreversible changes to the landscape, including slumping, erosion, ground instability, and forest mortality. Habitat is changing and, for some species, being lost altogether. Since permafrost impacts how far water can penetrate into the ground, permafrost degradation leads to changes in drainage patterns, expansion or drainage of ponds, lakes, and wetlands, changes in water quality, and shifts in the timing of peak and minimum flows in rivers and streams. For example, in the summer of 2015, a large permafrost thaw slump caused rapid drainage of a tundra lake near the Mackenzie Delta in the Northwest Territories. This event was driven, in part, by rising temperatures and increased rainfall. More information pertaining to permafrost impacts can be found in Chapter 8: Research and Systematic Observation of Climate Change.

Northern infrastructure, including roads, buildings, communications towers, energy systems and facilities, community landfills, sewage lagoons, and large-scale waste containment sites (including berms around tailings ponds), often depend on stable permafrost. Degradation causes costly damage and unsafe or unstable conditions.

Remote communities, Indigenous Peoples, and isolated economic sites often depend on a network of winter roads for critical shipments of medical supplies, food, fuel, and equipment. Climate change continues to affect the length of time that winter roads can be operational and whether they are viable at all, making these communities and sites more reliant on other transportation routes or modes. This significantly increases the cost of living and doing business in the North, affecting the ability to attract investment, the prosperity of local businesses, and the strength, health, and well-being of remote communities and Indigenous Peoples.

6.2.2.3 Canada's Coasts

Canada has the longest coastline in the world, and many coastal areas are of great economic, social, historical, and environmental significance. Through changes in relative sea level, rising water temperatures, increased ocean acidity, and loss of sea ice and permafrost, climate change is posing considerable challenges for Canada's coastal areas.

Coastlines projected to experience the greatest relative sea level rise are the Atlantic Provinces, the Gulf of St. Lawrence, the Beaufort Sea, Haida Gwaii, parts of Vancouver Island, and other parts of the British Columbia coast.[20] Relative sea level rise will negatively impact some coastal ecosystems (including dunes, wetlands, tidal flats, and shallow coastal waters) and the services they provide. When combined with high winds, storms, and high tides, sea level rise causes storm surges to reach higher elevations, affecting both natural shorelines and human built coastal infrastructure.

Sea ice acts as natural protection against waves and storm surges. The loss of sea ice further increases storm surge risks and coastal erosion in the Beaufort Sea and Atlantic region. Along the northern coast, the

additional challenges posed by the loss of permafrost are contributing to unprecedented rates of erosion.[21]

Coastal communities are experiencing challenges that include: unstable shorelines; flooding damage to property and agricultural lands; permanent loss of archaeological sites and cultural heritage landmarks; contamination of water supplies; increasing costs for protection, maintenance, and insurance; disrupted transportation and trade routes and infrastructure (e.g., small craft harbours); and impacts on human health (e.g., water-borne diseases). Increases in water temperatures and ocean acidity also impact fisheries, traditional foods, iconic species (e.g., salmon), and food and water safety (e.g., harmful algal blooms).[22]

In some cases, ensuring the continued safety of coastal communities will require considerable effort and resources, and in others it will be necessary to relocate. Given the strong ties to land and place, relocation is likely to have social, cultural, and mental health impacts.

6.2.2.4 Indigenous Peoples and Communities

Indigenous Peoples have a strong cultural connection to the land, water, and air. While this increases their exposure and sensitivity to climate change impacts, it is also a source of strength, understanding, and resilience.[23]

Indigenous Peoples are among the most vulnerable to climate change and experience unique challenges. A range of factors, largely related to historical legacies, contribute to this vulnerability.[24,25,26] Unprecedented changes to the environment and ecosystems challenge traditional ways of knowing and Indigenous Peoples' ability to maintain practices, languages, and culture. Indigenous Peoples also face challenges of access to climate change adaptation resources, programs, and tools.

Although Indigenous Peoples are among the most vulnerable to a changing climate due to their close relationship with the environment and its resources, they are not passive recipients of climate change impacts. Rather, they are active drivers of change who contribute vital knowledge, experience, and leadership to adaptation efforts across Canada. In the face of the challenges presented by climate change, Indigenous Peoples are changing the way they live and interact with the environment and each other, and are taking tangible steps to become agents of change.

Building resilience for Indigenous Peoples is fundamentally about food, water, and energy independence, where communities are self-sufficient in all means needed for survival and cultural expression.[27,28] Indigenous Peoples and their knowledge-holders have a long history of, and deep understanding about, adapting to changes in climate and the land.

6.2.2.5 Food and Water Security

Climate change is impacting agricultural productivity and access to traditional food sources. Risks are directly related to increased incidence of drought, floods, storms, and heat waves, as well as changes to plant lifecycles and productivity, shifting plant and animal ranges, the spread of invasive species, and the emergence and spread of pests and disease. Higher temperatures and potentially longer growing seasons present opportunities for agricultural production in certain areas.

In the North and for Indigenous Peoples, changes in seasonal weather and climate conditions impact the transportation of food and other supplies and have made some traditional travel and hunting routes unsafe, thereby deepening existing food security challenges. For example, climate change is affecting the timing of freeze- and break-up on rivers used for transportation and gathering food through hunting, trapping, and fishing. Reduced access to country foods is increasing reliance on expensive store-bought foods with negative effects on health (e.g., diabetes, obesity) and cultural identity. Costs for transporting food and other supplies have also increased, especially in areas that are increasingly dependent on shipments by air.

Water flows, availability, and quality are also changing due to temperature increases and precipitation changes. Rising temperatures are leading to a rapid loss of glaciers, impacting water flow and temperature in glacial-fed streams and rivers. More information pertaining to climate change impacts on glaciers can be found in Chapter 8: Research and Systemic Observations of Climate Change.

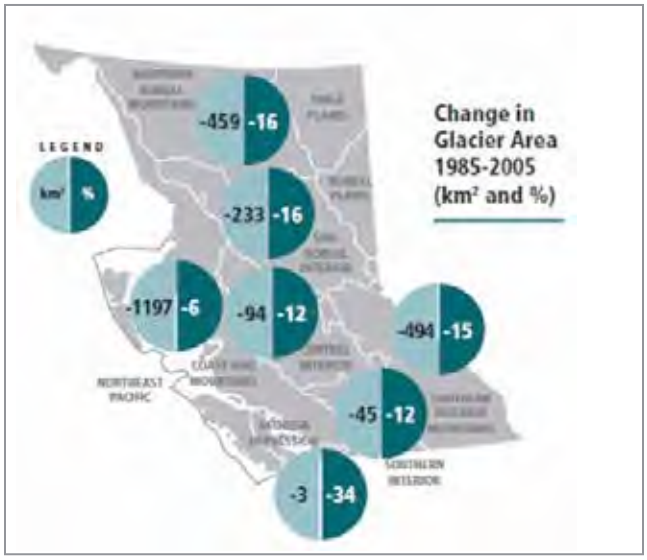

Figure 6-5: Change in Glacier Area 1985–2005 (km and %)
From 1985 to 2005 the glacier coverage in British Columbia decreased by 2,525 km^2 (Bolch et al, 2010).[29]

Water availability, in terms of both the amount of water and the times of minimum and peak flows, is also impacted by changes in spring precipitation and reduced snow accumulation. These changes in the timing and amount of water have consequences for agriculture, industrial activities, power generation, and ecological function.

Higher water temperatures (and less available oxygen) and higher acidity in the water threaten marine life and habitats, impacting commercial, recreational and subsistence fisheries and aquaculture activities. Shorter seasons of ice cover, higher water temperatures, and changing precipitation patterns can affect lake water levels, impacting shipping, tourism, and water quality. For example, observed water levels in the Great Lakes basin have been highly variable, making it difficult to predict the direction of long-term change. However, warming temperatures and changing precipitation patterns are expected to contribute to altered (increased or decreased) water levels, with implications for shipping capacity in the Great Lakes-St. Lawrence Seaway system.[30]

6.2.2.6 Health and Well-Being

Climate change impacts affect the health and well-being of Canadians in many ways, both directly and indirectly. More frequent and severe extreme weather events increase the risk of physical injury, illness, and death. Health systems are challenged and health care facilities can be impacted, with consequences for patient care, safety, and health care costs. In addition, the impact of natural disasters and changing landscapes, the loss of property and cultural heritage sites, and the inability to attend work or school have a negative impact on public health, including mental health, and can diminish individual and community resilience. This can have a significant impact on people, their families, communities, the economy, and the functioning of society as a whole.

Heat waves can cause heat-related illness and death, as well as exacerbate existing conditions, such as respiratory and cardiovascular diseases. Higher temperatures also contribute to increased air pollution and production of pollens, worsening allergies and asthma and exacerbating some existing health conditions. Smoke from wildland fires also impacts air quality. Increased contamination of drinking and recreational water by run-off from heavy rainfall can cause illness and disease outbreaks (e.g., acute gastrointestinal illness, E-coli).[31]

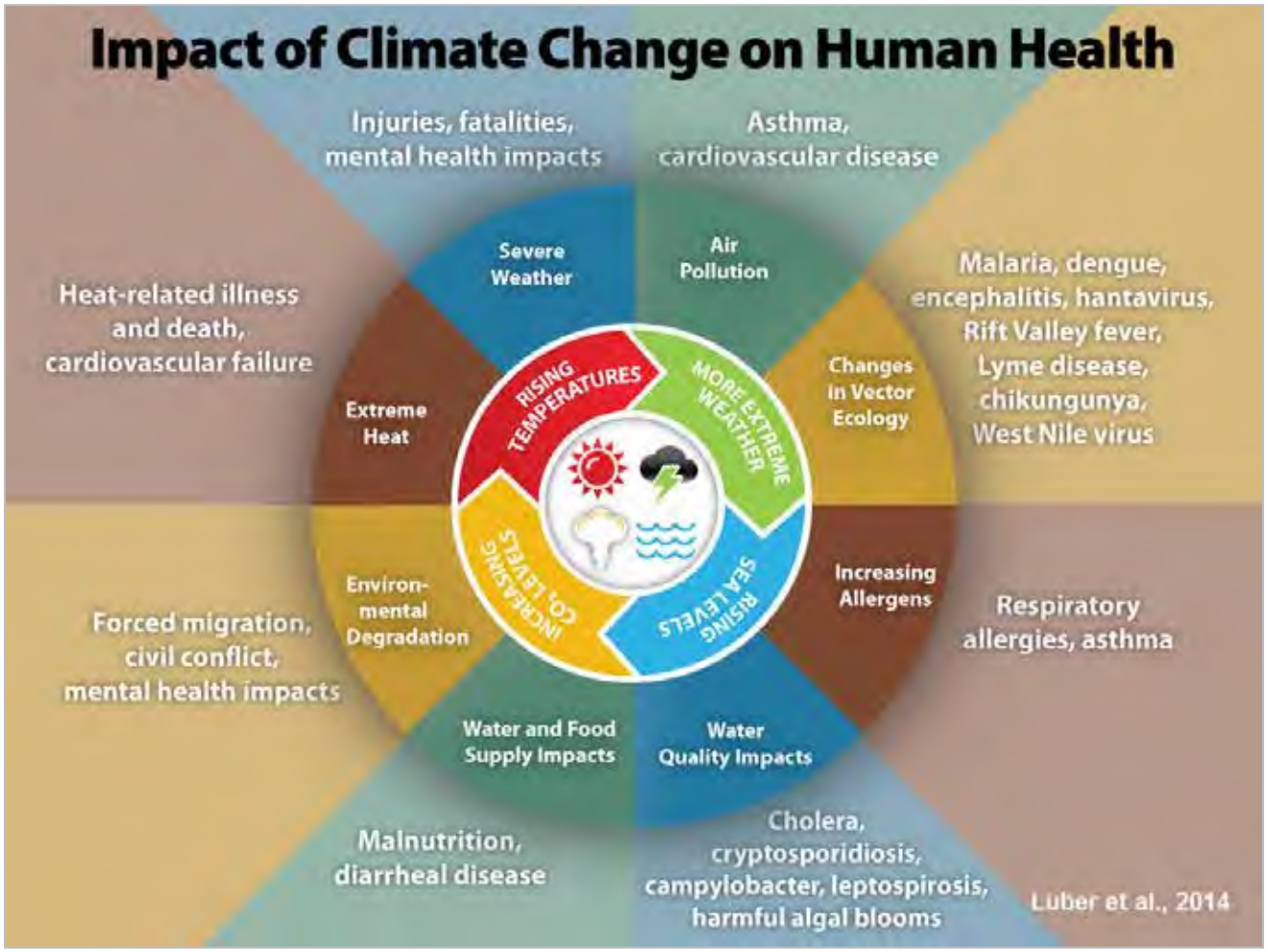

Figure 6-6: Climate Change Effects on Health and Well-Being
Overview of the ways in which climate change affects health and well-being.[32]

Climate change is also likely increasing the prevalence and spread of certain zoonotic, foodborne, or water-borne diseases. For example, Canada is already seeing increased prevalence and geographic range of vector-borne diseases, such as Lyme disease and West Nile virus, as higher temperatures and changes in precipitation can make the environment more hospitable for insects, such as ticks and mosquitoes. In addition, there may be an emergence or re-emergence of diseases that are currently considered to be rare or exotic to Canada (e.g., malaria, chikungunya, Zika virus).

More broadly, climate change affects the various social determinants of health (e.g., food security, availability of potable water, housing, working conditions, income) and reduces resilience. Household food insecurity has been associated with a range of poor physical and mental health outcomes, including multiple chronic conditions and depression.

6.2.2.7 Economic Prosperity

Canadian industries are affected by climate change in various ways. Impacts associated with climate change and extreme weather (for example, the loss of permafrost, coastal erosion, and changing precipitation patterns) are already affecting transportation systems, services and operations across all modes, in all regions of Canada. Associated disruptions in the movement of freight and people, represents risks to the economy and Canadians.

Disruptions in productivity, critical trade infrastructure, electricity generation, and supply chains have broad consequences for many economic sectors, services to consumers, and businesses. Climate change impacts in Canada and around the world affect global food and water security issues, commodity prices, trade, supply chains, conflict, and displaced people, which will have consequences for Canadian immigration, defense, and private sector prosperity. Tourism and recreation activities that rely on weather conditions are particularly sensitive to climate change.[33]

Canada's resource economy is vulnerable to the impacts of climate change. The forestry and agriculture sectors have been affected by increased incidence of drought, floods, storms, heat waves, wildfires, and pests and diseases (e.g., mountain pine beetle and spruce budworm), which has consequences for productivity, the quality of the harvest, and work opportunities.[34] Mining, oil and gas production, hydroelectric power generation, transportation, and agriculture are all affected by variable water levels. Increased temperatures, changing precipitation patterns, and increased frequency and intensity of extreme weather events are creating risks and operational challenges for agriculture and aquaculture production, though rising temperatures could also increase growing days and present opportunities for new crops or species in some regions.

Some of the most vulnerable components of Canada's transportation system are integral to the resource industry in the North. Climate change impacts, such as permafrost degradation, can cause infrastructure damage and deterioration, disruptions to transport operations, and unsafe conditions for the resource sector and for other local economies.

6.3 Climate Information and Services

Climate information can inform decision-making in key sectors such as health (e.g., air and water quality, heat, infectious diseases such as Lyme), agriculture (e.g., food production and security), infrastructure (buildings, roads, bridges and water assets), and natural resource management (e.g., energy, forestry, fisheries, and mining). It is also a foundation for developing appropriate adaptation and risk management strategies. Climate services include climate data, predictions, information, and tools to support adaptation decision-making. Climate services in Canada are a responsibility shared by federal, provincial, and territorial governments.

6.3.1 Federal Climate Information and Services

The Government of Canada undertakes science and monitoring activities related to past, present, and future states of the climate system and how it functions, as well as on the changing composition of the atmosphere and related impacts. These activities include foundational climate and climate change science as well as climate information and services provided by federal departments to inform effective adaptation planning and decision-making. Climate change science includes research related to the impacts of climate change on biodiversity and ecosystem services, as well as options and opportunities for using ecosystems to support climate change adaptation and mitigation. More information pertaining to climate modelling, projections, and scenarios can be found in Chapter 8: Research and Systematic Observation of Climate Change.

Environment and Climate Change Canada currently provides some climate information products and services including seasonal outlooks (e.g., bulletins and consultation process), historical climate data sets, trends analysis, and climate change scenarios. Environment and Climate Change Canada also provides some tailored climate information products and services. For example, the department provides long-term historical climate data sets for internal and external clients and users through its engineering climate services. This includes information about historical snow and ice conditions, which is incorporated into the development of rooftop snow load requirements for the National Building Code of Canada; wind pressure analysis that informs the telecommunications and renewable energy

This is Exhibit "K" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat, a Commissioner, etc., Province of Ontario, while a Student-at-Law. Expires May 1, 2020.

Court of Appeal for Saskatchewan
Docket: CACV3239

IN THE MATTER OF THE *GREENHOUSE GAS POLLUTION PRICING ACT*, BILL C-74, PART V

AND IN THE MATTER OF A REFERENCE BY THE LIEUTENANT GOVERNOR IN COUNCIL TO THE COURT OF APPEAL FOR SASKATCHEWAN UNDER *THE CONSTITUTIONAL QUESTIONS ACT, 2012*, SS 2012, c C-29.01;

SECOND ORDER RESPECTING INTERVENTIONS

Upon receipt of notices from the Attorneys General of Ontario, New Brunswick and British Columbia indicating their election to intervene in this Reference;

Upon receipt of applications for leave to intervene in this Reference;

And upon considering all of the material presented in support of and in opposition to the applications for leave to intervene;

IT IS ORDERED THAT:

1. The motions for leave to intervene by (a) Canadian Environmental Law Association and Environmental Defence Canada Inc., (b) Saskatchewan Power Corporation and SaskEnergy Incorporated, (c) The Canadian Taxpayers Federation, (d) Athabasca Chipewyan First Nation, (e) Climate Justice Saskatoon, National Farmers Union, Saskatchewan Coalition for Sustainable Development, Saskatchewan Council for International Cooperation, Saskatchewan Electric Vehicle Club, The Council of Canadians: Prairie and Northwest Territories, The Council of Canadians: Regina Chapter, The Council of Canadians: Saskatoon Chapter, The New Brunswick Anti-Shale Gas Alliance, and Youth of the Earth [Climate Justice *et al*], (f) Assembly of First Nations, (g) The Canadian Public Health Association, (h) United Conservative Association, (i) Intergenerational Climate Coalition, (j) Ecofiscal Commission of Canada, (k) David Suzuki Foundation, (l) Agricultural Producers Association of Saskatchewan Inc., and (m) International Emissions Trading Association, are granted.

2. The submissions of all intervenors must be limited to the legal issue before the Court, i.e. limited to the constitutional validity of the *Greenhouse Gas Pollution Pricing Act*, Part 5 of Bill C-74.

3. The Attorney General of British Columbia, Saskatchewan Power Corporation and SaskEnergy Incorporated, and Climate Justice *et al* are directed, on or before December 18, 2018, to serve the Attorneys General of Saskatchewan and Canada, and file with the Court the specific materials that they seek leave to add to the record. Such materials are to be filed electronically in a format acceptable to the Registrar. Five hard copies shall be filed as well.

4. On or before December 21, 2018, the Attorneys General of Saskatchewan and Canada shall provide their further submissions, if any, on the applications of the Attorney General of British Columbia, Saskatchewan Power Corporation and SaskEnergy Incorporated, and Climate Justice *et al* to supplement the record.

5. Applications to supplement the record and issues concerning the length of factums and the amount of time counsel will have for oral submissions will be dealt with in a subsequent order or orders.

DATED at the City of Regina, in the Province of Saskatchewan, this 10th day of December, 2018.

"Richards C.J.S."
Richards C.J.S.

"Jackson J.A."
Jackson J.A.

"Ottenbreit J.A."
Ottenbreit J.A.

"Richards C.J.S."
Caldwell J.A.

"Schwann J.A."
Schwann J.A.

This is Exhibit "L" referred to in the Affidavit of IAN CULBERT sworn December 19, 2018

Commissioner for Taking Affidavits (or as may be)

Wudassie Semaneh Tamrat, a Commissioner, etc., Province of Ontario, while a Student-at-Law. Expires May 1, 2020.

ASSOCIATION MÉDICALE CANADIENNE | CANADIAN MEDICAL ASSOCIATION

November 27, 2018

To whom it may concern:

I am writing on behalf of the Canadian Medical Association (CMA) to express support for the application of the Canadian Public Health Association (CPHA) to make intervention in the reference question on the constitutionality of the federal *Greenhouse Gas Pollution Pricing Act.*

Established in 1910, the CPHA has long been recognized as the respected voice of public health in Canada. As the publisher of the peer-reviewed *Canadian Journal of Public Health* and as a partner with the British medical journal *The Lancet*, the CPHA is a leading voice on evidence-informed public and population health policy in Canada.

As is noted in our 2010 comprehensive policy document on climate change and human health, the CMA has been working on the issue of climate change and human health for a number of years. CMA was supportive of Canada's ratification of the Kyoto Protocol, and urged the Government of Canada to commit to choosing a climate change strategy that satisfied Canada's international commitments while also maximizing the clean air co-benefits and smog-reduction potential of any greenhouse gas reduction initiatives.

In 2015 the CMA General Council adopted a resolution to promote the health benefits of a strong, predictable price on carbon emissions. In 2016, Dr. James Orbinski addressed General Council and made abundantly clear the disastrous consequences of climate change for human health if no action is taken.

In closing, the CPHA is a highly credible voice on this critically important issue and I hope that their application will receive favourable consideration.

Sincerely,

Owen Adams

Owen Adams, PhD
Chief Policy Advisor

IN THE MATTER OF A REFERENCE to the Court of Appeal pursuant to section 8 of the *Courts of Justice Act,* RSO 1990, c. C34, by Order-in-Council 1014/2018 respecting the constitutionality of the *Greenhouse Gas Pollution Pricing Act,* Part 5 of the *Budget Implementation Act, 2018, No. 1,* SC 2018, c. 12

Court of Appeal File No.: C65807

COURT OF APPEAL FOR ONTARIO

PROCEEDING COMMENCED AT
TORONTO

**RECORD OF THE INTERVENER,
CANADIAN PUBLIC HEALTH ASSOCIATION
(Reference returnable April 15-18, 2019)**

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