CANADA'S CONTRIBUTION TO MEETING THE TEMPERATURE LIMITS IN THE PARIS CLIMATE AGREEMENT

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At the 2015 United Nations Climate Change Conference (COP 21) in Paris, the world's governments agreed to limit global warming to "well below" 2°C above pre-industrial levels, and recognized that avoiding 1.5°C of warming "would significantly reduce the risks and impacts of climate change." Each of the parties to the United Nations Framework Convention on Climate Change (UNFCCC), including Canada, are responsible for setting national emissions targets as part of the global effort to avoid passing the stated temperature limits.

This brief report evaluates future CO_2 emissions trajectories for Canada that are consistent with the global temperature limits in the Paris Agreement, using a cumulative emissions framework. The cumulative CO_2 emissions over time can roughly predict the amount of long-term warming of the climate system[1,2]. According to the Intergovernmental Panel on Climate Change (IPCC), the ratio of global temperature change to total anthropogenic CO_2 emissions over time is likely to be 0.8°C to 2.5°C per 1000 PgC (for emissions < 2000 PgC)[3]. Here, a range of CO_2 emissions trajectories for Canada which are consistent with the proposed global temperature limits are estimated by scaling the global cumulative CO_2 emissions budgets reported by the IPCC[4] to Canada, and combining them with historical Canadian emissions data.

Due to the cumulative carbon budget methodology, the trajectories do not explicitly include emission of non-CO_2 gases, which comprises 22% of greenhouse gas emissions from Canada over the past decade. Though this analysis is based on the relationship between temperature and cumulative CO_2-only emissions, the computed percent reduction targets could be applied to CO_2 and non-CO_2 gases.

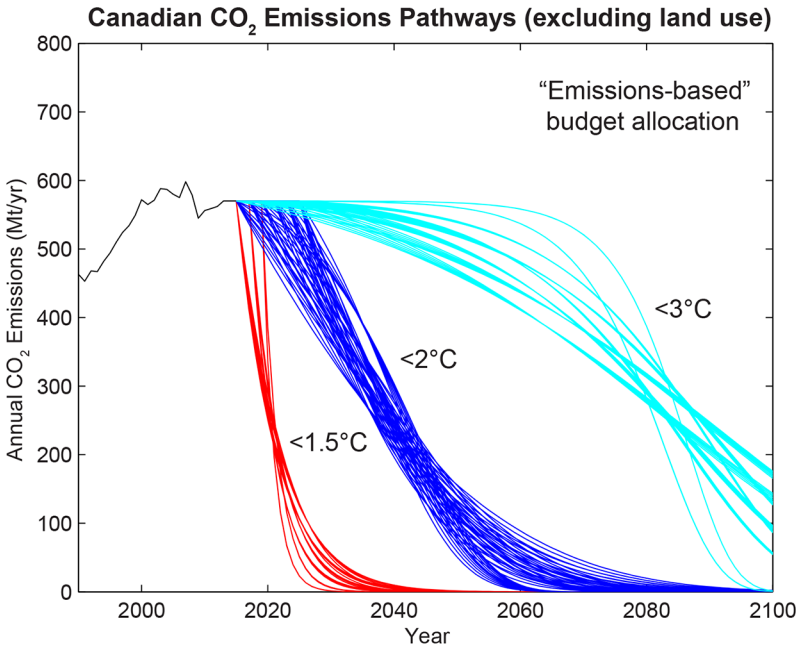
KEY FINDINGS

1. Canada's portion of the global carbon budget is substantially lower if based on a principle of international equity. The analysis assumes that the remaining carbon budget is distributed according to Canada's fraction of the world's CO_2 emissions (1.6-1.8%, see Methods), excluding land use change, land cover change, and forestry (referred to here as 'land use'). An "equity-based" carbon budget, determined based on Canada's fraction of the world's population, is one quarter or less of the size of an "emissions-based" budget.

Remaining Cumulative Canadian CO_2 Emissions (Gt CO_2) from 2016[1]									
Net warming	**<1.5°C**			**<2°C**			**<3°C**		
Probability	66%	50%	33%	66%	50%	33%	66%	50%	33%
Emissions-based budget[2]	3.9	6.6	11.8	14.4	19.7	23.2	38.9	45.9	53.7
Including land use[2]	6.3	9.8	16.7	20.2	27.2	31.8	52.8	62.1	72.5
Equity-based budget[3]	0.7	1.4	2.9	3.6	5.1	6.0	10.4	12.4	14.6

[1] Calculated following Table 2.2 in IPCC (2014), which assumes non-CO_2 forcings follow RCP8.5. Cumulative emissions are based on the time that the temperature limit is exceeded for the stated % of model simulations in the CMIP5 archive
[2] based on Canada's fraction of global CO_2 emissions, using the last ten years of available data
[3] based on Canada's fraction of world's population, excluding land use

2. A carbon budget for Canada with a likely (66%) chance of avoiding 1.5°C of warming globally is extremely limited given current emissions, even with the more generous "emissions-based" budget. It would require a 90% to 99% reduction in emissions below 2005 levels by 2030. The budget is equivalent to less than seven years of emissions at current (2013, year with most recent data) levels without efforts to expand the budget via negative emissions or international credits.



3. The current Canadian target of a 30% reduction below 2005 levels by 2030 is consistent with maintaining a likely chance of limiting warming to less than 2°C globally, only if the generous emissions-based budget is used. The emissions-based budget analysis indicates that emissions must be 15% to 41% below 2005 levels by 2030 to remain consistent with the 2°C warming limit. A target of 29% below 2005 levels by the year 2030 is consistent with the mean emissions pathway. Conversely, if an equity-based allocation is used, emissions would need to be reduced to effectively zero before 2030 to be consistent with the 2°C warming limit.

4. CO_2 emissions must drop to one-fifth of 2005 levels by 2050 to be consistent with maintaining a likely chance of limiting warming to less than 2°C globally in the emissions-based case. The budget analysis indicates that emissions must be 73% to 91% (mean of 81%) below 2005 levels by 2050 to remain consistent with the 2°C warming limit. To maintain a likely chance of avoiding 1.5°C of warming globally, net CO_2 emissions must decline to effectively zero before 2050. To maintain the < 2°C trajectory, emissions must be decreasing at a rate of 2% to 7% per year in 2030, suggesting that measures to accelerate decarbonisation of the economy would need to be in place before 2030.

5. The estimated remaining carbon budget for Canada could be increased through negative emissions, including land carbon uptake or direct air capture technology, through reducing non-CO_2 greenhouse gas emissions, or through securing credits from other nations. For example, to maintain a likely chance of limiting warming to less than 1.5°C globally, but with the larger domestic carbon emissions budget of a < 2°C target, would require 9.8-10.5 Gt CO_2, or 196-210 Mt CO_2/year over fifty years, of negative emissions or credits

6. The size of Canada's remaining emissions budget consistent with avoiding the different temperature limits could be sensitive to the treatment of land use. Net CO_2 emissions from "land use" (land use change, land cover change, and forestry) are highly variable from year to year nationally and globally due to climate and management. If an emissions-based approach is used and land use is included in this analysis, the remaining

budget increases by 0% to 62% and 0% to 43% in the 1.5°C and 2°C cases respectively, depending only on the choice of baseline year. To avoid this uncertainty, future carbon uptake by land may best be treated as a means to expand the remaining carbon budget (finding #5) rather than as a part of the historical budget. This approach is consistent with Canada's Intended Nationally Determined Contribution which includes land use as a possible mitigation measure but excludes land use from the historical emissions data.

METHODS

The Canadian cumulative CO_2 emissions budgets consistent with a likely (66%) chance of avoiding 1.5°C, 2°C, and 3°C of warming globally were computed as the fraction of the global cumulative CO_2 emissions from 2011 in Gt CO_2 from complex models, reported on Table 2.2, IPCC (2014). The fraction is based on Canada's percent of the world's CO_2 emissions over the last ten years as reported in the Global Carbon Project[5] (national emissions) and Canada's 2015 National Inventory Report. The budgets remaining from 2016 onwards in Canada, as reported in the Table above, were estimated by subtracting emissions for the past five years. To assess the sensitivity of the budget to the assumed baselines, the fraction was also calculated using the last five years of data. Emissions since 2013, the last year reported in the National Inventory Report, were assumed to be stable. For comparison, the Canadian cumulative emissions budgets were also calculated on the basis of Canada's proportion of the world's population, using 2014 population estimates from Statistics Canada and the CIA World Factbook.

The emissions trajectories were computed using logistic curves, as in other studies of future emissions trajectories[6]. The one key difference is that other studies compute emissions trajectories with an assigned rate of increase until the year mitigation begins[5]; here it is assumed, based on the past few years, that Canada's emissions will stay level or decline in the future.

The multiple possible trajectories consistent with each emissions budget were computed by varying the midpoint year (2030, 2070, 2100, 2200) and the year the emissions decline (lag of 0, 2, 6, 8, 10 years from 2016) in the logistic equation and solving for k[7]. This method created 56 possible trajectories for the < 2°C and < 3°C; only 20 trajectories are presented for < 1.5°C, because it is not possible for Canada to stay within the 1.5°C budget with six or more years of emissions at present levels.

The entire analysis was conducted twice, once excluding land use and once including land use in national and global historical emissions data. Canada's fraction of the world's emissions including land use varies from 1.6% to 3.2% over the past ten years.

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[1] Zickfeld K et al. (2009) PNAS 106, 16129-16134
[2] Matthews HD et al. (2009) Nature 459, 829-832
[3] IPCC (2014) Climate Change 2014: Synthesis Report
[4] Table 2.2, IPCC (2014)
[5] Data available at http://www.globalcarbonproject.org/carbonbudget/15/data.htm
[6] Raupach MR et al. (2011) Tellus B 63, 145-164
[7] $F(yr) = F_{peak} / (1 + e^{[k*(yr - yr_{midpoint})]})$