CO2 Budget For 4.0°C

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http://ccdatacenter.org/documents/CarbonBudget4DC.pdf

Abstract

If cumulative natural CO2e emissions are about 430 GTC between 2015 and 2100 then the remaining anthropogenic carbon budget for 4.0°C is about 720 GTC. *(Cumulative CO2 emissions will be about 750 GTC if they increase 1%/year through 2030 and decrease by 1%/year through 2100.)*

Details

A.1 Radiative Forcing of Non-CO2 climate factors (other than albedo) in 2100

(averages based on data from the spreadsheet associated with the IPCC 1.5 °C Report)

Count	MinTemp	MaxTemp	CO2	CH4	N2O	Other	Aerosol	Total	Total Non-CO2	CO2 PPM
62	3.51	5.40	5.79	0.71	0.42	0.78	-0.55	7.14	1.35	
53	3.51	4.40	5.62	0.68	0.42	0.76	-0.54	6.94	1.32	
37	3.71	4.26	5.67	0.69	0.42	0.77	-0.54	7.02	1.34	
19	3.81	4.18	5.74	0.69	0.43	0.72	-0.57	7.00	1.27	
12	3.85	4.13	5.68	0.68	0.43	0.68	-0.52	6.94	1.26	805
8	3.90	4.05	5.72	0.66	0.43	0.63	-0.51	6.92	1.21	
3	3.97	3.98	5.67	0.74	0.47	0.61	-0.53	6.95	1.28	

**Number of scenarios that fall within the specified temperature range*

The highlighted row appears to be a reasonable estimate

A.2 Additional Radiative Forcing from Albedo in 2100

A.2.1 Expected radiative forcing from albedo change in the Arctic in 2100 (by the climate models)

Brian J. Soden and Isaac M. Held ("An Assessment of Climate Feedbacks in Coupled Ocean–Atmosphere Models", 2006; http://journals.ametsoc.org/doi/full/10.1175/JCLI3799.1) estimated that the radiative forcing of the models they reviewed (roughly doubling in equivalent CO_2 between 2000 and 2100) was 4.3 W m^{-2} and, "[o]n average, the strongest positive feedback is due to water vapor (1.8 W m^{-2} K^{-1}), followed by clouds (0.68 W m^{-2} K^{-1}), and surface albedo (0.26 W m^{-2} K^{-1}), thus surface albedo changes (primarily Arctic sea ice and Northern Hemisphere snow cover extent) contribute about 6% of the total radiative forcing at the global tropopause.

If the total radiative forcing in 2100 is 6.94 W/m2, the expected contribution from albedo changes is about 0.42 W/m2.

A.2.2 Expected radiative forcing from albedo change in 2100 in the Arctic in 2100 (based on expected changes)

A global radiative heating of 0.71 W/m^2 relative to the 1979 baseline state is expected from an ice-free Arctic Ocean. (https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL082914)

Another estimate (http://ccdatacenter.org/documents/FeedbackFromArcticSeaIceMelt.pdf) which reached the same conclusion estimated that the change in radiative forcing from 1970 to 2100 for Arctic Sea Ice would be about 0.34 W/m2. A similar estimate (http://ccdatacenter.org/documents/FeedbackFromNHSnowCover.pdf) for the change in radiative forcing from 1970 to 2100 for Northern Hemisphere snow cover would be about 0.31 W/m2. This implies that the total albedo change from the Arctic would be about 0.65 W/m2, or about 0.23 W/m2 higher than expected by the climate models.

Note that tundra greening will also likely affect the Arctic's albedo

A.4 Calculate Maximum Radiative Forcing for CO2 in 2100

Radiative Forcing in 2100	
CH4	0.68
CH4 (Add'l-25%)*	0.17
N2O	0.43
Aerosol	-0.52
Other GHGs	0.68
Additional Albedo	0.23
Total Non-CO2 RF	1.67
Total RF	6.94
CO2	5.27

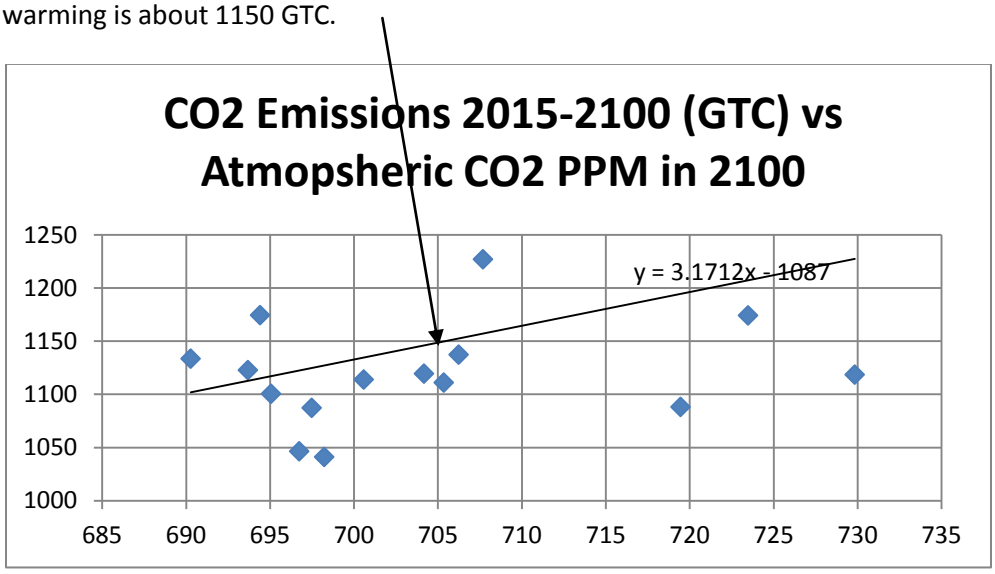
*Older climate models likely underestimated the radiative forcing of methane by 25% (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL071930)

A.5 Calculate PPM for CO2 in 2100 for a climate sensitivity of 2.6

705 PPM (PPM=278 * Power(2.718,CO2 Radiative Forcing/5.35))
(PPM=278*((Equilibrium Temperature/Climate Sensitivity) +1))

A.6 Estimate CO2 Emissions based on IPCC scenarios which resulted in about 705 CO2 PPM

Based on 18 scenarios where the resulting CO2 PPM was between 690 and 730. the expected CO2 emissions for 4°C of warming is about 1150 GTC.



A.7 Estimate Natural emissions 2015-2100 (GTC)

GHG Source	Carbon Store (GTC)	Notes	Likely CO2e Emissions (GTC)
Permafrost	1,600	Cumulative permafrost and wetland emissions (about 55 GTC) could cut 1.5C carbon budget 'by five years' Cumulative permafrost emissions could be 120 GTC by 2100	120
Soils		Cumulative emissions from soil carbon could be as high as 55 GTC through 2050	70
Peat	270 to 370	40% loss by 2100 (100 GTC) 80% loss by 2200 (220 GTC)	100
Surface waters		Cumulative methane emissions from reservoirs could be about 30 GTC through 2060 and 60 GTC through 2100[11] "[G]lobally, lakes and manmade "impoundments" like reservoirs emit about one-fifth the amount of greenhouse gases emitted by the burning of fossil fuels" "[S]cientists have found that this surge in aquatic plant growth could double the methane being emitted from lakes [(to 40% of current fossil fuel emissions)] ... over the next 50 years."	60
Forests		Forests will likely turn from sources to sinks	40
Methyl Hydrates	5,000 to 20,000		
Amazon	86		40
Total			**430**

http://ccdatacenter.org/documents/NaturalEmissionsExpectations.pdf

A.7 Estimate Remaining Anthropogenic Carbon budget for 4.0°C

If all of the above assumptions are correct the remaining anthropogenic carbon budget for 4.0°C is about 720 GTC (1150 -430). *(Cumulative CO2 emissions will be about 750 GTC If the increase 1%/year through 2030 and decrease by 1%/year through 2100)*