Equilibrium Temperature Based on CO2 Emissions

Bruce Parker (bruce@chesdata.com)

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(http://ccdatacenter.org/documents/EquilTempFromEmissions.pdf)

Tables were created for the expected equilibrium temperature for various combinations of for CO2 emissions from 2019-2100, non-CO2 radiative forcing in 2100, and climate sensitivity. The values in the tables were calculated by starting with a formula that calculates a CO2 budget based on nonCO2 radiative forcing, equilibrium temperature, and climate sensitivity[1]: CO2 Budget = (278 * e((5.35 * Ln(1 + ET / CS) - NonCO2RF) /5.35) - 342.87)/ 0.2586. The formula was then "solved" for equilibrium temperature:

ET= (e((ln((0.2586 * CO2 Emissions + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS

Non-CO2 radiative forcing

The Non-CO2 radiative forcing (NonCO2RF) expected for 2100 needs to examined more carefully as the requirements to meet various levels are not well defined. The following table gives the values for the various RCPS (from IPCC Physical Basis AR5):

			IPCC Radiative Forcing Estimates				
Greenhouse Gas	Chemical Formula	Residency Time	2011	2100 - RCP 2.6	2100 - RCP 4.5	2100 - RCP 6.0	2100 - RCP 8.5
Carbon dioxide	CO2	5-200	1.68	2.22	3.54	4.70	6.49
Nitrous oxide	N2O	114	0.17	0.23	0.32	0.41	0.49
CFCs		45-85	0.34	0.10	0.10	0.10	0.10
Methane	CH4	12	0.97	0.27	0.41	0.44	1.08
Other Climate Factors			-0.87	-0.22	0.13	0.35	0.34
Non-CO2 Rad. Forc.			0.61	0.38	0.96	1.30	2.01
Total			2.29	2.60	4.50	6.00	8.50

Natural feedbacks

Many of the emissions from natural feedbacks are temperature-dependent. Given a likely temperature increase of at least 2° C by 2050[2] it seems reasonable that cumulative emissions from natural emissions will likely be in the range of 120-200 GTC by 2100 (not including methane from methyl hydrates)[3,4]

Anthropogenic CO2 emissions

The following tables show the CO2 emissions from 2019-2100 for various combinations of fossil fuel reductions (without BECCS, CCS, or CDR):

9.86	2015 Fossil Fuel Emissions (GTC)
1.6	2015 land use emissions (GTC)
2070	Year when land use emissions reach zero
0.029	Land use decline/year (GTC)
35	CO2 Emissions 2016-2018

	Peak Yr:	2020			2025			2030		
	Pct Chg to Peak Yr:	0	1	2	0	1	2	0	1	2
Annual Pct Change After Peak Yr	0	846	888	931	846	929	1020	846	970	1111
	-1	597	626	656	624	683	748	649	741	846
	-2	445	466	488	484	529	578	522	593	674
	-3	348	365	382	393	429	467	437	495	560
	-4	285	298	312	332	362	393	379	427	482
		Emissions 2019-2100			Emissions 2019-2100			Emissions 2019-2100		

Climate sensitivity

A reasonable value for climate sensitivity (based on is about demonstrated by the models that best capture current conditions) is 3.7[5,6].

Equilibrium Temperature

The following tables show calculations of the equilibrium temperature for various combinations of non-CO2 radiative forcing, climate sensitivity, and total CO2 emissions from 2018-2100 (total CO2 emissions include both anthropogenic and natural and the formula used in the calculation was adjusted to account for 35 GTC of anthropogenic emissions between 2016 and 2018). Yellow highlighted cells give an indication of the maximum emissions that will result in a temperature increase of 1.5° C. Magenta highlighted cells give an indication of the maximum emissions that will result in a temperature increase of 2.0 ° C.

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS																	
		Non-CO2 RF (W/m-2)	0.4	°C													
		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Emissions after 2018 (GTC)	-200	0.33	0.36	0.39	0.43	0.46	0.49	0.52	0.56	0.59	0.62	0.65	0.69	0.72	0.75	0.79	0.82
	-100	0.53	0.58	0.63	0.69	0.74	0.79	0.84	0.90	0.95	1.00	1.06	1.11	1.16	1.21	1.27	1.32
	0	0.73	0.80	0.87	0.95	1.02	1.09	1.17	1.24	1.31	1.38	1.46	1.53	1.60	1.68	1.75	1.82
	100	0.93	1.02	1.11	1.21	1.30	1.39	1.49	1.58	1.67	1.76	1.86	1.95	2.04	2.14	2.23	2.32
	200	1.13	1.24	1.36	1.47	1.58	1.69	1.81	1.92	2.03	2.15	2.26	2.37	2.48	2.60	2.71	2.82
	300	1.33	1.46	1.60	1.73	1.86	1.99	2.13	2.26	2.39	2.53	2.66	2.79	2.93	3.06	3.19	3.32
	400	1.53	1.68	1.84	1.99	2.14	2.30	2.45	2.60	2.75	2.91	3.06	3.21	3.37	3.52	3.67	3.83
	500	1.73	1.90	2.08	2.25	2.42	2.60	2.77	2.94	3.11	3.29	3.46	3.63	3.81	3.98	4.15	4.33
	600	1.93	2.12	2.32	2.51	2.70	2.90	3.09	3.28	3.48	3.67	3.86	4.06	4.25	4.44	4.63	4.83
	700	2.13	2.34	2.56	2.77	2.98	3.20	3.41	3.62	3.84	4.05	4.26	4.48	4.69	4.90	5.12	5.33
	800	2.33	2.57	2.80	3.03	3.26	3.50	3.73	3.96	4.20	4.43	4.66	4.90	5.13	5.36	5.60	5.83
	900	2.53	2.79	3.04	3.29	3.55	3.80	4.05	4.30	4.56	4.81	5.06	5.32	5.57	5.82	6.08	6.33
	1000	2.73	3.01	3.28	3.55	3.83	4.10	4.37	4.65	4.92	5.19	5.47	5.74	6.01	6.29	6.56	6.83
	1100	2.93	3.23	3.52	3.81	4.11	4.40	4.69	4.99	5.28	5.57	5.87	6.16	6.45	6.75	7.04	7.33
	1200	3.13	3.45	3.76	4.07	4.39	4.70	5.01	5.33	5.64	5.95	6.27	6.58	6.89	7.21	7.52	7.83

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS																	
		Non-CO2 RF (W/m-2)	0.6	°C													
		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
	-200	0.42	0.46	0.50	0.54	0.58	0.62	0.67	0.71	0.75	0.79	0.83	0.87	0.92	0.96	1.00	1.04
	-100	0.62	0.69	0.75	0.81	0.87	0.94	1.00	1.06	1.12	1.19	1.25	1.31	1.37	1.44	1.50	1.56
	0	0.83	0.92	1.00	1.08	1.17	1.25	1.33	1.41	1.50	1.58	1.66	1.75	1.83	1.91	2.00	2.08
	100	1.04	1.14	1.25	1.35	1.46	1.56	1.66	1.77	1.87	1.98	2.08	2.18	2.29	2.39	2.50	2.60
	200	1.25	1.37	1.50	1.62	1.75	1.87	2.00	2.12	2.25	2.37	2.50	2.62	2.75	2.87	3.00	3.12
	300	1.46	1.60	1.75	1.89	2.04	2.18	2.33	2.48	2.62	2.77	2.91	3.06	3.20	3.35	3.50	3.64
Emissions	400	1.66	1.83	2.00	2.16	2.33	2.50	2.66	2.83	3.00	3.16	3.33	3.50	3.66	3.83	3.99	4.16
after 2018	500	1.87	2.06	2.25	2.43	2.62	2.81	3.00	3.18	3.37	3.56	3.75	3.93	4.12	4.31	4.49	4.68
(GTC)	600	2.08	2.29	2.50	2.70	2.91	3.12	3.33	3.54	3.75	3.95	4.16	4.37	4.58	4.79	4.99	5.20
	700	2.29	2.52	2.75	2.98	3.20	3.43	3.66	3.89	4.12	4.35	4.58	4.81	5.04	5.26	5.49	5.72
	800	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.24	4.49	4.74	4.99	5.24	5.49	5.74	5.99	6.24
	900	2.70	2.98	3.25	3.52	3.79	4.06	4.33	4.60	4.87	5.14	5.41	5.68	5.95	6.22	6.49	6.76
	1000	2.91	3.20	3.50	3.79	4.08	4.37	4.66	4.95	5.24	5.53	5.83	6.12	6.41	6.70	6.99	7.28
	1100	3.12	3.43	3.75	4.06	4.37	4.68	4.99	5.31	5.62	5.93	6.24	6.55	6.87	7.18	7.49	7.80
	1200	3.33	3.66	4.00	4.33	4.66	4.99	5.33	5.66	5.99	6.33	6.66	6.99	7.32	7.66	7.99	8.32

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS																	
		Non-CO2 RF (W/m-2)	0.8	°C													
		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
	-200	0.51	0.56	0.61	0.66	0.71	0.76	0.81	0.86	0.91	0.97	1.02	1.07	1.12	1.17	1.22	1.27
	-100	0.72	0.80	0.87	0.94	1.01	1.09	1.16	1.23	1.30	1.38	1.45	1.52	1.59	1.67	1.74	1.81
	0	0.94	1.03	1.13	1.22	1.32	1.41	1.50	1.60	1.69	1.79	1.88	1.97	2.07	2.16	2.26	2.35
	100	1.16	1.27	1.39	1.50	1.62	1.73	1.85	1.97	2.08	2.20	2.31	2.43	2.54	2.66	2.77	2.89
	200	1.37	1.51	1.65	1.78	1.92	2.06	2.20	2.33	2.47	2.61	2.74	2.88	3.02	3.16	3.29	3.43
	300	1.59	1.75	1.91	2.06	2.22	2.38	2.54	2.70	2.86	3.02	3.18	3.34	3.49	3.65	3.81	3.97
Emissions	400	1.80	1.98	2.16	2.35	2.53	2.71	2.89	3.07	3.25	3.43	3.61	3.79	3.97	4.15	4.33	4.51
after 2018	500	2.02	2.22	2.42	2.63	2.83	3.03	3.23	3.43	3.64	3.84	4.04	4.24	4.44	4.65	4.85	5.05
(GTC)	600	2.24	2.46	2.68	2.91	3.13	3.35	3.58	3.80	4.03	4.25	4.47	4.70	4.92	5.14	5.37	5.59
	700	2.45	2.70	2.94	3.19	3.43	3.68	3.92	4.17	4.41	4.66	4.90	5.15	5.39	5.64	5.89	6.13
	800	2.67	2.93	3.20	3.47	3.74	4.00	4.27	4.54	4.80	5.07	5.34	5.60	5.87	6.14	6.40	6.67
	900	2.88	3.17	3.46	3.75	4.04	4.33	4.61	4.90	5.19	5.48	5.77	6.06	6.35	6.63	6.92	7.21
	1000	3.10	3.41	3.72	4.03	4.34	4.65	4.96	5.27	5.58	5.89	6.20	6.51	6.82	7.13	7.44	7.75
	1100	3.32	3.65	3.98	4.31	4.64	4.97	5.31	5.64	5.97	6.30	6.63	6.96	7.30	7.63	7.96	8.29
	1200	3.53	3.89	4.24	4.59	4.95	5.30	5.65	6.00	6.36	6.71	7.06	7.42	7.77	8.12	8.48	8.83

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS

Non-CO2 RF (W/m-2) 1.0 °C

		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Emissions after 2018 (GTC)	**-200**	0.60	0.66	0.72	0.78	0.84	0.91	0.97	1.03	1.09	1.15	1.21	1.27	1.33	1.39	1.45	1.51
	-100	0.83	0.91	0.99	1.08	1.16	1.24	1.32	1.41	1.49	1.57	1.66	1.74	1.82	1.90	1.99	2.07
	0	1.05	1.16	1.26	1.37	1.47	1.58	1.68	1.79	1.89	2.00	2.10	2.21	2.31	2.42	2.52	2.63
	100	1.28	1.40	1.53	1.66	1.79	1.91	2.04	2.17	2.30	2.42	2.55	2.68	2.81	2.94	3.06	3.19
	200	1.50	1.65	1.80	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00	3.15	3.30	3.45	3.60	3.75
	300	1.72	1.90	2.07	2.24	2.41	2.59	2.76	2.93	3.10	3.28	3.45	3.62	3.79	3.97	4.14	4.31
	400	1.95	2.14	2.34	2.53	2.73	2.92	3.12	3.31	3.51	3.70	3.90	4.09	4.29	4.48	4.68	4.87
	500	2.17	2.39	2.61	2.83	3.04	3.26	3.48	3.69	3.91	4.13	4.35	4.56	4.78	5.00	5.22	5.43
	600	2.40	2.64	2.88	3.12	3.36	3.60	3.84	4.08	4.32	4.56	4.79	5.03	5.27	5.51	5.75	5.99
	700	2.62	2.88	3.15	3.41	3.67	3.93	4.19	4.46	4.72	4.98	5.24	5.51	5.77	6.03	6.29	6.55
	800	2.85	3.13	3.42	3.70	3.98	4.27	4.55	4.84	5.12	5.41	5.69	5.98	6.26	6.55	6.83	7.11
	900	3.07	3.38	3.68	3.99	4.30	4.61	4.91	5.22	5.53	5.83	6.14	6.45	6.75	7.06	7.37	7.68
	1000	3.29	3.62	3.95	4.28	4.61	4.94	5.27	5.60	5.93	6.26	6.59	6.92	7.25	7.58	7.91	8.24
	1100	3.52	3.87	4.22	4.57	4.93	5.28	5.63	5.98	6.33	6.69	7.04	7.39	7.74	8.09	8.44	8.80
	1200	3.74	4.12	4.49	4.87	5.24	5.61	5.99	6.36	6.74	7.11	7.49	7.86	8.23	8.61	8.98	9.36

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS

Non-CO2 RF (W/m-2) 1.2 °C

		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Emissions after 2018 (GTC)	**-200**	0.70	0.77	0.84	0.91	0.98	1.05	1.12	1.19	1.26	1.34	1.41	1.48	1.55	1.62	1.69	1.76
	-100	0.94	1.03	1.12	1.22	1.31	1.40	1.50	1.59	1.68	1.78	1.87	1.96	2.06	2.15	2.25	2.34
	0	1.17	1.29	1.40	1.52	1.64	1.75	1.87	1.99	2.10	2.22	2.34	2.45	2.57	2.69	2.80	2.92
	100	1.40	1.54	1.68	1.82	1.96	2.10	2.24	2.38	2.52	2.66	2.80	2.94	3.08	3.22	3.36	3.50
	200	1.63	1.80	1.96	2.12	2.29	2.45	2.61	2.78	2.94	3.10	3.27	3.43	3.59	3.76	3.92	4.08
	300	1.87	2.05	2.24	2.43	2.61	2.80	2.99	3.17	3.36	3.55	3.73	3.92	4.11	4.29	4.48	4.67
	400	2.10	2.31	2.52	2.73	2.94	3.15	3.36	3.57	3.78	3.99	4.20	4.41	4.62	4.83	5.04	5.25
	500	2.33	2.57	2.80	3.03	3.27	3.50	3.73	3.96	4.20	4.43	4.66	4.90	5.13	5.36	5.60	5.83
	600	2.56	2.82	3.08	3.33	3.59	3.85	4.10	4.36	4.62	4.87	5.13	5.39	5.64	5.90	6.16	6.41
	700	2.80	3.08	3.36	3.64	3.92	4.20	4.48	4.76	5.04	5.32	5.60	5.88	6.16	6.43	6.71	6.99
	800	3.03	3.33	3.64	3.94	4.24	4.55	4.85	5.15	5.45	5.76	6.06	6.36	6.67	6.97	7.27	7.58
	900	3.26	3.59	3.92	4.24	4.57	4.89	5.22	5.55	5.87	6.20	6.53	6.85	7.18	7.51	7.83	8.16
	1000	3.50	3.85	4.20	4.54	4.89	5.24	5.59	5.94	6.29	6.64	6.99	7.34	7.69	8.04	8.39	8.74
	1100	3.73	4.10	4.47	4.85	5.22	5.59	5.97	6.34	6.71	7.08	7.46	7.83	8.20	8.58	8.95	9.32
	1200	3.96	4.36	4.75	5.15	5.55	5.94	6.34	6.73	7.13	7.53	7.92	8.32	8.72	9.11	9.51	9.90

ET= (power(2.718,((ln((0.2586 * CO2 Emissions after 2015 + 342.87)/278) * 5.35) + NonCO2RF) /5.35) - 1) * CS																	
		Non-CO2 RF (W/m-2]	1.4		°C												
		Climate Sensititivity															
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Emissions after 2018 (GTC)	-200	0.81	0.89	0.97	1.05	1.13	1.21	1.29	1.37	1.45	1.53	1.61	1.69	1.77	1.85	1.93	2.01
	-100	1.05	1.15	1.26	1.36	1.47	1.57	1.68	1.78	1.89	1.99	2.09	2.20	2.30	2.41	2.51	2.62
	0	1.29	1.42	1.55	1.68	1.80	1.93	2.06	2.19	2.32	2.45	2.58	2.71	2.84	2.96	3.09	3.22
	100	1.53	1.68	1.84	1.99	2.14	2.30	2.45	2.60	2.76	2.91	3.06	3.21	3.37	3.52	3.67	3.83
	200	1.77	1.95	2.13	2.30	2.48	2.66	2.84	3.01	3.19	3.37	3.54	3.72	3.90	4.08	4.25	4.43
	300	2.01	2.22	2.42	2.62	2.82	3.02	3.22	3.42	3.62	3.83	4.03	4.23	4.43	4.63	4.83	5.03
	400	2.26	2.48	2.71	2.93	3.16	3.38	3.61	3.83	4.06	4.29	4.51	4.74	4.96	5.19	5.41	5.64
	500	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.49	4.74	4.99	5.24	5.49	5.74	5.99	6.24
	600	2.74	3.01	3.29	3.56	3.83	4.11	4.38	4.66	4.93	5.20	5.48	5.75	6.03	6.30	6.57	6.85
	700	2.98	3.28	3.58	3.87	4.17	4.47	4.77	5.07	5.36	5.66	5.96	6.26	6.56	6.86	7.15	7.45
	800	3.22	3.54	3.87	4.19	4.51	4.83	5.16	5.48	5.80	6.12	6.44	6.77	7.09	7.41	7.73	8.06
	900	3.46	3.81	4.16	4.50	4.85	5.20	5.54	5.89	6.23	6.58	6.93	7.27	7.62	7.97	8.31	8.66
	1000	3.71	4.08	4.45	4.82	5.19	5.56	5.93	6.30	6.67	7.04	7.41	7.78	8.15	8.52	8.89	9.26
	1100	3.95	4.34	4.74	5.13	5.53	5.92	6.32	6.71	7.10	7.50	7.89	8.29	8.68	9.08	9.47	9.87
	1200	4.19	4.61	5.03	5.45	5.86	6.28	6.70	7.12	7.54	7.96	8.38	8.80	9.22	9.63	10.05	10.47

End Notes

1	http://ccdatacenter.org/documents/CO2UptakeExpectations.pdf
2	http://ccdatacenter.org/documents/TempIncreaseExpectations.pdf
3	http://ccdatacenter.org/documents/NaturalEmissionsExpectations.pdf
4	http://ccdatacenter.org/documents/GlobalWarmingFeedbackExpectations.pdf
5	(Footnote #68 in What Lies Beneath (download PDF from https://www.breakthroughonline.org.au/Xu, Y & Ramanathan, V 2017, 'Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes', Proceedings of the National Academy of Sciences, vol. 114, pp. 10315-10323.
6	http://ccdatacenter.org/documents/ClimateSensitivityExpectations.pdf