Developing a Really Simple CO2 Emissions Budget Formula

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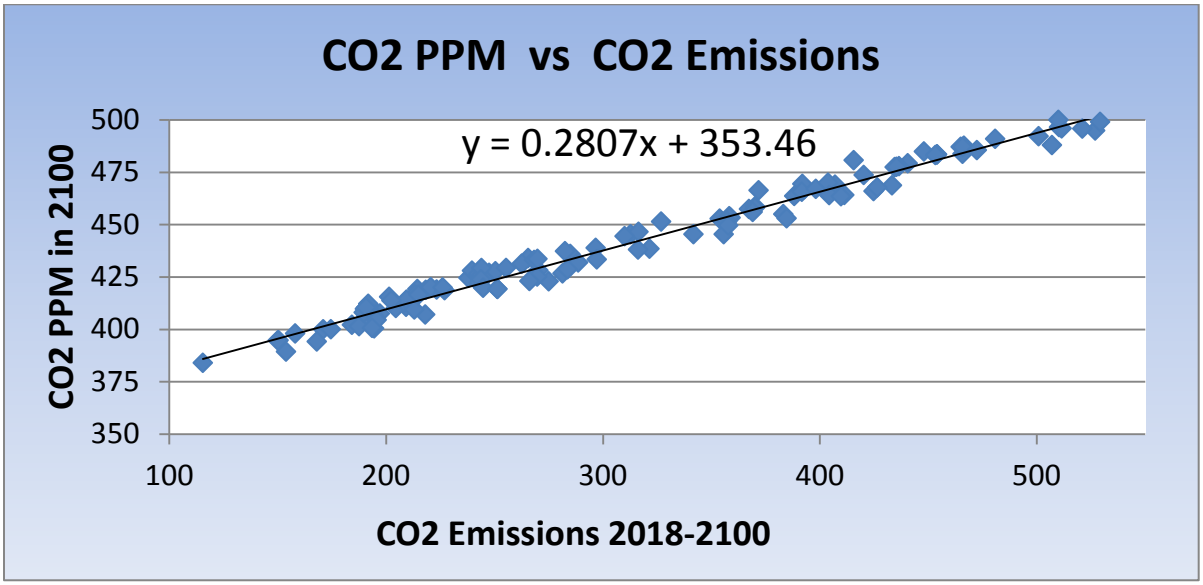
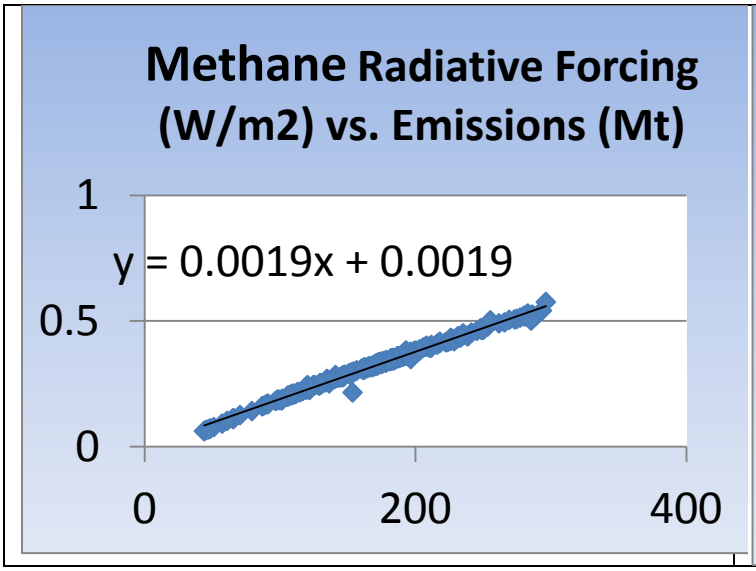
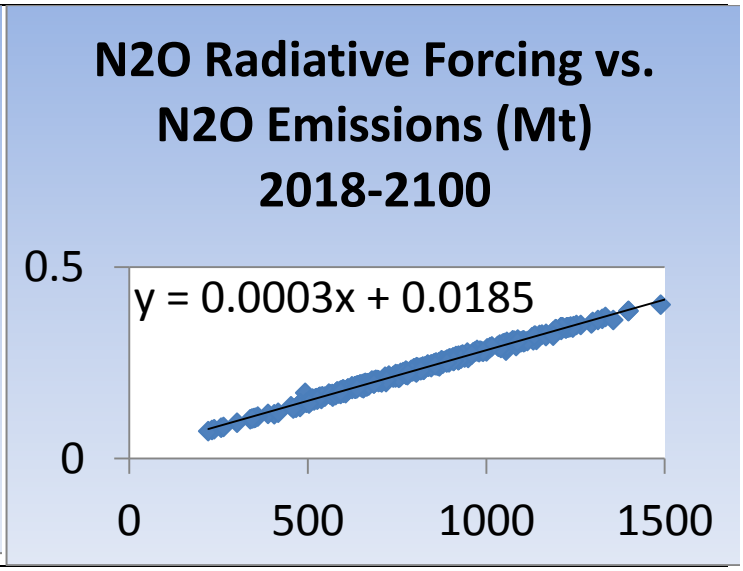
Use the data from the recent IPCC1.5°C report to determine correlations among "climate factors" and create formulas for estimating a CO2 emissions budget:







I could not discover a similar correlation for any of the other radiative forcing elements. But a value of -0.05 W/m2 for all the radiative forcing elements other than CO2, CH2, and N2O provides a relatively close estimate for many of the climate scenarios. This results in the following formula:

Non-CO2RF = 0.0019 * CH4Emissions + 0.0003 * N2OEmissions - 0.03

Combine the above with: Equil. Temp Incr. = Climate Sensitivity * (CO2 PPM - CO2Orig PPM)/ CO2Orig PPM

Radiative Forcing=ln(CO2 PPM / CO2Orig PPM) * 5.35

To get: CO2 emissions budget 2018-2100 =

$$3.5007 * CO2OrigPPM * (1 + ET / CS) * e^{(- Non\text{-}CO2RF /5.35)} - 1232.1$$

where Non-CO2RF =(0.0019*CH4Emissions+0.0003* N2OEmissions -0.03)

How good is the formula?

The formula with values for non-CO2 RF calculates the CO2 emissions budget within 10% for 95% of the 182 FAIR scenarios where the P66 temperature increase is >= 1.4 and CO2 emissions > 60GTC and atmospheric CO2 in 2100 < 500 PPM

The following table shows how the formula using CH4 and N2O emissions compares with the scenario values.

FAIR scenarios where the P66 Temperature increase is >= 1.4 and CO2 Emissions > 60GTC and atmospheric CO2 in 2100 < 500 PPM					
Number of Scenarios	Percentage of Difference Between Scenario CO2 Emissions and Emissions Calculated Based on CH2 and N2O				
	<5%	<10%	<15%	<20%	<25%
182	29	58	80	92	95
135*	40	76	88	96	97
45*+	44	71	84	91	91
30*#	50	96	100	100	100
	Percentage of scenarios where the calculated emissions differ from the scenario emissions by less than a given percent				
*"Other radiative forcing" between -0.18 and 0.1 W/m2					
+ P66 Temperature increase between 1.45 and 1.55					
# 30 of 35 scenarios which used the 'AIM/CGE 2.0' model					

Create tables based on the CO2 emissions budget formulas:

		Temp Increase:	**1.5**	**°C**					
		Climate Sensitivity							
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4
Non-CO2 RF (W/m2)	**0.3**	378	315	263	219	181	148	119	94
	0.4	348	287	235	192	155	122	94	69
	0.5	319	259	208	166	129	97	70	45
	0.6	290	231	182	140	104	73	46	22
	0.7	262	204	155	114	79	49	22	-2
		CO2 Emissions Budget 2018-2100 (Emissions - GTC)							

		Climate Sensitivity:2.6									
		Temp Increase: 1.5 °C									
		Cumulative N2O Emissions (Mt)									
		500	**550**	**600**	**650**	**700**	**750**	**800**	**850**	**900**	**950**
CH4 Emissions 2100	**150**	200	196	192	188	184	180	176	172	168	164
	250	150	146	142	138	134	130	127	123	119	115
	350	101	98	94	90	87	83	79	75	72	68
	450	55	51	48	44	41	37	33	30	26	23
	550	10	6	3	0	-4	-7	-11	-14	-18	-21
	650	-33	-37	-40	-43	-47	-50	-53	-57	-60	-63
	750	-75	-78	-82	-85	-88	-91	-94	-98	-101	-104
		CO2 budget from 2018-2100 (Based on CH4 and N2O - GTC)									

Use the formulas to determine the "model sensitivity":

		Climate Sens.	Temp Increase	Radiative Forcing	Atmos. CO2	CO2 Emis	CH4 Ann. Emis	N2O Emis	$100/ Ton CO2
Climate Factor	**Amt**		°C	W/m2	PPM	(GTC)	(MT)	(MT)	**$Billion**
Climate Sensitivity	0.1		0.063	0.074	5.685	19.9	39.3	248.8	7,303
°C	0.1	0.156		0.117	8.941	31.3	61.8	391.3	11,487
W/m2	0.1	0.135	0.085		7.713	27.0	53.3	337.5	9,909
PPM CO2	1	0.017	0.011	0.013		3.5	6.9	43.8	1,285
CO2 Emissions (GTC)	10	0.050	0.031	0.037	2.857	10.0	19.7	125.0	3,670
CH4 Ann. Emissions (MT)	10	0.025	0.016	0.019	1.457	5.1		63.8	1,872
NO2 Emissions (MT)	100	0.040	0.025	0.030	2.285	8.0	15.8		2,936

It could cost about $11 Trillion to decrease the global temperature 0.1°C by removing 31.3 GTC of CO2 from the atmosphere.

CO2 Emissions Budget Adjustments

CO2 Cumulative Emissions	GTC	115	Initial CO2 emissions budget
CH4 2100 Emissions	Mt	250	Plus 100 Mt from surface waters
N2O Cumulative Emissions	Mt	950	
IPCC 1.5°C report feedbacks	GTC	-30	
CH4 - 25% additional forcing	GTC	-32	=(5.1 GTC/10 Mt CH4) * 250 * 0.25
CH4 - Additional emissions	GTC	-64	=(5.1 GTC/10 Mt CH4) * 100 * 1.25
Adjusted CO2 Emiss. Budget	GTC	-11	(Adjusted anthropogenic CO2 emissions budget)

With adjustments likely needed for climate sensitivity, CH4, and natural emissions, we should plan on there being no remaining anthropogenic CO2 emissions budget.

Carbon Capture and Sequestration Costs

With "business as usual" (BAU), CO2e could be over 750 PPM in 2100. With a temperature increase over 5°C there could be quite significant CH4 emissions from methyl hydrates.
*We are currently at about 500 PPM CO2e. If anthropogenic and natural emissions are about 880 GT though 2100, CO2e PPM would be about 750 PPM CO2e (500 + 880 GTC * .286 PPM/GTC) (assuming the RF from other GHGs remained the same as today). If natural emissions (not including those surface waters, as those emissions are about the same as the carbon budget) are about 250 GTC, then only 630 GTC of anthropogenic emissions are needed. We will almost certainly exceed that.*

If our global society is not willing to fund very significant carbon sequestration (due to high costs at the scale needed) there is a good chance that we could end up with a "hothouse Earth" that is incompatible with life as we know it.

United States Fair Share of Total Carbon Budget

The US has 4% of world's population; historical US CO2 emissions are about 17% of the total carbon budget.

If future US emissions are 100 GTCCO2 and average capture and sequestration costs are $100/Ton CO2, then the US would need to spend at least $10 Trillion (about 1/2 of the total US debt) in the next 40 years to capture future CO2 emissions.