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Assessment of Global Temperature Rise Based Upon Approved Algorithms

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Abstract

This Article presents the results of an independent assessment of the estimated global temperature increase since the 1.1degree Celsius measured in 2020. It illustrates that the goals of the 2015 Paris Climate Agreement can be met by the end of the century by gradually reducing Carbon Dioxide emissions from present levels. The required rate of global emissions reductions is significantly less than those estimated by the United Nations reports. Most of the difference in estimates can be attributed to an error that was made by the UN in figuring the future atmospheric concentration of Methane. All of the various agency reports forgot to account for the short 12-year lifetime of CH4 that must be subtracted from the total new yearly emissions to then yield very small net concentration and temperature increases. The Nations of the World will be jubilant to hear that they now have both more time and lower yearly emission reduction requirements than currently reported.

Introduction

The purpose of this Article is primarily to present a new methodology for the accurate estimation of future global warming caused by continued worldwide greenhouse gas (GHG) emissions, primarily carbon dioxide (CO2). The objective is to determine how rapidly CO2 emissions must be reduced to meet the temperature-rise goals of the 2015 Paris Agreement (PA). Those goals were to limit the average global increase to 1.5 degrees Celsius (C) as soon as feasible, or if not possible, to limit the rise to well below 2.0 C by the year 2100. These increases are measured with respect to pre-industrial levels in 1880. We presently stand at 1.1 deg. C rise in 2020 (1).

A complimentary objective of this Article is to present the analysis with accompanying discussion that will enable the typical reader to better follow and understand the complex derivation process involved. This means that climate scientists must tolerate information of which they are already aware, but that will be new to others. These dual purposes are desired for all Articles to serve the widest reader audience. For example, an average 1.5 deg. C global temperature rise would consist of approximately 1.0 deg. rise for ocean waters (75% of global surface area), and approximately 3.0 deg. C for inland locations (apart from the coastal areas) with 25% surface area. Please be made aware that the 3.0 deg. C is the average land rise, while many areas are likely to be nearly twice that amount. For those on the Fahrenheit (F) temperature scale, those figures translate to 5.4 deg. to 10.8 deg. F. Those larger numbers will attract peoples' attention to the fact that this is indeed a serious problem.

It is recognized that the United Nations (UN) and other climate specialists have taken the lead role in determining how GHGs cause global temperature to increase, and how quickly emissions must be reduced to limit that increase to the goals of the PA. Technically, this thermodynamic process is referred to as the "anthropogenic" heating of our planet. The UN coordinates the efforts of nearly 200 countries to make their own nationally determined contributions (NDCs) towards the overall reduction amount required to meet their goals. The latest detailed planning information is documented in the Climate Action Tracker (CAT) Report (2) which summarizes the results from the November 2021 Conference of Parties (COP26) held in Glasgow, Scotland. Additional information is available in the recent International Panel on Climate Change (IPCC) Assessment Report (AR) No. 6 (1). This Article will have been peer-reviewed for authenticity based upon the included detailed calculations and referenced material. Two relatively new published papers have been used to improve the fidelity of the calculations. Additionally, the equilibrium climate sensitivity (ECS) factor has been redetermined to reflect the 20th century cooling caused by two volcanic eruptions. It is 25% higher going forward than presently used by the UN.

Summary of Results

This Article on how to combat global Warming of our planet represents a "technical breakthrough" for all our nations' ability to both lower their required carbon dioxide emissions and do so more gradually and still meet the goals of the 2015 PA. The details of the entire computational process are included in both an Extended Data and a Supplemental Data Addendum for reviewers to verify all the results presented and online. Fortuitously, this independent analysis shows that the 1.5-degree C temperature rise goal set by the PA-2015 is still realistically achievable. This assumes that the NDCs submitted by most countries to the UN Conference of Parties (COP in 2021) remain partially in effect. In fact, significant reductions in the pledged amounts made by individual nations would be allowed according to this new analysis. This occurs because the targeted 0.4 deg. C temperature rise goal, above 1.1 deg. C. in 2020 (+/-0.1 C) can be met with a CO2 reduction rate of 0.6 Gigatonne (Gt) per year 26 (from 40 Gt in 2020) to 2066, where a 12.4 Gt net-zero value will exist for emissions.

This shows a need for a 70% reduction. Note that one Gt is a billion metric tonnes and a metric tonne is 1,000 kilograms or 2,200 pounds. For clarification, net zero is the point in time where the CO2 emissions will be reduced to the same level as the carbon sinks (the sinks are the amount of CO2 absorptions made by the earth at that time). The amount of those carbon sinks each year is a function of the individual CO2 emissions made over the last 100 years. Table 1 in the Extended Data shows the emission values used from 1900 to 2020, while Table 2 in the main text shows the simplified method for calculating carbon sink values by year. It should be noted that CO2 emissions are gradually dissipated down to 40% of their initial amount. The temperature rise is halted at the net-zero point because there is no further increase in atmospheric concentrations. To view a range of possibilities that meet the PA goals, three different reduction pathways were selected that meet their objectives. Tables 8, 10 and 12 in the Extended Data show the sink calculations made for the three selected pathways of 0.4, 0.5 and 0.6 GtCO2 per year reductions, respectively. Next, Tables 9, 11 and 13 in the Extended Data show the yearly CO2 concentrations for the 0.4, 0.5 and 0.6 GtCO2 per year pathways, respectively. The pathways end at net-zero values of 10.4 Gt/yr, 12.0 Gt/yr and 12.4 Gt/yr in 2094, 2076, and 2066, respectively.

Table 1: List of Past Annual Carbon Dioxide Emissions Used From 1900 to 2020

Year	Gigatonne	Year	Gigatonne	Year	Gigatonne
1900	6.0	1971	20.5	1997	29.1
1910	7.0	1972	21.0	1998	29.4
1920	8.0	1973	21.5	1999	29.7
1930	9.0	1974	22.0	2000	30.0
1940	10.0	1975	22.5	2001	31.0
1950	10.0	1976	23.0	2002	32.0
1951	10.5	1977	23.5	2003	33.0
1952	11.0	1978	24.0	2004	34.0
1953	11.5	1979	24.5	2005	35.0
1954	12.0	1980	25.0	2006	38.0
1955	12.5	1981	25.2	2007	39.0
1956	13.0	1982	25.4	2008	40.0
1957	13.5	1983	25.6	2009	41.0
1958	14.0	1984	25.8	2010	41.2
1959	14.5	1985	26.0	2011	41.4
1960	15.0	1986	26.2	2012	41.6
1961	15.5	1987	26.4	2013	41.8
1962	16.0	1988	26.6	2014	41.0
1963	16.5	1989	26.8	2015	41.2
1964	17.0	1990	27.0	2016	41.4
1965	17.5	1991	27.3	2017	41.6
1966	18.0	1992	27.6	2018	41.8
1967	18.5	1993	27.9	2019	42.0
1968	19.0	1994	28.2	2020	40.5
1969	19.5	1995	28.5		
1970	20.0	1996	28.8		

The net result in 2066 represents a 27.6 GtCO2 reduction from the initial 40 GtCO2 in 2020. It can be reached through the yearly emission reduction of 0.6 Gt, and possibly with supplemental carbon capture technology if available. Realize that 12.4 GtCO2 of emissions will still be allowed. On average, this value approximately 1.5 tonne per capita of the world population. Hence, it is not necessary to halt all CO2 emissions when calculating net-zero reductions applicable for a country. If emissions reductions should be extended to 2100, there is still a feasible pathway to limit the temperature overall rise to 1.7 +/- 0.15 deg. C. This is still much lower than the 2.4-deg. C rise published by the UN through the CAT Report. Hence, it shows that the PA-2015 secondary goal of "well below 2.0 deg. C by year 2100" can also be met using the lowered annual reduction amount of 0.4 GtCO2 per year to meet a 10.4 Gt net-zero value in 2094 (which is a 75% CO2 reduction). Note that these temperature-rise estimates include the expected smaller contributions made by methane (CH4) and nitrous oxide (N20). Such significantly improved results deserve further investigation, and verification revision by the UN.

Methodology

To provide the UN and all nations with a better understanding of the various final temperature-goal options, three idealized CO2 emission reduction pathways were used to calculate estimated temperature increases above the 1.1 deg. C level seen in 2020. They are represented by linear annual reductions of 0.4, 0.5 and 0.6 GtCO2. These reference pathways start at 40 Gt in 2020 and end when they reach a carbon neutral condition (called net-zero) with the Earth's carbon sinks absorbing the same amount as new CO2 emissions made at that year. This has been 12 calculated to occur in 2094, 2076 and 2066 at CO2 emission levels of 10.4 Gt, 12.0 Gt and 12.4 Gt, respectively. Thereafter, smaller annual reduction amounts are still needed because the sink amounts will continue to fall-off slowly. It is hopeful that carbon capture technology can then be utilized to fill the difference. These three pathways and their corresponding sink amounts are plotted in Figure 1 to be discussed next.

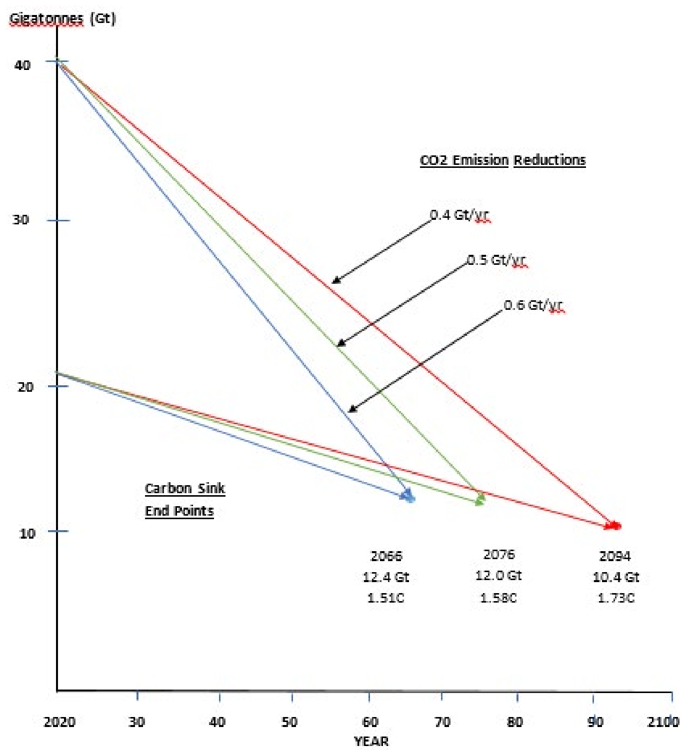

Figure 1: CO2 Emission reduction pathways to net-zero

The first step was to compute the values of what the CO2 sinks would be for each year of the proposed pathways. Then, those sink values are subtracted from the yearly emissions to yield the net increase in CO2 concentrations out to the year where the net increase will be zero for each pathway. It is those accumulated CO2 concentrations that are used by the American Geophysical Union (AGU) (3) equations to calculate the radiative forcing (in Watts per square meter) that will exist at that time. In addition, the accumulated concentrations of both CH4 and N2O are used to separately-compute their forcing. The sum of the three forcings is then used to determine the temperature rise using a predetermined equalization climate sensitivity (ECS) factor. Recall that the amount of heat that can be radiated to deep space is proportional to the fourth power of absolute temperature. Hence, it takes only a small change in temperature to radiate a very large amount of heat. In addition, approximately 90% of the GHG heat generated is absorbed by ocean waters so which acts as a major buffer to limit the global temperature increase that we experience.

What is new to the analysis performed is the application of recent calculations of the amount of CO_2 that is absorbed from the atmosphere each year based upon CO_2 emissions made over the prior 100 years (4). Also new is a set of equations in Table 3 that better estimate the radiative forcing in Watts/sq-meter for each of the three GHGs of CO_2, CH_4 and N_2O that are converted to temperature increases using the new ECS. A new higher value for the ECS factor has been derived to compensate for the negative forcing introduced by the past volcanic eruptions that have allegedly reduced the 1.1 C measured temperature rise by approximately 0.3 deg. The CH_4 global warming potential (GWP) of 25 was incorrectly applied by CAT to new emissions and not the atmospheric concentrations. This incorrect application fails to compensate for dissipations due to the 12-year lifetime of that gas (the GWP of 25 means that CH_4 is approximately 25 times more effective in GHG heating than CO_2). Similarly, the GWP for N_2O is nearly 300 but those emissions are low, and the average lifetime is 100 years, so there is little difference.

The CH_4 misinterpretation was also made by the IPCC in their Special Report on 1.5 C of Global Warming (5), and by the United Nations Environmental Programme (UNEP) Emission Gap Report (6). Consequently, their CH_4 concentrations and temperature rise were higher than they should be the wide difference in results seen were also complicated using carbon emissions budgets that were far smaller than they should be even the IPCC's AR6 report incorrectly used the application of the CH_4 GWP value to the new emission amounts (rather than the resultant small increase in concentration) in their calculation of temperature increases for their five representative concentration pathways (RCPs). No attempt has been made to calculate the effects of atmospheric water vapor content, other gases, cloud cover, Pacific Ocean currents or odd weather effects that have both increased and decreased the global temperature rise that is measured throughout each year. It is left up to analysts to "try to separate the noise from the signal" over temperature changes seen due to fossil fuels.

Pictorial Presentation of Results

These selected reduction pathway results are shown in Figure 1 along with their approximate carbon sink paths out to their net-zero years. Table 4 shows the exact amounts of the carbon sinks as calculated in the Extended Data. Table 5 shows a tabulation of the year when CO_2 concentrations reach net-zero, along with the concentrations and net increases in both Gt and parts-per-million (ppm). Table 6 shows the three GHG concentrations at their net-zero year compared to 2020 in both ppm and parts-per-billion (ppb). These concentrations are used to compute both radiative forcing and temperature rise as shown in Table 7. The nominal temperature rises above 1.1 deg. C in 2020 are shown as 0.63-, 0.48- and 0.41-degree C (these figures should be accurate to +/- 25%) for the reductions increments of 0.4, 0.5 and 0.6 Gt, respectively.

The post- industrial totals are then 1.73-, 1.58- and 1.51 deg. C (+/- 0.15 C) for 2094, 2076 and 2066, respectively. The reason for splitting the overall temperature rise into pre and post 2020 is that two different ECS values (3.7 and 4.7, respectively) are used for pre and post 2020 added GHG concentrations and the associated radiative forcings. Note that the ECS factors differ by nearly 30% after accounting for the observed temperature decrease caused by 20th century century. The volcanic ash contribution has been calculated to have caused he two volcanic eruptions in the approximately a 0.3 deg. C temperature decrease from 1900 to 2020. Please see Table 20 and Figure 2 in the Supplemental Data. Observe the calculated CO_2 concentration increases from 2020 to net-zero are 683, 503 and 422 $GtCO_2$, respectively They represent gradients of 1084, 1048 and 1029 $GtCO_2$ per deg C, respectively, and illustrate the consistency of the results. The notes at the bottom of Table 7 explain how the estimated CH_4 increases were specifically handled.

Background Research

An extensive review was made of historical climate records related to greenhouse gas (GHG) emissions of all types, their atmospheric concentrations, and the resulting global temperature rise of 1.1 deg. C occurring from 1880 to 2020. It was verified that CO_2 was by far the dominant greenhouse gas with methane (CH_4) and nitrous oxide (N_2O) significantly playing lessor roles. For simpler analysis purposes, many scientists have used the CO_2-equivalent method to help translate the higher per unit mass heating effects of CH_4 and N_2O. This is accomplished by assigning global warming Potential (GWP) values to create a composite CO_2e (equivalent) amount. However, experience has shown that it is best to determine the temperature rise using the more accurate radiative forcing concept for each gas. That is what has been done herein. The use of so-called carbon budgets based upon accumulated CO_2 emissions has not been shown to be of sufficient accuracy for predicting temperature increases. The radiative forcing equations were obtained from a Research Letter by the American Geophysical Union (AGU) (3).

They are rewritten and attached as supporting material. Also included are data tables for the detailed computations for the three selected CO_2 pathways so all numbers can be verified. The most recently published results from the Global Carbon Project (7) were used for the estimation of past global GHG quantities of emissions, net added emissions and future annual atmospheric concentration estimates for each gas. The calculations for the Earth's carbon sinks were taken from Figure 3-4 shown in the AR5 report (4). The algorithm was simplified for ease in the hand calculations covering past the100-year periods. The declining exponential profile was broken into seven time periods of 3, 3, 4, 10, 20, 20, and 40 years. This procedure is shown in Table 2.

Table 2: Simplified Method for Calculating Carbon Sink Values by Year

Years Past	% per year	Cum %	Interval Years	Amount Gt	Sink Amount
1 - 3	7.00	21.0	3	125	8.75
4 - 6	3.00	9.0	3	124	3.72
7 - 10	1.50	6.0	4	165	2.40
11 -19	0.50	5.0	10	340	1.70
20-39	0.40	8.0	20	550	2.20
40 – 59	0.30	6.0	20	400	1.20
60 – 100	0.15	6.0	40	415	0.62

This table presents the simplified method used for calculating the yearly carbon sink values based upon the reduction curve presented in Reference 2, for a 100-year period and 60% total CO2 reduction. It breaks down the 100 -year period into seven intervals and assigns an average percentage decrease for years in those periods. This was done to facilitate the ease of hand calculation for selected years. The numerical results shown in Table 1 and for 2020, use the CO2 emission data from Table 1 for 1920 to 2020. The Gt CO2 amount column was derived directly from that data, and the sink amount column reflects the application of the collective present values shown in column three.

The 2020 sink amount of 20.67 Gt implies a concentratiKeeling Curve measurements increase of 19.5 Gt. on increase of 19.83 Gt. This figure agrees with the Other tables are included to show the individual calculations made for multiple points on each pathway. An increase was made to the climate sensitivity factor going forward because the 2020 temperature of 1.1 deg. C was influenced by the negative forcings of volcanic ash in the 20th century. The new factor is based upon CO2 concentration history only and leads to a separately calculated anthropogenic value of 1.4 deg. C., not 1.1 deg. C. This is illustrated by Figure 2 in the Supplemental Data.

Detailed Calculations of Results

Calculations were completed showing the CO2 concentration build-ups year after year based upon each emission pathway selected, minus the annual carbon sink amounts. The carbon sink amounts were calculated each year based upon the individual yearly emission amounts over the last 100 years as convolved with the IPCC AR5 (4) algorithm showing how CO2 is gradually absorbed down to 40% of the original emission amount. Figure 1 provides a graphical overview to illustrate how the linear emission reduction pathways decline to meet the slowly decreasing annual carbon sink amounts. The year of those intersections and net-zero emissions are shown. The continuing effect of CH4 and N2O added concentrations at those times are small enough to be neglected, as will be shown, so they do not need to be offset by further CO2 decreases. Carbon sink amounts were calculated on 20-year intervals with straight-lines used between points. Table 4 shows the results of the CO2 sink calculations, with a note that the variations seen become more logical when plotted as in Figure 1.

Table 5 shows the tabulation of results after the year-by-year net CO2 concentration calculations for the three pathways. One can see the sharp rise in added concentration of Gt, 87.6 parts-per-million (ppm) in going out to the 0.4 GtCO2 per year reduction limit for 2094. The concentrations for 2066, 2076 and 2094 for the calculation of their radiative forcing starting from 2020 increased by 132 ppm above the 1880 level of 280 ppm. Table 6 shows the values of atmospheric concentrations for CH4 and N2O (ref4) to be used for their separate calculations of radiative forcing to be added to those for CO2 (also shown). Table 7 presents a summary of the total forcings for the three pathways and the associated temperature-rise estimates as a function of the assumed climate-sensitivity factor and the endpoint CH4 concentration amount.

While one can compute the climate sensitivity seen between 1880 and 2020, one cannot assume that volcanic action will continue. There were many unpredictable negative natural forcing events that occurred that could change the eventual future outcome. The uncertain final CH4 concentration was also used as a parameter to assess its impact on the temperature rise. Figure 2 is a graphical comparison of the temperature rise profile for 0.6 GtCO2/year of emissions versus the natural logarithm of the actual CO2 emissions. Their close correspondence is as expected There is concern that widespread future CO2 emissions reductions may not occur until 2030, so it would be ducational to know how this would impact the present temperature estimates. In all cases, there would be approximately a ten-year delay in reaching net-zero, and the temperature increase would be approximately 0.16 deg. for a CO2 concentration increase of 200 GtCO2 during the 2020-2030 decade. As one can see, such an unfortunate delay in making CO2 reductions would be significant but not catastrophic.

Table 3: Formulae for Calculating Radiative Forcing for CO2, CH4 and N2O from 2016 AGU Paper

CO2	RF = [a1(C-CO)exp2 + b1(C-Co) + c1Navg + 5.36] x ln(C/CO) W/sqm
with:	a1=-2.4X(10exp-7) (W/mexp2)/ppm
	b1=7.2X(10exp-4) (W/mexp2)/ppm
	c1=-2.1X(10exp-4) (W/mexp2)/ppb
	C= Final CO2 concentration in ppm
	CO= Initial CO2 concentration in ppm
	ppm= parts per million
	ppb=parts per billion
	exp=exponent value
	Navg=middle N20 values in ppb over interval (N+ND)/2
N20	RF = [a2Cavg. + b2Navg+c2Mavg + 0.117] (sqrtN - sqrtND) W/sqm
with:	a2=-8.0X(10exp-6) (W/mexp2)/ppm
	b2=4.7K(10exp-6) (W/mexp2)/ppb
	c2=-4.9X(10exp-6) (W/mexp2)/ppb
	N= Final N20 concentration in ppb
	ND= Initial N20 concentration in ppb
	Cavg= middle CO2 value in ppm over interval; (C+CO)/2
	Mavg= middle CH4 value in ppb over interval; (M+MO/2
	C, CO, Navg are as above
	sqrt= square root
CH4	RF = [a3 Mavg + b3Navg + 0.043] (sqrtM - sqrtMO) W/sqm
with:	a3=-1.3X(10exp-6) (W/mexp2)/ppb
	b3=8.2X(10exp-6) (W/mexp2)/ppb
	M=Final Methane concentration in ppb
	MO= Initial Methane concentration in ppb
	CO= Initial CO2 concentration in ppm
	See above for other definitions

Table 4: Carbon Sink Values for Three CO2 Pathways

Year/Pathway	0.6Gt/year	0.5Gt/year	0.4Gt/year
2020	20.67	20.67	20.67
2040	18.33	18.48	19.59
2060	14.12	15.68	16.07
2080	8.42	11.19	12.22
2100	–	5.96	9.70

Table 5: Years and CO2 Emissions for Carbon Neutral Status

Item/Pathway	0.6Gt/year	0.5Gt/year	0.4Gt/year
Year	2066	2076	2094
CO2 Emissions Gt	12.4	12.0	10.4
% Reduction	69%	70%	74%
CO2 Concentration Gt	3642	3722	3892
CO2 Concentration ppm	466.9	477.2	499.6
CO2 Rise Gt	422	508	683
CO2 Rise ppm	54.1	65.2	87.6

Table 6: Atmospheric Concentration Summary

Pathway	Year 2020	0.6 Gt/yr	0.5 Gt/yr	0.4 Gt/yr
Year of Neutral	n/a	2066	2076	2094
CO2 Increase – ppm	–	54.1	65.2	87.6
CO2 Total – ppm	412	466.1	477.2	499.6
CH4 Increase – ppb	–	210	210	210
CH4 Total – ppb	1890	2100	2100	2100
N20 Increase – ppb	–	46	56	80
N20 Total – ppb	333	379	389	413

Table 7: Radiative forcings and temperature increases from 2020 to Net-Zero Year

Pathway	0.6Gt/yr	0.5Gt/yr	0.4Gt/yr
Net Zero Year	2066	2076	2094
CO2 Forcing - Watts/sqm	.654	.783	1.025
CO2 Temp Rise - degC	0.24	0.30	0.38
CH4 Forcing - Watts/sqm	0.089	0.089	0.089
CH4 Temp Rise - degC**	0.033	0.033	0.033
N20 Forcing - Watts/sqm	0.128	0.154	0.226
N20 Temp Rise - degC	0.047	0.057	0.084
Total Forcing - Watts/sqm	0.871	1.026	1.340
Total Temp Rise - degC*	0.32	0.39	0.50
(CSF = 0.37C/Watts/sqm) Maximum Temp Rise - degC* (CSF=0.47C/ Watts/sqm)	0.41	0.48	0.63

*The maximum values assume that the Climate Sensitivity Factor (CSF) is increased from 0.37 deg. C per RF observed amount in 1880 to 0.47 in 2020, to allow for the volcanic cooling seen. **It is further noted that the temperature increase due to a higher fixed CH4 concentration than the assumed 2100 ppb was computed as an approximate 0.04 deg. C per 100 ppb added increase.

Grateful to Nature

We humans must be extremely thankful that the laws of nature and physics have worked in our favor to prevent us from destroying the planet upon which life has been sustained for millenniums. Our ever-increasing production of heat energy from the burning of fossil fuels has led to a critical juncture in time. We simply cannot continue to produce CO2 emissions that add to the present concentrations and threaten the existing stable living environment upon this Earth. Fortunately, the laws of physics have played a very forgiving role in diminishing the adverse impact we have made in pursuit of the energy-intensive, pleasurable lifestyles we now demand. One must realize that our cool ocean waters absorb 90% of the heat generated by greenhouse gas emissions.Otherwise, the present global temperature rise would already be unbearable. Yes, of course, it punishes life in the oceans, but that’s the alternative, however it cannot be sustained forever. Also, were it not for the fact that the remaining 10% of GHG heat gets radiated to deep space according to the fourth power of absolute temperature, we would see much a higher global temperature rise.

This means that very little surface temperature increase is required to make a large change in the heat radiated. Thankfully, the CO2 emissions do not stay in the atmosphere forever. They will dissipate approximately 60% over a 100-year period, and it is those dissipations that sum-up to the total sink amount for a given future year. Here again, it is the ocean waters that pay the price with increased acidification as they absorb large amounts of CO2. Also gratefully, the thermal energy absorption by CO2 molecules diminishes with increased CO2 concentration buildup, so a mild saturation effect is present as represented by the natural logarithm of the fractional increase, e.g., a doubling of CO2 would lead to only a 69% increase above the prior temperature. It may not sound like much, but the 20th century volcanic activity lowered the average global temperature by an estimated 0.3 deg. C., but we should not hope for a repeat performance. Next, the Pacific Ocean's La Nina currents appreciably lowered the global average temperature near the end of 2021 to 1.05 deg. C. per recent reports, but the trend in 2022 is closer to a 1.2 C. average. Now you be the judge, just how protective and forgiving is our planet to our ever-increasing energy demands.

Conclusions

It has been demonstrated that the proper application of a new algorithm for the determination of yearly carbon sink values has led to a lower atmospheric concentration of CO2 than UN reports would indicate for the same number of emissions. In addition, the use of the more refined equations for calculating radiative forcing based upon the GHG concentrations has shown the Watts/sq-meter values to be less than those used by the UN. Consequently, the resultant temperature rise values are appreciably lower. This enables an extension of the time frame over which reductions can be made and the reductions required can be less per year (0.6 GtCO2) to reach the net-zero level of 12.4 GtCO2 per year in 2066. Also note the ending net-zero value is much higher as it is based upon the larger sink values. This means that the final total reduction amount below the 40 Gt level in 2020 can be less at 27.6-Gt. The temperature rise for the same emissions would still be lower were it not for the need to increase the ECS from 3.7 to 4.7 to compensate for the negative temperature due to volcanic ash during the 1900s. It is recommended that the UN take immediate action to investigate their results and take remedial action.

We Can do Better

We should be preparing ourselves for a transitional mode of low fossil energy living for future generations. However, we humans continue to push the limits on our Earthen environment and survival in favor of near-term economic gains with grandiose lifestyles that simply cannot be sustained much longer. It will eventually take a total transformational change by all of society to live with very low energy consumption. The anticipated large increase in renewable energy production alone (solar, wind, tides, waves and geothermal) cannot close the gap caused by massive fossil fuel usage reductions. The increased use of nuclear power may be an option as well. The anticipated carbon dioxide recapture process may provide only a partial solution. It could take the exorbitant pricing of fossil fuels to limit consumer demand because of their lack of affordability. As a last resort, governments might resort to usage restrictions or possibly even rationing as done in the US during World War II. Gone will be the days of limitless energy consumption. Society must reluctantly adapt to new, more conservative living standards. However, of course, the rich and famous will likely be slow to comply.

Acknowledgements

This author is grateful to the members of the American Geophysical Union (AGU) for providing their 2016 Geophysical Research Letter containing detailed analysis of how to accurately compute Radiative Forcing based upon the atmospheric concentrations of CO2, CH4 and N20. It is the cornerstone of this Article. This author is also thankful that a more precise model was developed by multiple agencies for the estimation of 26 yearly carbon sink amounts based upon the CO2 emissions history over the last 100 years. The authors are identified in the Section 6 AR5 description.

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