

Necessary Change in CO2 Emissions per Capita to Reach 1.5°C-2.0°C Climate Change Limit in 2100

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Abstract

The necessary cumulative CO2 emissions reduction to reach the 1.5°C Global Warming limit in 2100 is 2,359,526 MtCO₂. This may be done by decreasing the world's CO2 emissions per capita (CpC) annually by 17%.

The necessary cumulative CO2 emissions reduction to reach the 1.7°C Global Warming limit in 2100 is 2,085,593 MtCO₂. This may be done by decreasing the world's CO2 emissions per capita (CpC) annually by 7.85%.

The necessary cumulative CO2 emissions reduction to reach the 2.0°C Global Warming limit in 2100 is 1,683,503 MtCO₂. This may be done by decreasing the world's CO2 emissions per capita (CpC) annually by 4.46%.

Keywords: Climate Change, Global Warming, CO2 emissions, CO2 per capita, Global Warming forecast

Glossary

ΔCO_2	CO2 emissions of the country above the world emissions per capita in the period 1991-2020, tCO2
$\Delta\text{CO}_2/\text{y}$	change in CO2 emissions per year
$\Sigma\Delta\text{CO}_2/\text{y}$	cumulative change in CO2 emissions per year in 2100 in the mitigation program
$\Sigma\Sigma\Delta\text{CO}_2/\text{y}$	sum of cumulative (2026-2100) change in CO2 emissions per year in the mitigation program
Ave	average
BAU	Business as Usual
BL	baseline
CCO2	global cumulative CO2 emissions according to publication [1] [2], CO2 emissions produced from fossil fuels and cement production only – land use change is not included, tCO2
CO2	emissions of Carbon Dioxide, CO2
$\text{CO}_2 \rightarrow \text{GW}$	correlation between cumulative CO2 emissions and Global Warming = 0.000745°C/GtCO2 [3]
CpC	CO2 emissions per capita, tCO2/y,cap (ton CO2 per year, per population of the country)
Global Warming	global surface temperature change over land+ocean above 1850-1900 baseline (°C)
GtCO2	Giga-ton of CO2, 10 ⁹ ton, 10 ⁹ ton, 1,000,000,000 ton of CO2
MtCO2	Mega-ton CO2 = 10 ⁶ ton, 10 ⁶ ton, 1,000,000 ton CO2
OWID	Our World in Data – Internet site [1] [2]
Ref	reference
tCO2	ton CO2
tCO2/y,cap	ton CO2 per year, per capita

Formula for Average Annual Change

Formula 1 - Average annual change of parameter X in the period 1990-2020 [%/year]

$$rX = (X2/X1)^{(1/(y2-y1))} - 1$$

- rX average annual change of parameter X in the period from y1 to y2, %/year
- X1 value of parameter X at the beginning of the period
- X2 value of parameter X at the end of the period
- y1 beginning of the period = 1990
- y2 end of the period = 2020

Correlation between Cumulative CO2 Emissions and Global Warming

The correlation between cumulative CO2 emissions and Global Warming was analyzed in the publication “Global Warming and Cumulative CO2” [3].

Formula 2 - Correlation between Cumulative CO2 Emissions and Global Warming [3] [°C/GtCO2]

$$CO2 \rightarrow GW = 0.000745^\circ C / GtCO2$$

Dataset

Table 1 - CO2 emissions and population dataset [1] [2]

	CO2 emissions	Population
Source of data	OWID	OWID
Reference	[1] [2]	[1] [2]
From year	1950	1750
To year	2020	2020
CO2 from fossil fuels	Yes	
CO2 from cement production	Yes	
CO2 from other sources	No	
Other GHG	No	
Land use change	No	
Units	tCO2/y	
Resolution	1 tCO2/y	1 Resident

The datasets are from publication [1] [2], CO2 emissions produced from fossil fuels and cement production only – land use change is not included.

Cumulative Global CO2 Emissions

Total global CO2 emissions per year are from 1750 [1] [2]. This is also the first year of calculations of the cumulative CO2 emissions of the world, which means that for this parameter the baseline is 1749.

However, international transport CO2 emissions are from 1950 and the first year of the cumulative CO2 emissions is 1950 [1] [2], which means that for this parameter the baseline is 1949.

The datasets were converted to the 1875 baseline in publication [4].

Table 2 - Global cumulative CO2 emissions and international transport [4] [tCO2 above 1875 baseline]

		1990	2020
Global cumulative CO2 emissions including international transport	tCO2	792,689,057,443	1,681,608,597,211
International transport cumulative CO2 emissions	tCO2	16,042,804,984	43,700,803,946
Global cumulative CO2 emissions without international transport	tCO2	776,646,252,459	1,637,907,793,265

World CO2 Emissions per Capita 1990-2020

World CO2 Emissions per Capita 1990-2020 were analyzed in the publication "CO2 Emissions per Capita" [5]

Chart 1 - World averages of CO2 emissions per capita 1990-2020 [5] [tCO2 per year, per capita]

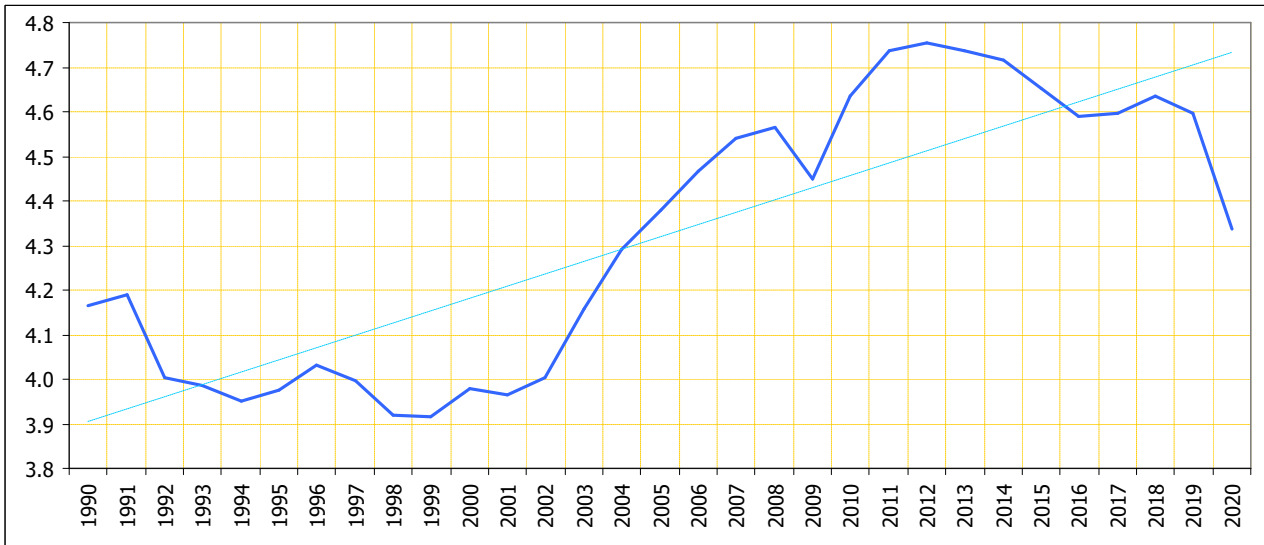


Table 3 - World averages [1] [2]

		1990	2020
CO2 emissions	MtCO2/y	22,192	33,803
1990-2020 change	%/year		+1.41%
Population		5,327,529,078	7,794,798,725
1990-2020 change	%/year		+1.28%
CO2 per Capita	tCO2/y,cap	4.1655	4.3366
1990-2020 change	per period		4.1%
average annual change	%/year		+0.134%

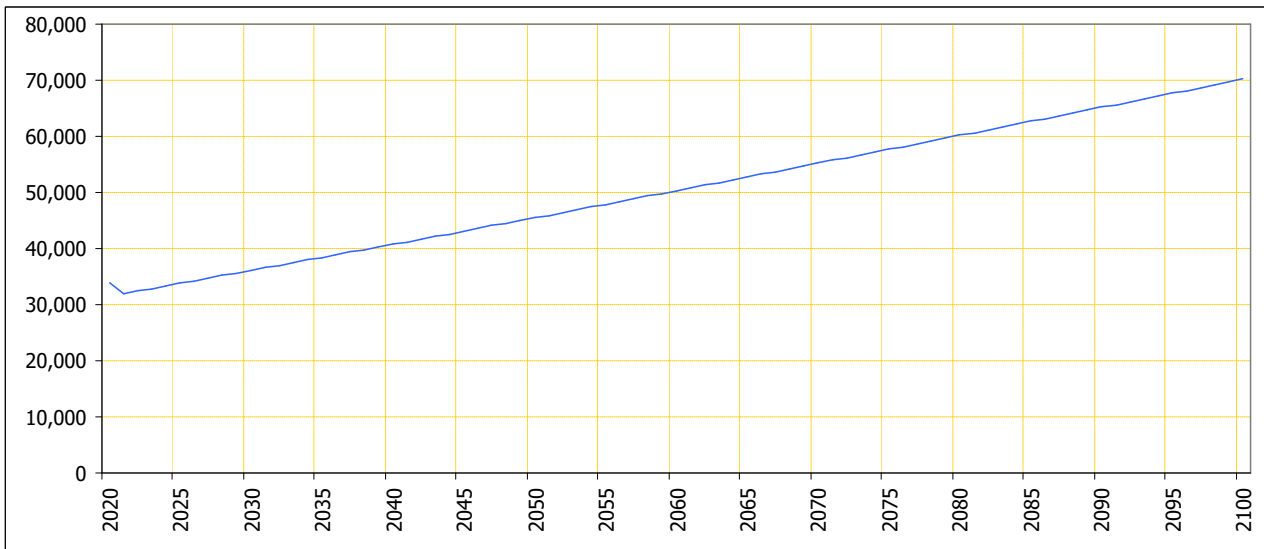
The average annual change in the world CO2 emissions per capita in the period 1990-2020 was calculated using Formula 1.

The average change is +0.134% per year.

CO2 Emissions Forecast

The CO2 emissions forecast for 2020-2100 is from the publication “CO2 Emission per Capita Forecast 2020-2100” [6].

Chart 2 - CO2 emissions per year without international transport BAU forecast for 2020-2100 [MtCO2/y] [6]



The dataset of CO2 emissions forecast for 2020-2100 is available in the publication [7].

World Population Forecast

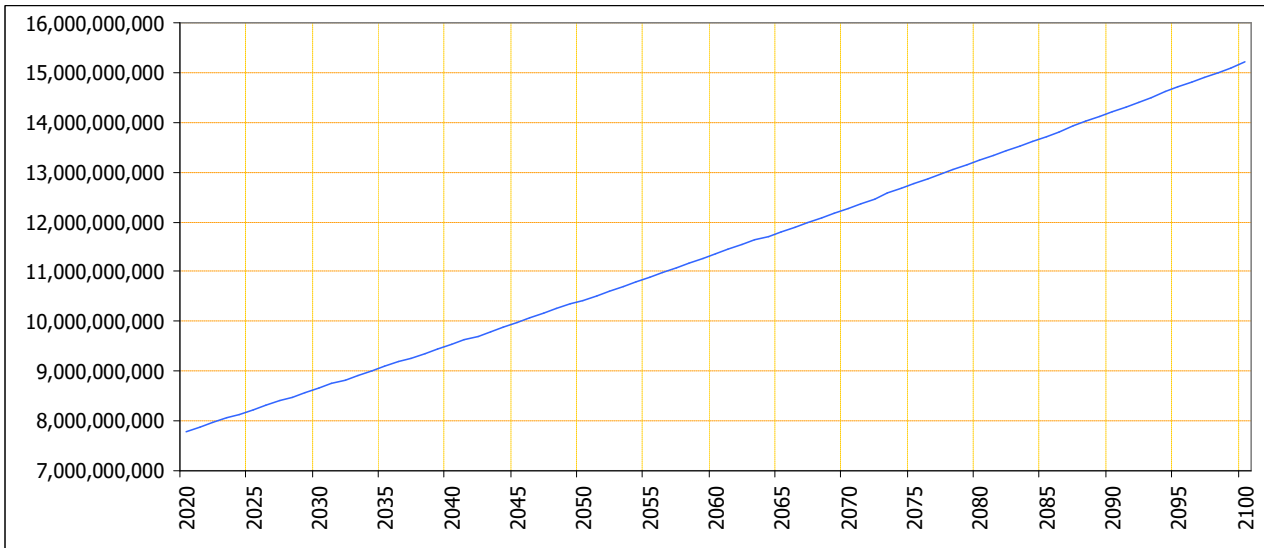
The population forecast for 2020-2100 is from the publication “CO2 Emission per Capita Forecast 2020-2100” [6].

The population forecast for 2020-2100 is based on the Excel chart parabolic trendline formula of the actual world population in the period 1990-2020 [1] [2].

Table 4 - World population forecast [6]

World population 1990	5,327,529,078
World population 2020	7,794,798,725
Parabolic trendline chart formula:	
$y = 97038.960947752x^2 + 78816017.1242695x + 5261771158.06877$	
World population 2020 according to the formula	7,798,322,130
Δ to actual	0.045%
World population in 2100 forecast	15,205,966,097

Chart 3 - World population forecast 2020-2100 [6] [7]



The dataset of population forecast for 2020-2100 is available in the publication [7].

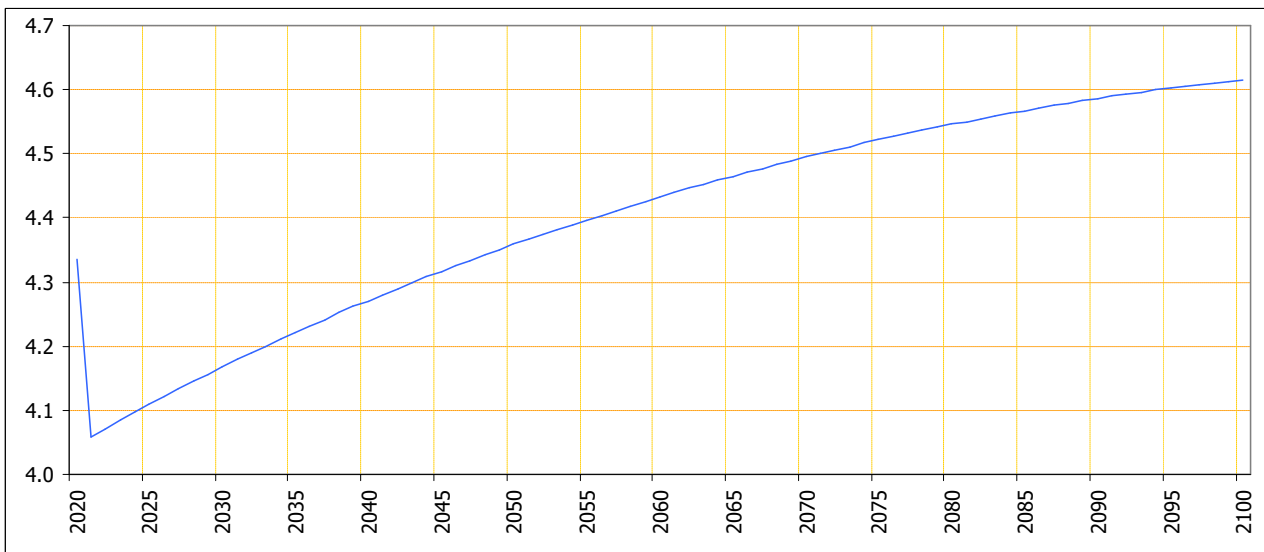
CO2 Emissions per Capita Forecast

CO2 emissions per capita (CpC) are calculated by dividing the CO2 emissions per year by the population in the same year.

Table 5 - CO2 emissions per capita forecast

		1990	2020	2100
CO2 emissions	MtCO2/y	22,192	33,803	70,191
Population		5,327,529,078	7,794,798,725	15,205,966,097
CO2 per Capita (CpC)	tCO2/y,cap	4.165	4.337	4.616
average annual change in CpC	%/year		0.134%	0.078%

Chart 4 - CO2 emissions per capita 2020-2100 [tCO2/y,cap]



Business as Usual Forecast for 2025

It is assumed in this work that the CO2 mitigation measures additional to BAU will not start before the end of 2025.

Table 6 - BAU forecast for 2025 [4]

Year	without International Transport				Global		
	Population	CpC	CO2/y	CCO2	International	CCO2	GW
		tCO2/y,cap	MtCO2/y	BL1875 MtCO2	Transport MtCO2/y	BL1875 MtCO2	BL1850-1900 °C
2020	7,798,322,130	4.3347	33,803	1,613,287	1,004	1,656,988	1.235
2021	7,883,251,602	4.0586	31,995	1,645,282	1,024	1,690,007	1.260
2022	7,968,375,152	4.0716	32,444	1,677,726	1,044	1,723,495	1.285
2023	8,053,692,779	4.0843	32,894	1,710,619	1,065	1,757,454	1.310
2024	8,139,204,485	4.0968	33,345	1,743,964	1,086	1,791,885	1.336
2025	8,224,910,268	4.1091	33,797	1,777,761	1,108	1,826,789	1.362

Necessary Annual Change in CO2 Emissions per Capita to Reach 1.5°C Global Warming Limit in 2100

Table 7 - Years to Global Warming 1.5°C

$\Delta C_p/y$	year	$\Delta CO_2/y$	$\Delta CO_2/y$	$\Sigma \Delta CO_2/y$	$\Sigma \Delta CO_2/y$	GW in 2100
	GW=1.5°C	2026	2026	2100	2026-2100	BL1850-1900
%/y		%/y	MtCO ₂ /y	MtCO ₂ /y	MtCO ₂ /y	°C
+0.0781%	2031	+1.123%	380	32,453	1,181,672	+4.136
-5.0000%	2032	-4.008%	-1,355	-32,464	-1,781,561	+1.927
-10.0000%	2034	-9.060%	-3,062	-33,774	-2,198,419	+1.616
-15.0000%	2040	-14.112%	-4,770	-33,797	-2,329,764	+1.518
-17.0000%	>2100	-16.133%	-5,453	-33,797	-2,359,526	+1.496

$\Delta C_p/y$ average annual change in CpC 2025-2100, %/y
 year GW=1.5°C year when Global Warming will reach 1.5°C
 $\Delta CO_2/y$ 2026 change in CO2 emissions per year in 2026
 $\Sigma \Delta CO_2/y$ cumulative change in CO2 emissions per year in 2100
 $\Sigma \Delta CO_2/y$ sum of cumulative (2026-2100) change in CO2 emissions per year
 GW in 2100 Global Warming in 2100 above 1850-1900 baseline

Necessary Annual Change in CO2 Emissions per Capita to Reach 1.7°C Global Warming Limit in 2100

Table 8 - Years to Global Warming 1.7°C

$\Delta C_p/y$	year	Countries	$\Delta CO_2/y$	$\Sigma \Delta CO_2/y$	$\Sigma \Delta CO_2/y$	GW in 2100
	GW=1.7°C		2026	2100	2026-2100	BL1850-1900
%/y		%/y	MtCO ₂ /y	MtCO ₂ /y	MtCO ₂ /y	°C
+0.0781%	2038	+1.123%	380	32,453	1,181,672	+4.136
-5.00%	2046	-4.008%	-1,355	-32,464	-1,781,561	+1.927
-6.00%	2049	-5.018%	-1,696	-33,194	-1,920,388	+1.823
-7.00%	2057	-6.029%	-2,038	-33,527	-2,020,702	+1.749
-7.85%	2097	-6.888%	-2,328	-33,661	-2,085,593	+1.700

year GW=1.7°C year when Global Warming will reach 1.7°C

Necessary Annual Change in CO2 Emissions per Capita to Reach 2.0°C Global Warming Limit in 2100

Table 9 - Years to Global Warming 2.0°C

$\Delta\text{CpC}/\text{y}$	year	Countries	$\Delta\text{CO}_2/\text{y}$	$\Sigma\Delta\text{CO}_2/\text{y}$	$\Sigma\Sigma\Delta\text{CO}_2/\text{y}$	GW in 2100
%/y	GW=2.0°C	$\Delta\text{CO}_2/\text{y}$	2026	2100	2026-2100	BL1850-1900
		%/y	MtCO ₂ /y	MtCO ₂ /y	MtCO ₂ /y	°C
+0.0781%	2048	+1.123%	380	32,453	1,181,672	+4.136
-3.00%	2062	-1.987%	-672	-27,434	-1,287,655	+2.295
-4.00%	2078	-2.997%	-1,013	-30,872	-1,582,714	+2.075
-4.46%	2100	-3.462%	-1,170	-31,757	-1,683,503	+2.000

year GW=2.0°C year when Global Warming will reach 2.0°C

Scenarios of Annual Change in CpC

Chart 5 - CO2 emissions per capita (CpC) [tCO2/y,cap]

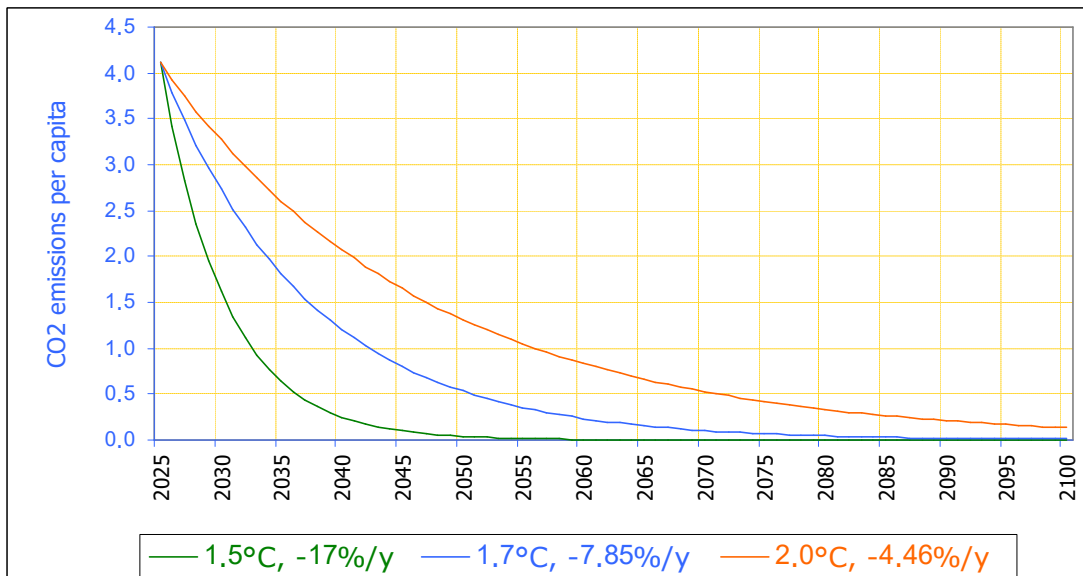


Chart 6 - Cumulative CO2 emissions reduction per year in scenarios of average annual change in CpC [MtCO2/y]

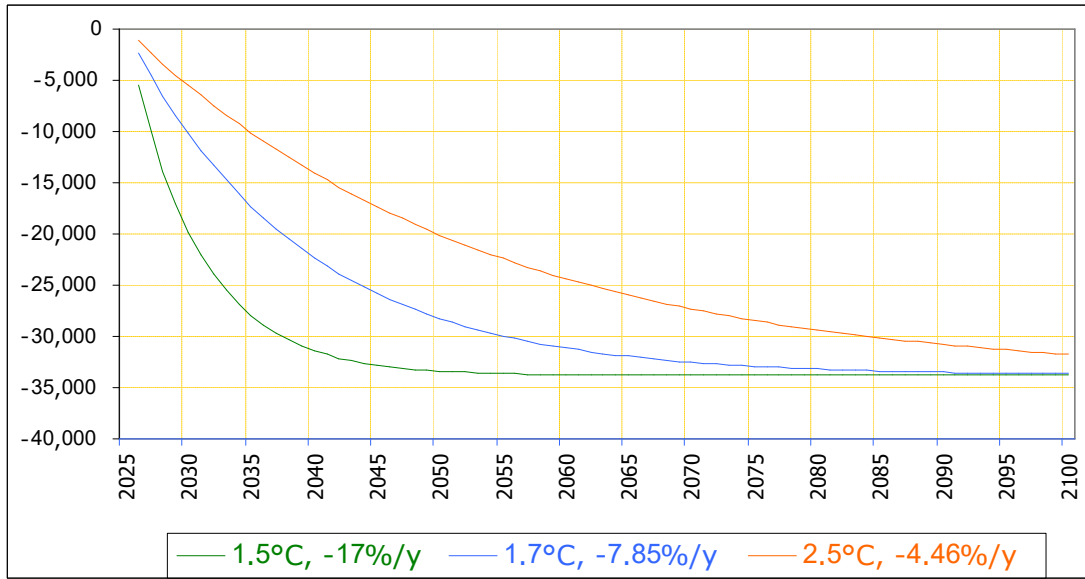


Chart 7 - Cumulative CO2 emissions reduction per period (2025-2100) in scenarios of average annual change in CpC [MtCO2/period]

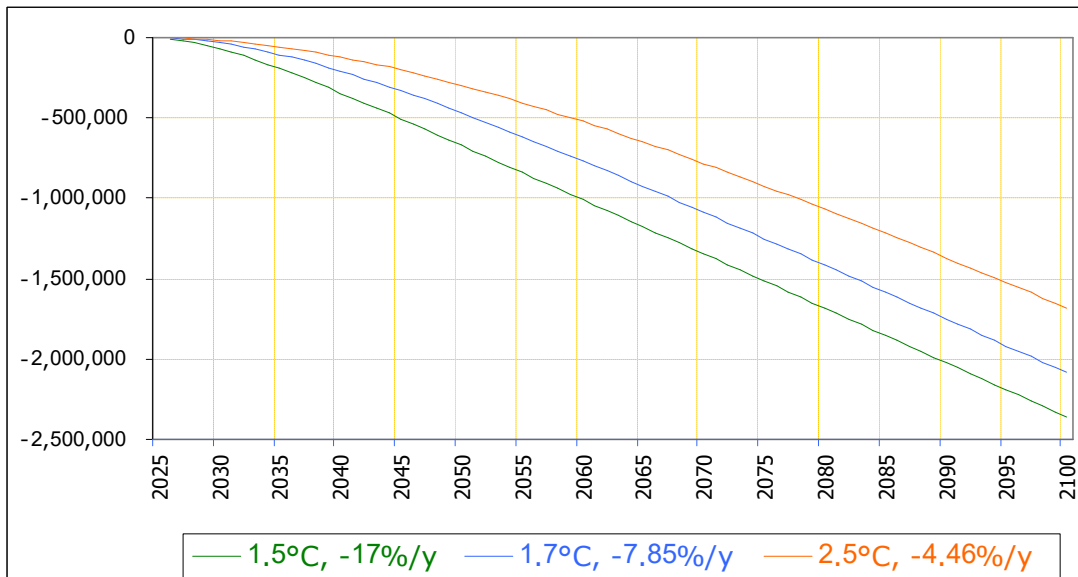


Chart 8 - Global Warming in scenarios of annual change in CpC [°C]

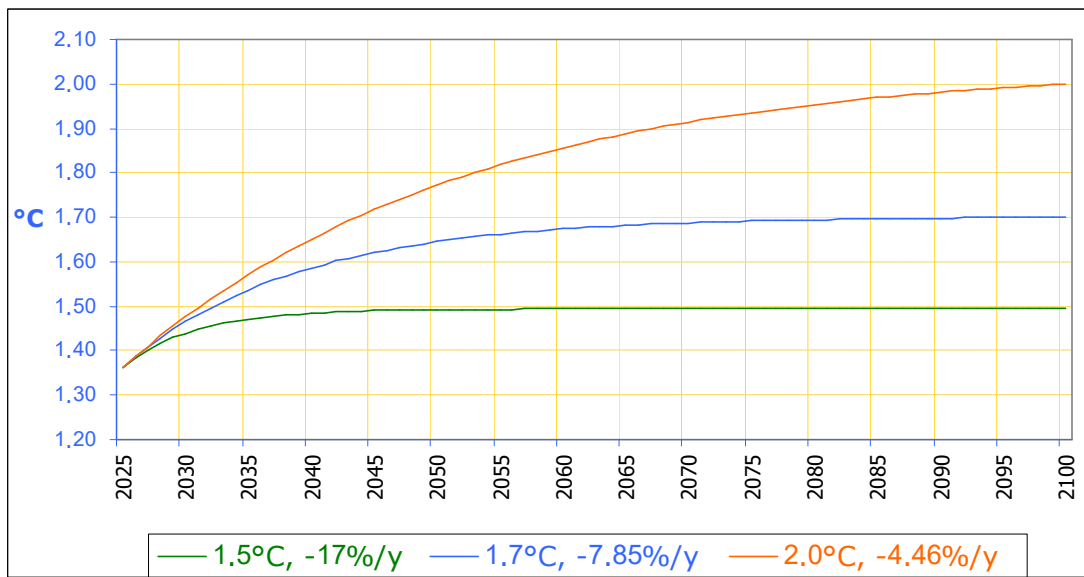


Table 10 - Maximum CO2 emissions per capita (CpC) to reach 1.5°C-2.0°C Climate Change limit in 2100

target	2.0°C	1.7°C	1.5°C
ΔCpC/y	-4.46%	-7.85%	-17.00%
	%/y	%/y	%/y
2020	4.335	4.335	4.335
2021	4.059	4.059	4.059
2022	4.072	4.072	4.072
2023	4.084	4.084	4.084
2024	4.097	4.097	4.097
2025	4.109	4.109	4.109
2026	3.926	3.787	3.411
2027	3.751	3.489	2.831
2028	3.583	3.215	2.350
2029	3.424	2.963	1.950
2030	3.271	2.730	1.619
2031	3.125	2.516	1.343
2032	2.986	2.319	1.115
2033	2.853	2.137	0.925
2034	2.725	1.969	0.768
2035	2.604	1.814	0.638
2036	2.488	1.672	0.529
2037	2.377	1.541	0.439
2038	2.271	1.420	0.365
2039	2.169	1.308	0.303
2040	2.073	1.206	0.251
2041	1.980	1.111	0.208
2042	1.892	1.024	0.173
2043	1.808	0.943	0.144
2044	1.727	0.869	0.119
2045	1.650	0.801	0.099
2046	1.576	0.738	0.082
2047	1.506	0.680	0.068
2048	1.439	0.627	0.057
2049	1.375	0.578	0.047
2050	1.313	0.532	0.039
2051	1.255	0.490	0.032
2052	1.199	0.452	0.027
2053	1.145	0.417	0.022
2054	1.094	0.384	0.018
2055	1.045	0.354	0.015
2056	0.999	0.326	0.013
2057	0.954	0.300	0.011
2058	0.912	0.277	0.009
2059	0.871	0.255	0.007
2060	0.832	0.235	0.006
2061	0.795	0.217	0.005
2062	0.760	0.200	0.004
2063	0.726	0.184	0.003
2064	0.693	0.169	0.003
2065	0.662	0.156	0.002
2066	0.633	0.144	0.002
2067	0.605	0.133	0.002
2068	0.578	0.122	0.001
2069	0.552	0.113	0.001
2070	0.527	0.104	0.001
2071	0.504	0.096	0.001
2072	0.481	0.088	0.001
2073	0.460	0.081	0.001
2074	0.439	0.075	0.000
2075	0.420	0.069	0.000
2076	0.401	0.064	0.000
2077	0.383	0.059	0.000
2078	0.366	0.054	0.000
2079	0.350	0.050	0.000
2080	0.334	0.046	0.000
2081	0.319	0.042	0.000
2082	0.305	0.039	0.000
2083	0.291	0.036	0.000
2084	0.278	0.033	0.000
2085	0.266	0.030	0.000
2086	0.254	0.028	0.000
2087	0.243	0.026	0.000
2088	0.232	0.024	0.000
2089	0.222	0.022	0.000
2090	0.212	0.020	0.000
2091	0.202	0.019	0.000
2092	0.193	0.017	0.000
2093	0.185	0.016	0.000
2094	0.176	0.015	0.000
2095	0.169	0.013	0.000
2096	0.161	0.012	0.000
2097	0.154	0.011	0.000
2098	0.147	0.011	0.000
2099	0.140	0.010	0.000
2100	0.134	0.009	0.000

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