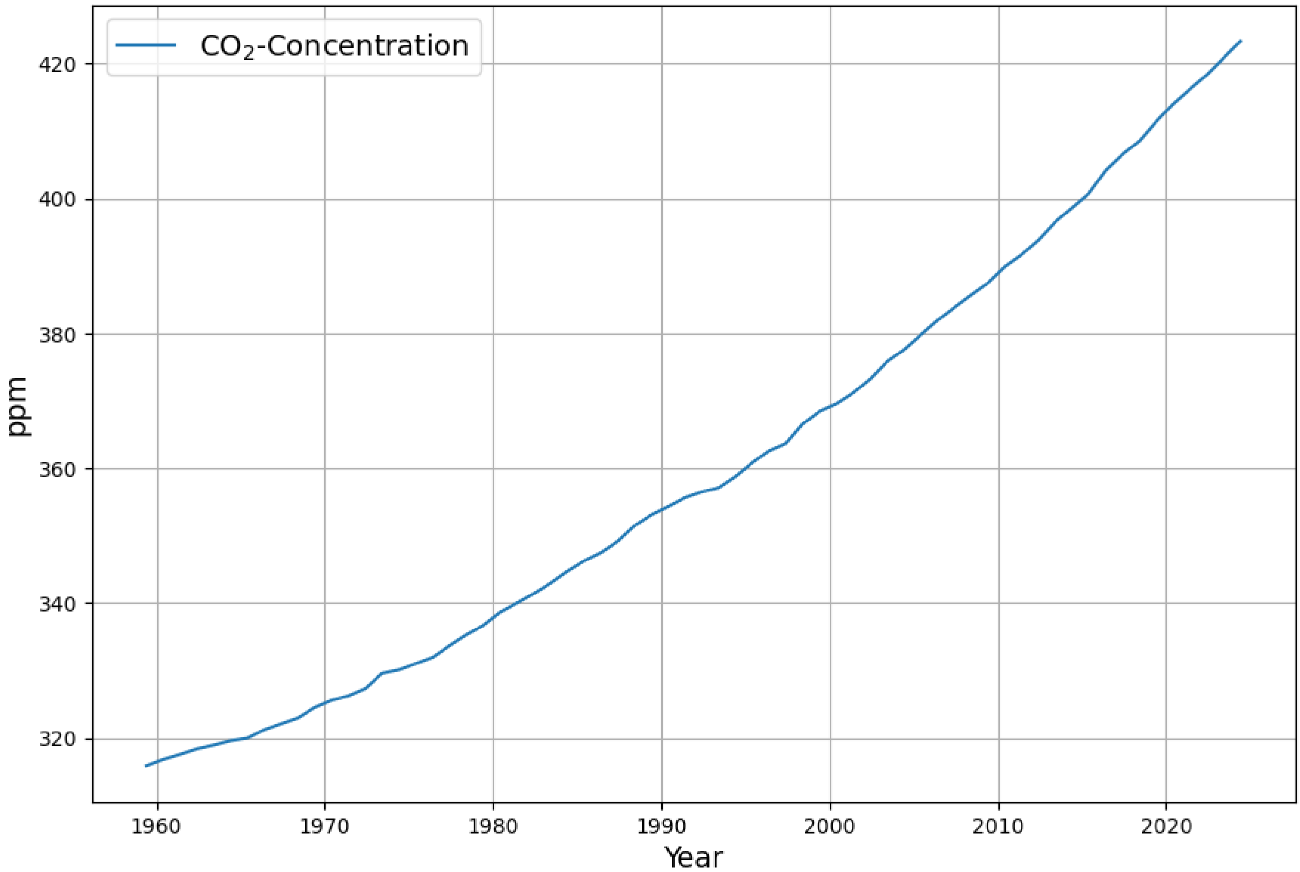
The inflection point of CO2 concentration

[latexpage]

And rising and rising…?

At first glance, the atmospheric CO_2 concentration is constantly rising, as shown by the annual mean values measured at Maona Loa:



The central question that arises is whether the concentration is growing faster and faster, i.e. whether more is being added each year? If so, the curve would be concave, i.e. curved upwards.

Or is the annual increase in concentration getting smaller and smaller? Then it would be convex, i.e. curved downwards.

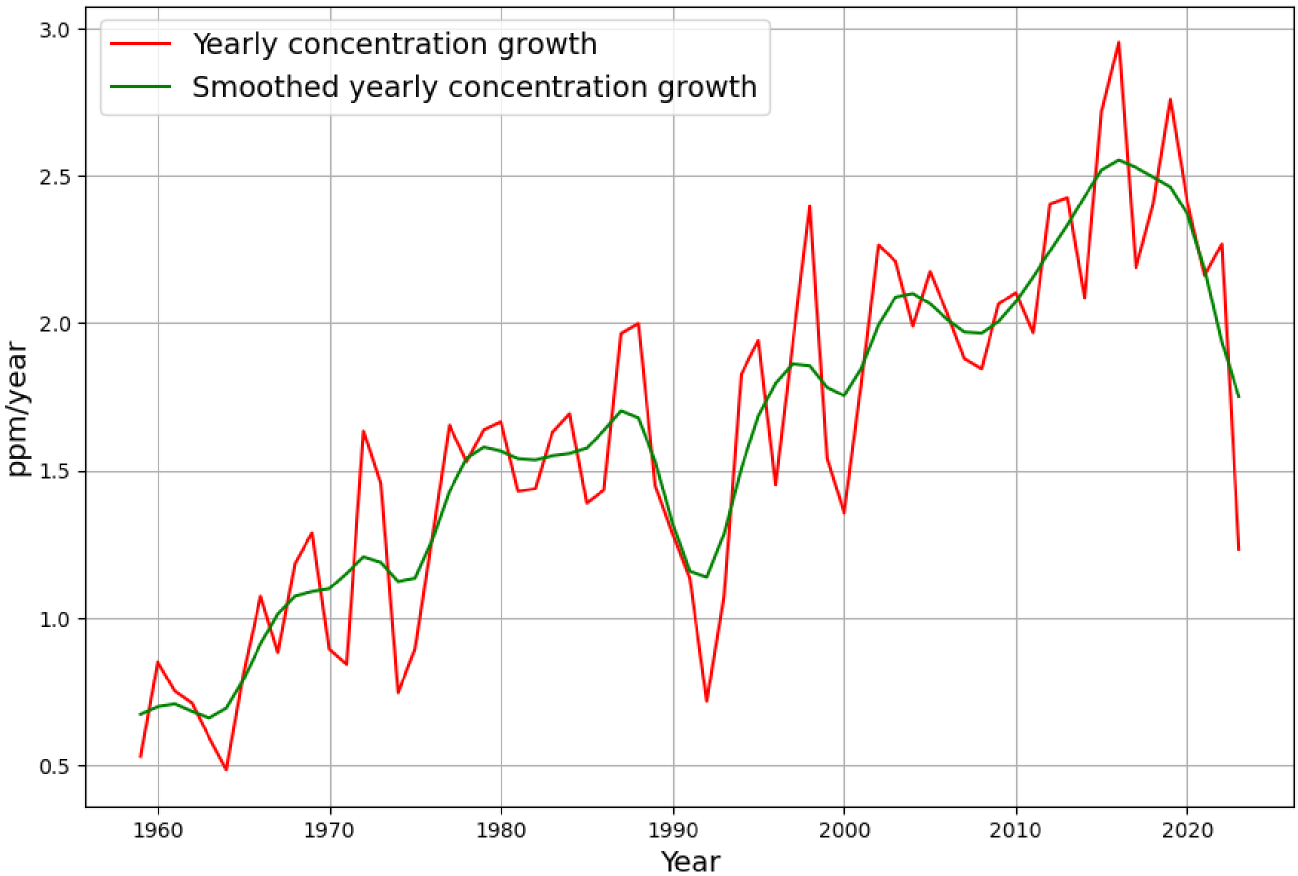
Or is there a transition, i.e. a turning point in the mathematical sense? This could be recognized by the fact that the annual increase initially increases and then decreases from a certain point in time.

At first glance, the overall curve appears concave, which means that the annual increase in concentration appears to increase with each year.

The answer to this question is crucial for the question of how urgent measures to curb CO_2 emissions are.

Closer examination with the measured annual increase

To get a more accurate impression, we calculate the – raw and slightly smoothed – annual increase in CO_2 concentration:



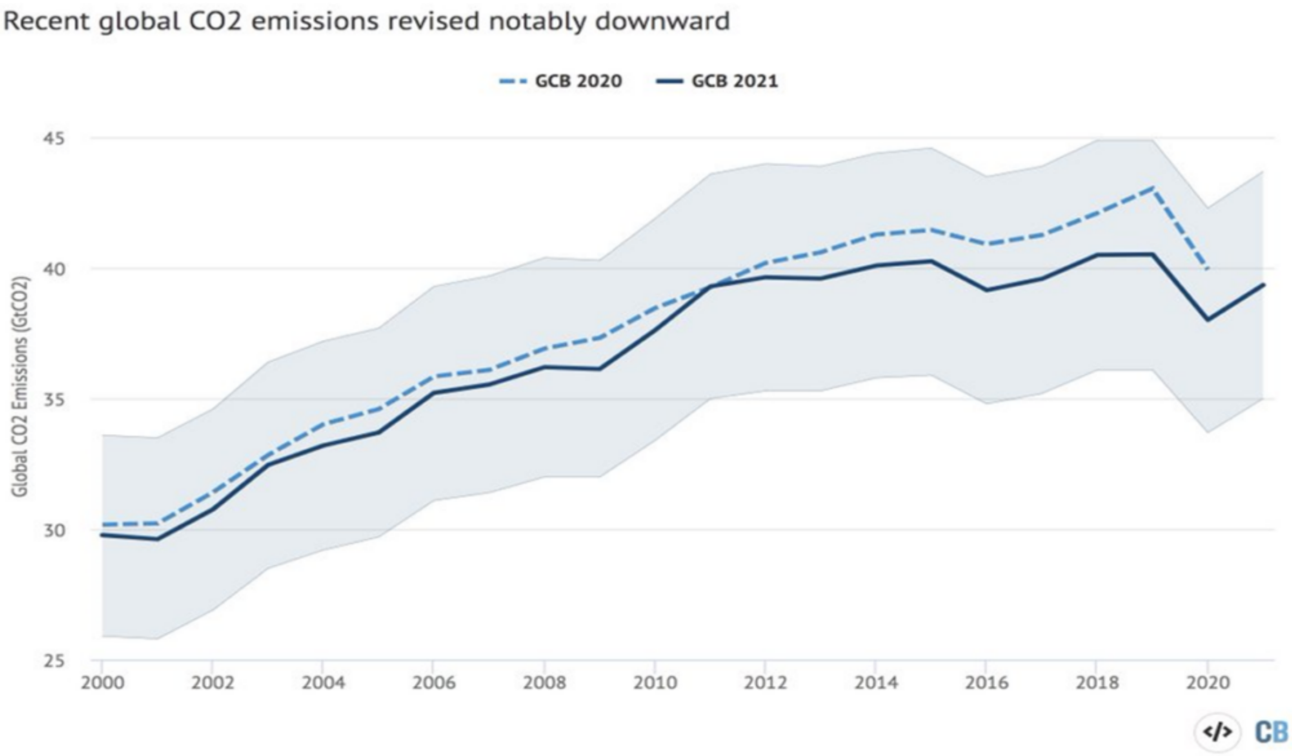
This confirms that until 2016 there was a clear trend towards ever higher annual concentration increases, from just under 0.75 ppm/year in 1960 to over 2.5 ppm/year in 2016.

Since 2016, however, the annual increase has been declining, initially slightly, but significantly more strongly in 2020 and 2021. The corona-related decline in emissions certainly plays a role here, but this does not explain the decline that began in 2016.

There is therefore an undisputed turning point in the concentration curve in 2016, i.e. a trend reversal from increasing concentration growth to decreasing concentration growth. Is there a satisfactory explanation for this? This is essential, because if we can foresee that the trend of decreasing concentration growth will continue, then it is foreseeable that the concentration will stop increasing at some point and the goal of the Paris Climate Agreement, the balance between CO_2 sources and CO_2 sinks, can be achieved in the foreseeable future.

Explanation due to stagnating emissions

As part of the Global Carbon Brief project, Zeke Hausfather 2021 revised the values of global CO_2 emissions over the last 20 years based on new findings, with the important result that global emissions have been constant for 10 years within the limits of measurement accuracy:

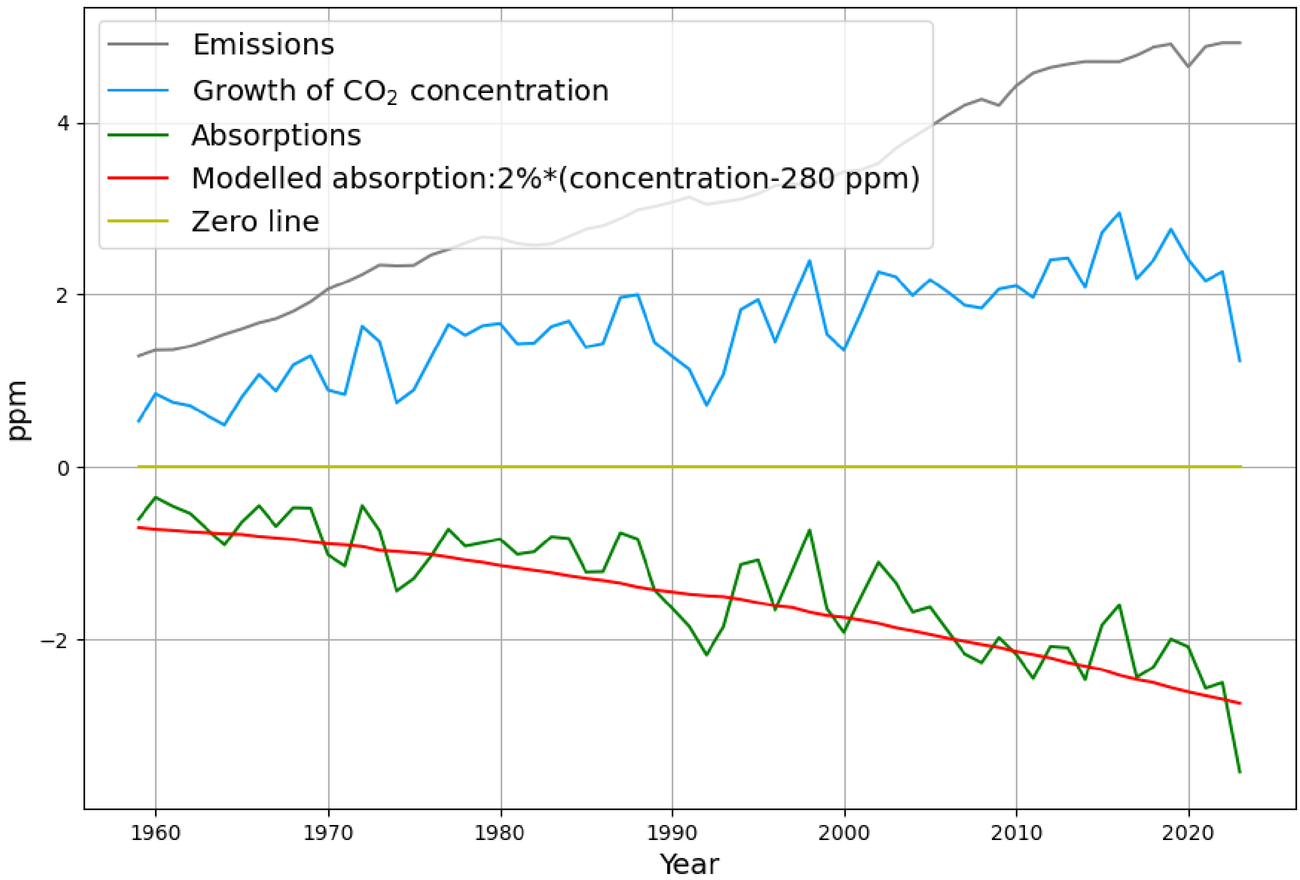


To assess the implications of this important finding, one needs to know the relationship between emissions and CO2 concentration.

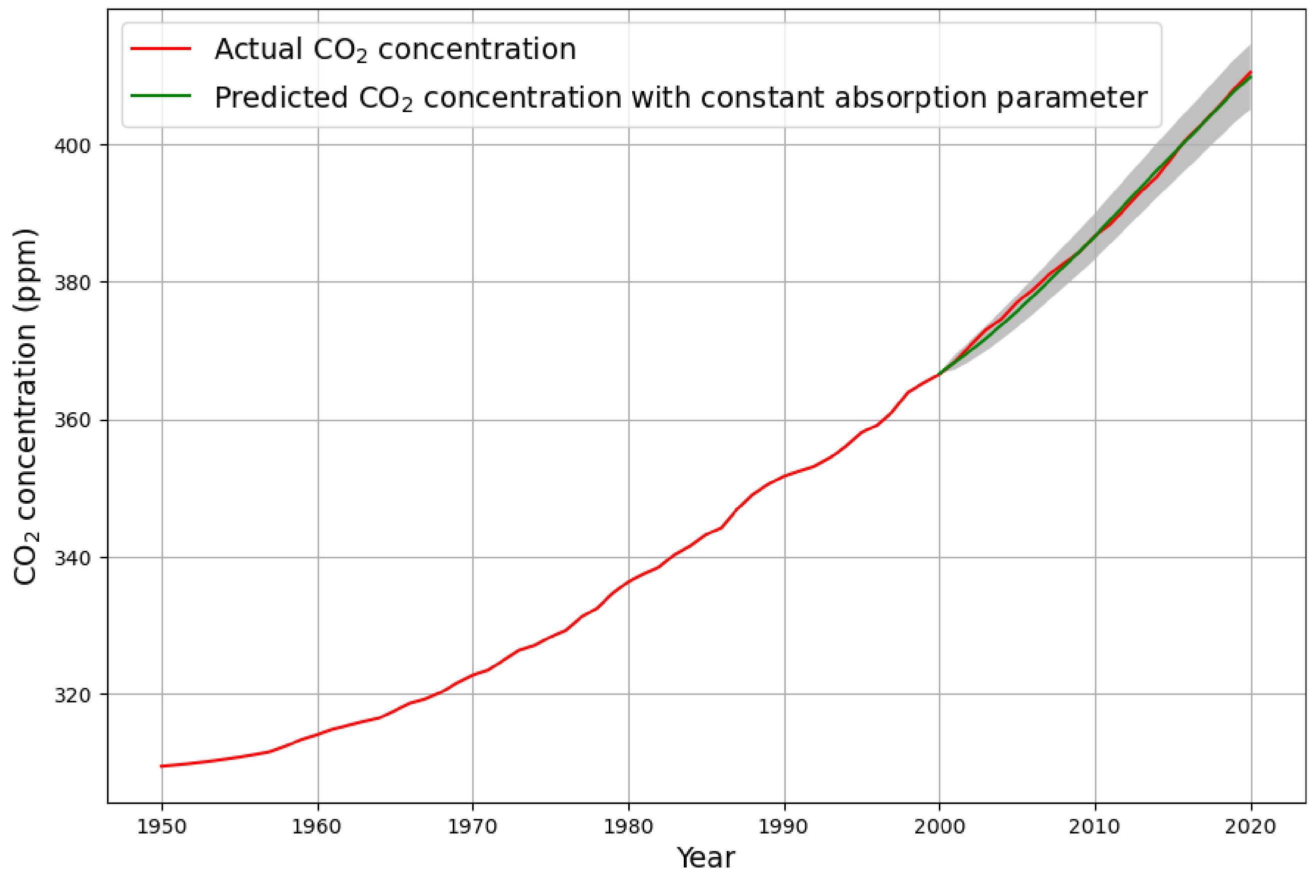
From my own research on this in a publication and in a subsequent blog post, it follows that the increase in concentration results from the emissions and absorptions, which are proportional to the CO_2 concentration:

Trivially, it follows from the conservation of mass that the concentration C_i at the end of the year i results from the concentration of the previous year C_{i-1}, the natural emissions N_i, the anthropogenic emissions E_i and the absorptions A_i:
\begin{equation}\label{mass_conservation}C_i = C_{i-1} + N_i + E_i – A_i \end{equation} This directly results in the effective absorption calculated from emissions and the measured increase in concentration:
\begin{equation}\label{absorption_measurement}$A_i – N_i = E_i – (C_i – C_{i-1}) \end{equation} Assuming constant annual natural emissions
$N_i = n$

and the linear model assumption, i.e. that the absorptions are proportional to the concentration of the previous year,
$A_i = a\cdot C_{i-1}$
the absorption model is created (these two assumptions are explained in detail in the publication above), where $n = a\cdot C_0$:
\begin{equation}\label{absorption_equ}A_i – N_i = a\cdot(C_{i-1} – C_0)\end{equation} with the result $a=0.02$ and $C_0 = 280 ppm $. In this calculation, emissions due to land use changes are not taken into account. This explains the numerical differences between the result and those of the cited publications. The omission of land-use changes is justified by the fact that in this way natural emissions lead to the pre-industrial equilibrium concentration of 280 ppm.



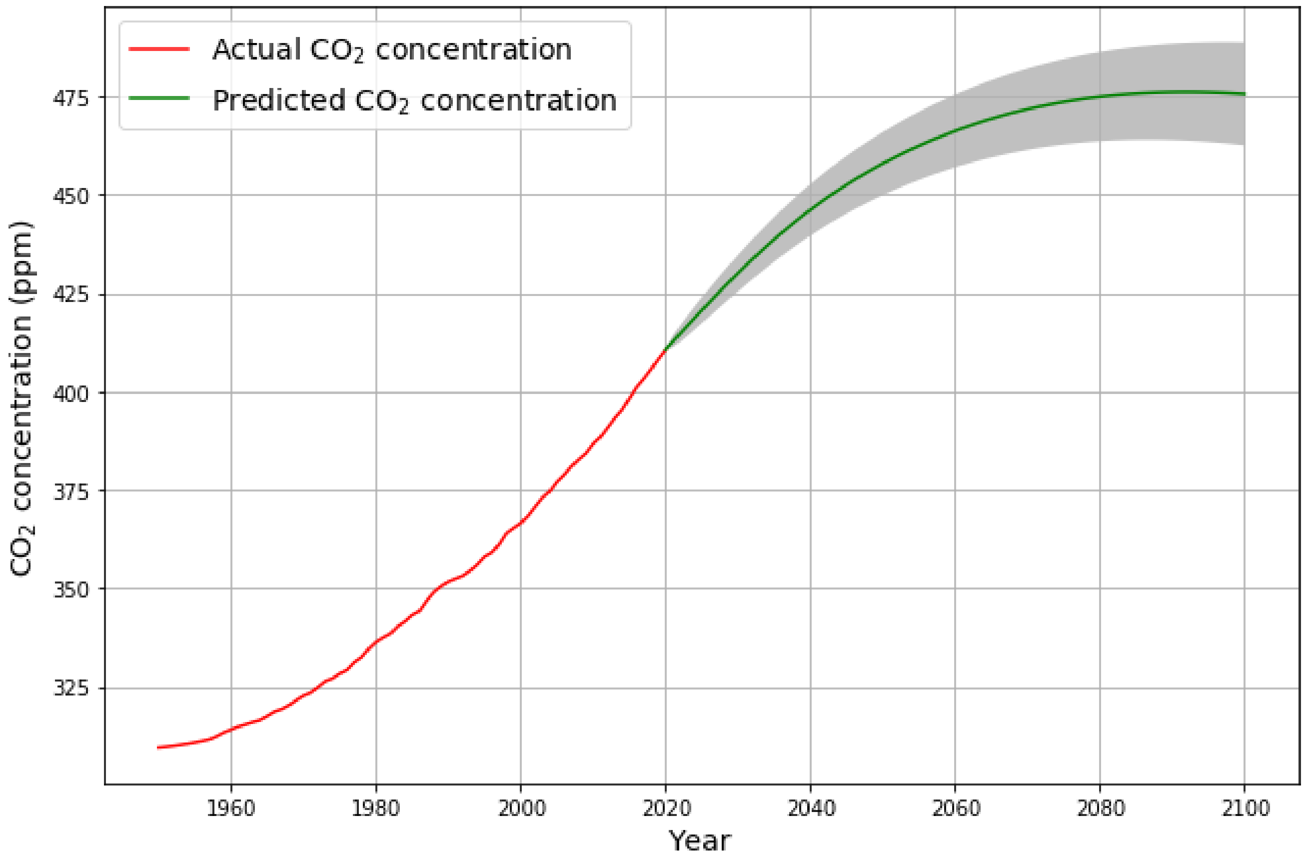
With this model, the known concentration between 2000 and 2020 is projected very accurately from the data between 1950-2000:



Evolution of CO_2 concentration at constant emissions

In order to understand the turning point of the CO_2 concentration, we want to calculate the predicted course with the assumption of constant emissions $E_i = E$ and the equations (\ref{absorption_measurement}) and (\ref{absorption_equ}): \begin{equation}\label{const_E_equ}C_i – C_{i-1} = E-a\cdot(C_{i-1} – C_0)\end{equation} The left-hand side describes the increase in concentration. On the right-hand side, an amount that increases with increasing concentration C_{i-1} is subtracted from the constant emissions E, which means that the increase in concentration decreases with increasing concentration. [This can be illustrated with a special bank account](). As soon as the concentration reaches the value $\frac{E}{a} + C_0$, the equilibrium state is reached in which the concentration no longer increases, i.e. the often used „net zero“ situation. With current emissions of 4.7 ppm,

„net zero“ would be at 515 ppm, while the „Stated Policies“ emissions scenario of the International Energy Agency (IEA), which envisages a slight reduction in the future, reaches equilibrium at 475 ppm, as described in the publication above. According to the IEA’s forecast data, this will probably be the case in 2080:



According to this, constant emissions are sufficient justification for a convex course of CO_2 concentrations, as we have seen since 2016. At the same time, this proves that CO_2 absorption does indeed increase with increasing concentration.