Climate Change Calculated Part 1

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Introduction

- I am Gerald Schuller, Professor in Media Technology, TU Ilmenau, Germany,
- Head of Department for Applied Media Systems
- I will present a series of videos that deal with:
- Calculating climate change
- Possible solutions due to the shown results
- pointing out media technological approaches and techniques
- and to give ideas for own calculations

- climate change is everywhere in the news

- media technologies, such as the Internet and social media, easily lead to confusion and misinformation
- But the internet can also be used to check information.
- This is essential in times of unfiltered mass information.
- This will be shown below.

Numbers and Calculations

- Numbers and calculations help for checking claims
- Numbers are verifiable (reproducible research) and comparable,
- references are important for verifiability.
- The Internet offers new opportunities with "**Open Data**".
- Often, rough estimates of **magnitude are** sufficient, focusing on the **main effects** to check for plausibility.
- An order of magnitude means that the decimal point is in the right place, so an accuracy better than factor 10.
- Perhaps better

Our Tools

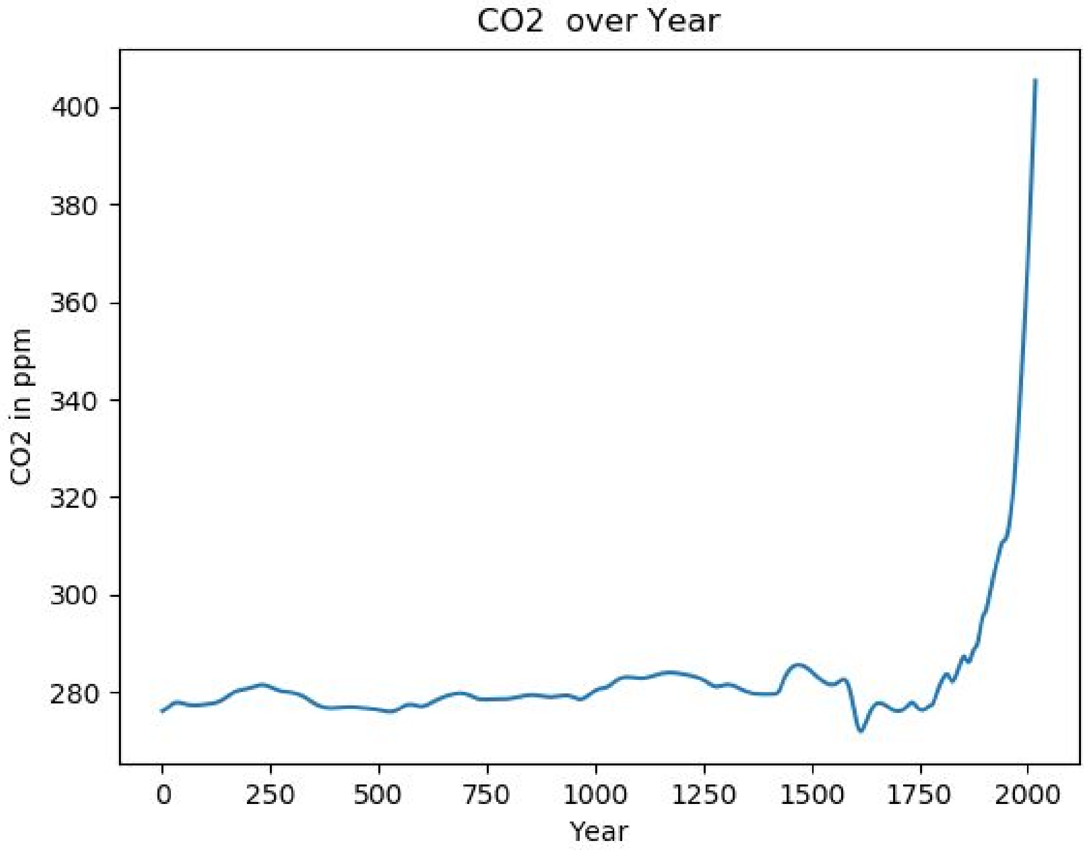
- Mathematics,
- Physics,
- Engineering,
- the programming language Python under Linux (but usually a normal scientific calculator does it too),
- General Methods and Tools of Media Technology,
- Open Data

Problem Description:

- **References, Links:**
- https://climate.nasa.gov/evidence/
- **Further reference for comparison:** CO2 readings from other sources, from Thuringia:
- https://www.thueringen.de/mam/th8/klimaagentur/co2_bericht_stand_2015.pdf
- As a downloadable csv (comma separated variable) file from year 1 to:
- http://scrippsco2.ucsd.edu/data/atmospheric_co2/icecore_merged_products
- These values are obtained by ice core analysis

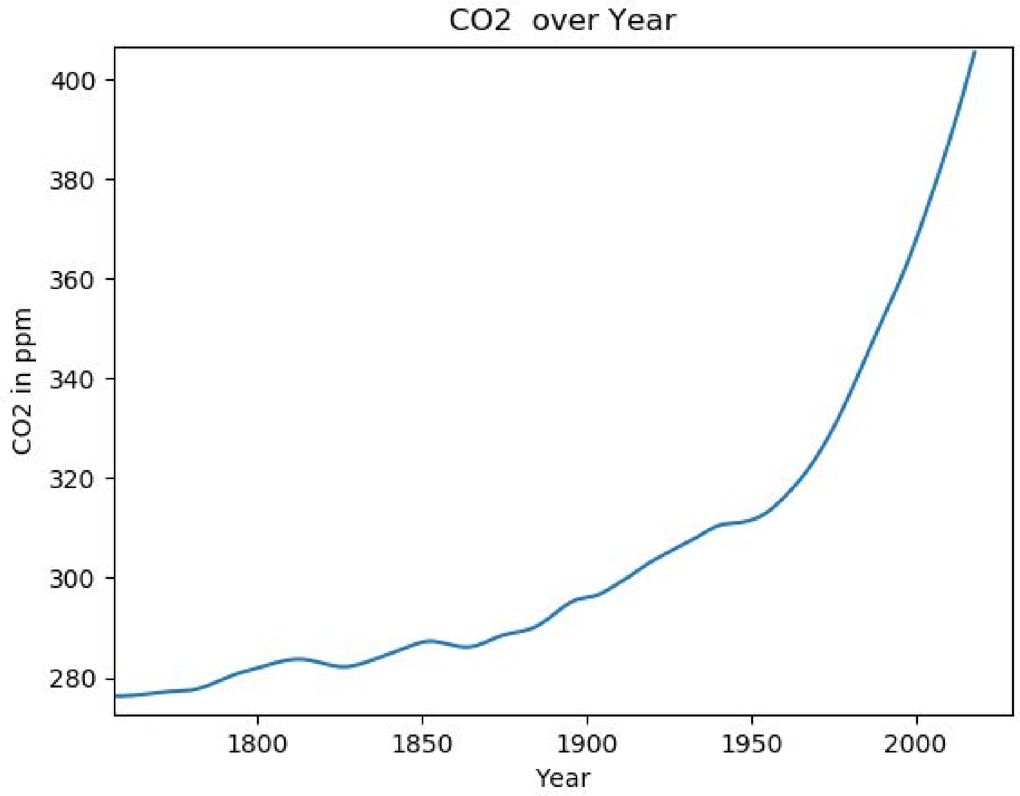
CO2 concentration since year 0

- We can read and plot the data from the csv file of the last link into a Python program. In a terminal shell we type:
- `python3 co2plot.py`
- Here we can see the more recent CO2 increase.



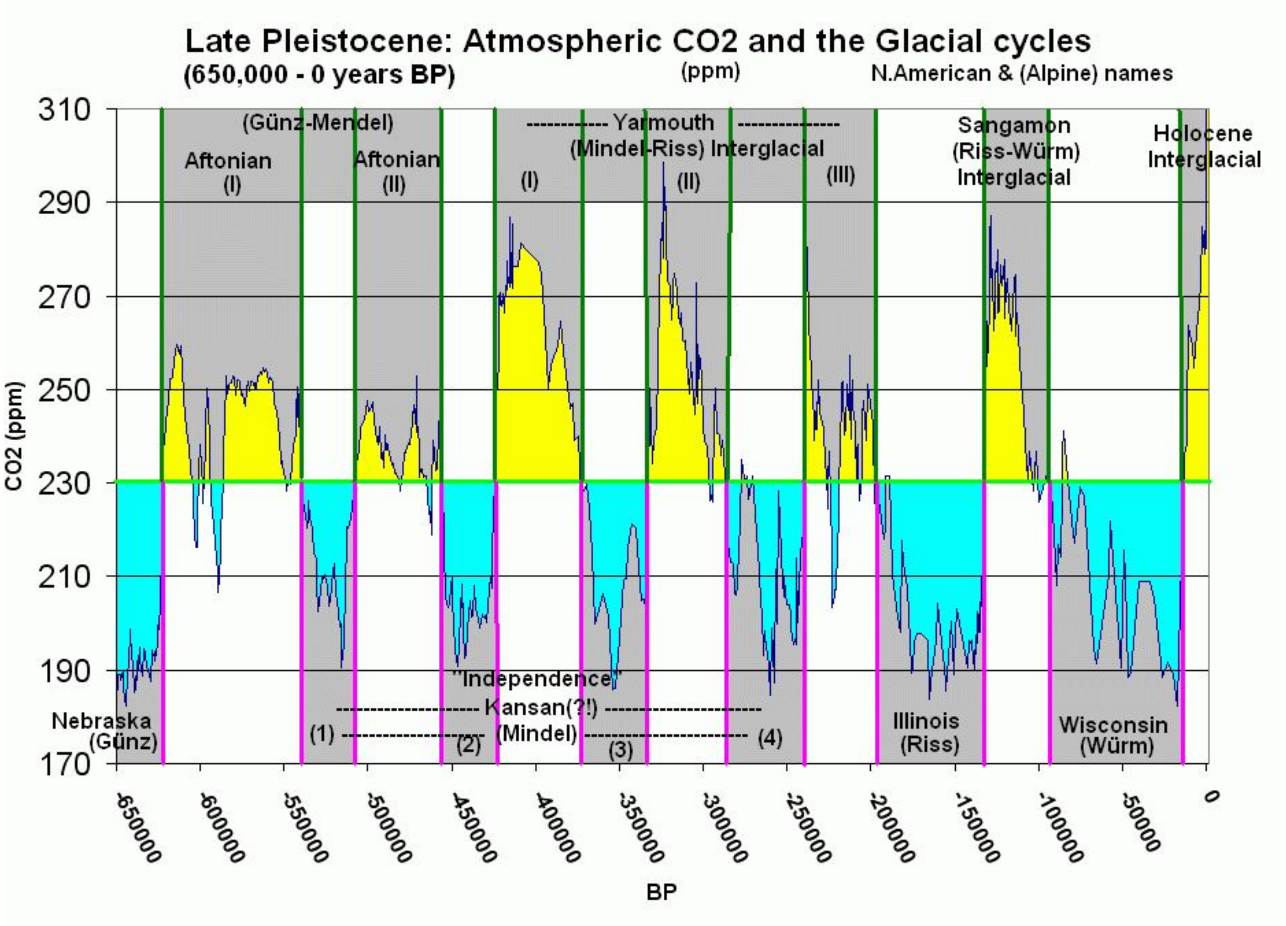
CO_2 since 1750

- We can zoom in here to see the period from 1750 to today.
- Approximately In 1910 we have exceeded the 300 ppm mark
- In 1944 we have exceeded the 310 ppm mark
- 2016 the 400 ppm mark.



- # Ice ages and CO2

- ice ages and CO2, for the period of 650000-0:
- https://de.wikipedia.org/wiki/Kaltzeit#/media/file:Atmospheric_CO2_with_glaciers_cycles.png



- **Note:** During ice ages (cold periods) the CO2 concentration is approx. **200 ppm** (by volume) CO2, while warm periods approx. **280 ppm**

Observation

- Over millions of years of equilibrium,
- CO2 production by living things, air decaying plants, and volcanoes,
- CO2 decomposition by plants and weathering of mountains.
- The approximately 100,000-year-old "oscillations" of the CO2 of cold and warm times are said to come from corresponding "oscillations" of the Earth's orbit and by ocean currents, which sometimes bring more and less

seaweeds such as algae to the surface and absorb more or less CO_2 accordingly.

- https://en.wikipedia.org/wiki/Ice_age

Problem

- **we see that** during ice ages (glacial periods) the CO2 concentration is around **200 ppm** (by volume) of CO2, during warm periods about **280 ppm**
- since about 1950, we observe a **sharp increase**
- At the moment (2019) the CO2 concentration is about **410 ppm, about 50% higher than the historical value for warm times!**
- And **this is bigger than the difference between cold and warm times!**
- The increase is also **faster** than ever before!
- **Question:** What **does** the modern-day CO2 increase mean, what is the **cause** and what are the **consequences**?

PPM, Parts Per million

- "ppm" stands for a ratio of "**parts per million**" or 10^{-6} (https://en.wikipedia.org/wiki/Parts_per_million).
- For comparison, "permille" stands for "**thousandths**", or 10^{-3}.

- We can therefore convert: **400 ppm** = $400 * 10^{-6} = 0.4 * 10^{-3}$ = **0.4 permille**.
- That does not sound very much, but if you think of it as a **blood-alcohol** level you can see that it can still be **significant** (this level is enough for inability to drive). (https://de.wikipedia.org/wiki/Blutalkoholkonzentration https://en.wikipedia.org/wiki/Blood_alcohol_content)
- The ratio may refer to **volume** (usually for gases, such as CO2) or **mass**.

Question: What has changed in modern times?

- For many millennia, humanity has used the burning of **wood** as the **main energy source**. The released CO2 was extracted from the atmosphere only decades earlier by the growth of trees.
- But since industrialization, and especially since the 1950s through mass production and mass mobility, **coal and oil has been** the main source of energy, **fossil** fuels.

- The released CO2 was withdrawn from the atmosphere in the Earth Age of Carboniferous (https://de.wikipedia.org/wiki/Karbon https://en.wikipedia.org/wiki/Carboniferous)
- That was about **300 million years ago** and over a period of about 60 million years.

- From that age came the plants that have formed coal and oil over these millenia.
- That's before the age of dinosaurs

- What we do with the burning of coal and oil is similar to the film "Jurassic Park", only that we don’t bring the dinosaurs back, but the CO2 from before their era.
- This has been removed from the atmosphere over a period of some **60 million years**,
- we are releasing it within only a **few centuries** in the present.

Question: Is human activity sufficient to explain the CO2 increase?

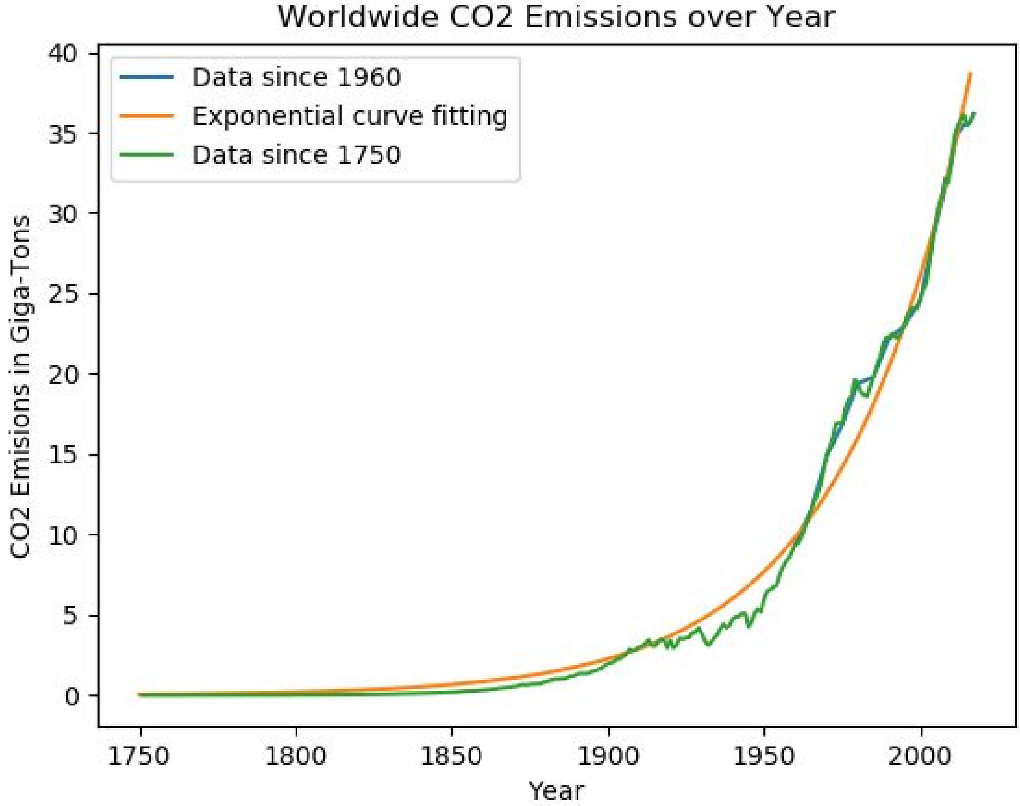
- Answer by calculation and use of Open Data.
- Note the spelling of floating point numbers, eg 2000 = 2 * 10^3 = 2e3 (also in Python)
- Total fossil CO2 emissions Worldwide since 1960:
- https://de.statista.com/statistik/daten/studie/37187/umfrage/der-worldwide-co2-emissions-since-1751/
- Fossil CO2 emissions since 1750:
- https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions
- (below, CO2 Emissions by Fuel Type)

Data Science

- We can Download the data from the websites
- Convert to the "Comma Separated Variable" (csv) format
- And read in a Python program.
- This program plotted the two data sets on each other
- Fits an exponential function to the approximation
- and calculates the total amount of actual CO_2 emissions since 1750 to
- **1580 giga tons!** (Giga = 10^9)
- Run in the terminal with: `python3 CO2global_twinplot.py`

Plot of global CO_2 emissions since 1750

- Global CO_2 emissions can be described by an **exponential function** :
- y = np.exp ((x-1866.5) /40.9)
- X: year, Y: yearly CO_2 emissions in Gigatons. The coefficients are obtained from optimization.
- Since 2016 we are observing again a rise in fossil CO_2 emissions after a flattening approx. from 2012
- Its sum since 1750 is calculated by the program: **1580 Giga Tons.**



Calculation of the concentration

- From this mass of CO2 emissions, the **increase of the CO2 concentration** caused by it can be calculated, if we set it in **relation** to the mass of the entire earth's atmosphere.
- We use Open Data again: Total mass of the Earth's atmosphere:
- https://de.wikipedia.org/wiki/Erdatmosph%C3%A4re https://en.wikipedia.org/wiki/Atmosphere_of_Earth
- The atmosphere has a mass of about $5.15 \cdot 10^{18}$ kg, which is $5.15 * 10^{15}$ tonnes or **$5.15 * 10^{6}$ giga tons**.

- The concentration of the CO2 emitted by humanity since industrialization would therefore be:

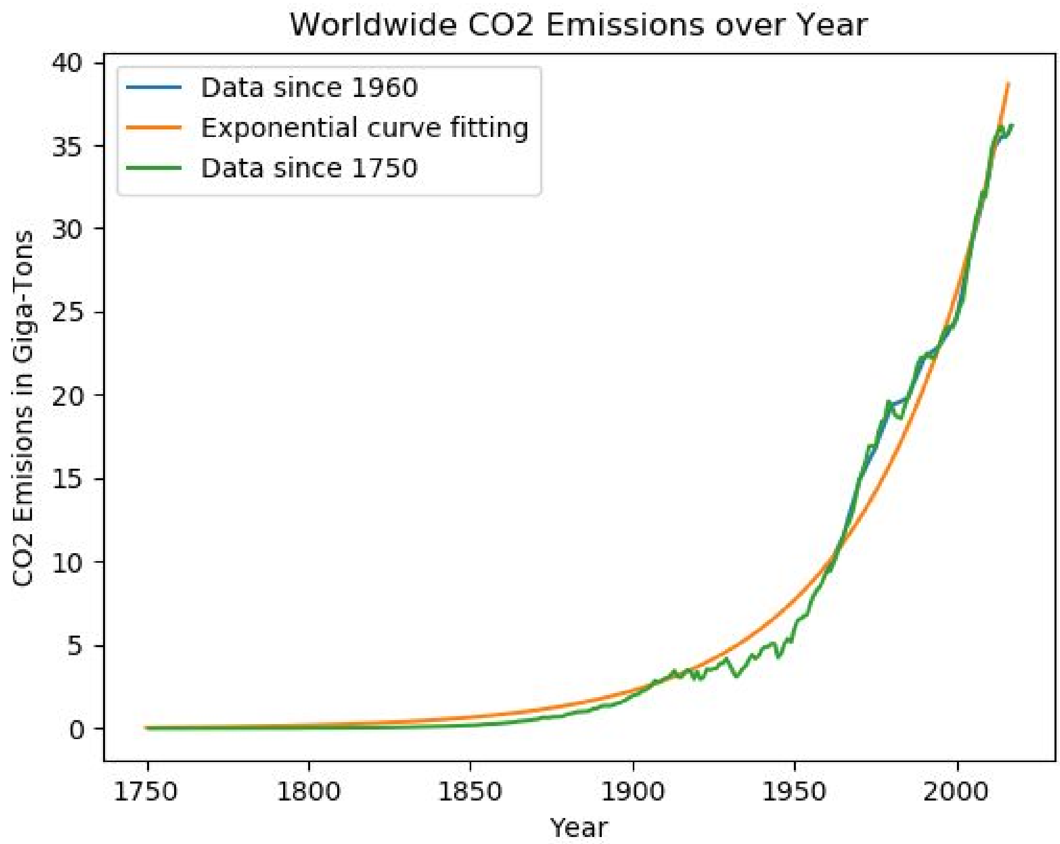
- CO_2 Mass divided by Atmospheric Mass:
- In Python:
- 1580 Giga Tons/ 5.15e6 Giga Tons= 1580 / 5.15e6 = 0.000306 = 306e-6 = **306ppm** (for mass)
- Since it is a gas we have to convert it into volume ppm:
- According to https://en.wikipedia.org/wiki/Carbon_dioxide CO_2 has a density about 1.6 times higher than air, so it takes up less volume. Therefore, we have to divide by this factor for the conversion:
- 306ppm (mass) /1.6= **191ppm (volume)**

- Adding this concentration to the pre-industrial value of about 280ppm gives us:
- 280ppm + 190ppm = 470ppm
- This is about **60ppm more** than we observe (410ppm).
- Human activity is therefore **more than 100% responsible** for the observed increase in CO_2!
- This is a **surprisingly clear** answer.
- This additional amount of 60 ppm could have been absorbed by nature (e.g. Oceans, leading to them becoming more acidic, and forests) as part of a slow control loop

The emissions for no further increase

- Suppose this control loop of nature has been active since the significant increase in CO_2 from 1950, so for about 70 years,
- then we have an annual CO_2 reduction of
- 60ppm / 70 years = **0.85ppm per year**
- Back to the masses of CO_2 per year this is:
- ppm (volume) * 1.6 * Earth's atmosphere mass =
  = 0.85e-6 * 1.6 * 5.15e6 giga Tons = **7 Giga Tons**
- In our Python plot we see that this roughly the **output of 1950** corresponds to.
- With this value we would not have any further increase in CO_2 concentration.

- An annual CO_2 emissions of 7 gigatonnes CO_2 corresponds to the output of 1950



Degradation time

- Assuming we reduce the fossil CO2 emission value to **zero**, then we can estimate the time it takes to return the CO2 concentration to the pre-industrial value of 280ppm.
- Let's assume a **linear** degradation, with a fixed degradation value of 0.85 ppm per year
- Then the degradation time is our increase in CO2 divided by the degradation value :
- (410-280) ppm / (0.85ppm / year), approx. **150** years.
- Note, however, that this is an estimate for **linear** degradation. Exponential decay, with a fixed percentage every year, is likely to be more realistic and accurate.

- For comparison: https://www.theguardian.com/environment/2012/jan/16/greenhouse-gases-remain-air
- "Between 65% and 80% of CO_2 released into the air dissolves into the ocean over a period of 20-200 years
- “The rest is removed by slower processes that take up to several hundreds of thousands of years, including chemical weathering and rock formation.”
- Our rough estimate therefore has a good match again.

Conclusion

- For the CO_2 concentration to **not further increase**, we would have to reduce the annual **fossil CO_2 emissions** to the **value of approx. 7 Giga tons, the value of 1950!**
- Our plot also shows: At the moment we are at about **35 Giga tons, about five times the value of 1950!**
- That means a **reduction of** (35-7) / 35 * 100 = **80 percent!**
- This is just to keep the atmospheric CO_2 concentration from increasing any further.
- If we want to reduce the concentration, we need to reduce our CO_2 emissions even **further!**

- **Saving energy is no longer enough** for the reduction by 80%
- -> We should **barely burn any fossil fuels**

- Instead we need to **switch completely to renewable energy**.
- It is not enough to just change the biggest emitters.
- All have to join, all countries, big and small, and all sectors, whether transport or industry or households.
- In order to preserve or strengthen nature's ability to decompose CO_2 (the 0.85 ppm per year), we must protect oceans and and reforest forests.

Next Video:

We answer the question: does the CO_2 concentration influence the global temperature?