3. CO2 Emissions and Concentration

Asko Vuorinen
Ekoenergo Oy

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Based on the Book:
"Fundamentals of Global Warming"

Presentations about Global Warming

1. Global Warming 1901-2018
2. Influence of the Sun
3. CO2 Emissions and Concentration
4. Forecasting Global Warming
5. Seawater and Ice Conditions
6. Milankovich Cycles
7. Action Plans
8. Target Scenario 2050

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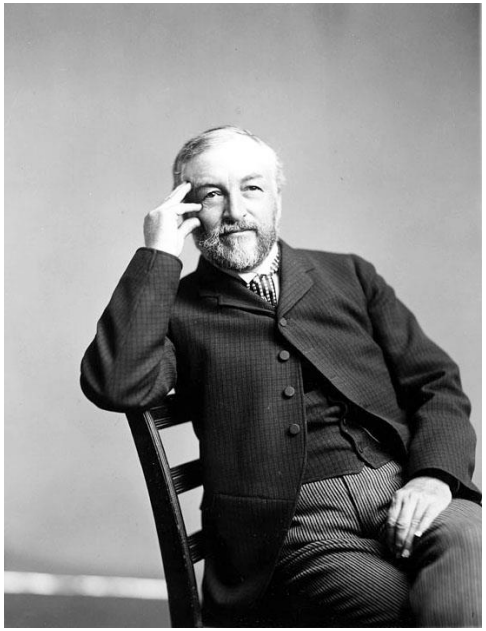
INTRODUCTION

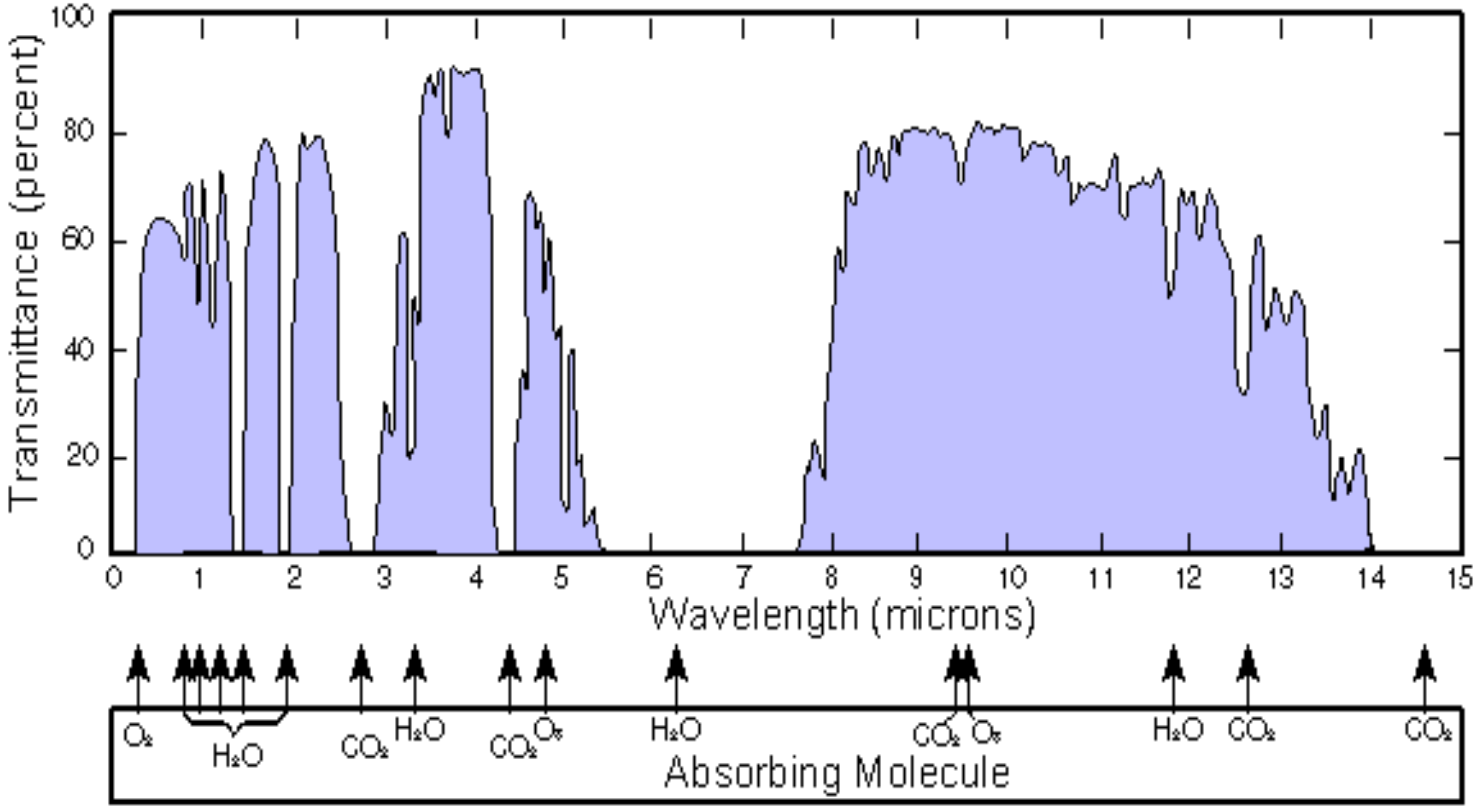
Samuel Langley (1834-1906)



Invented bolometer to measure infrared radiation.

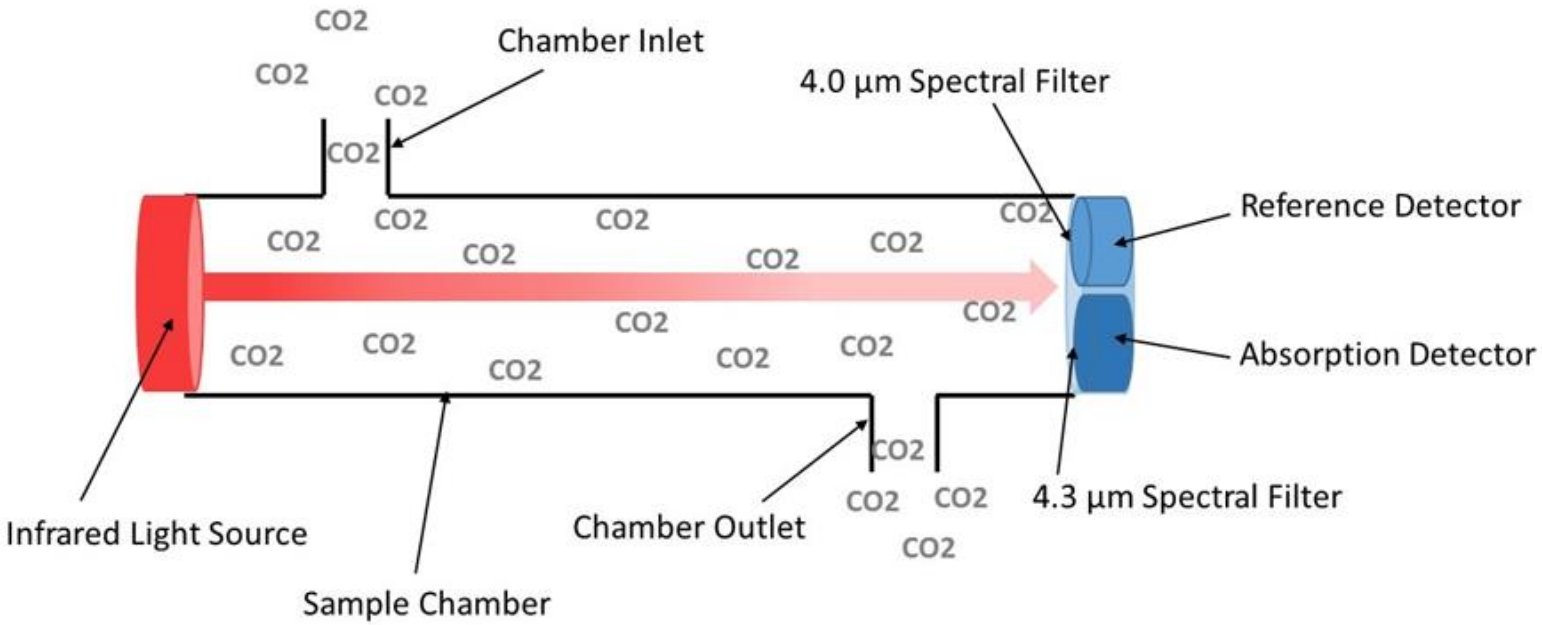
Made tables of infrared radiation of the moon by measuring moon radiation in Rocky Mountains

Measurement of CO2 concentration is based on IR-radiation



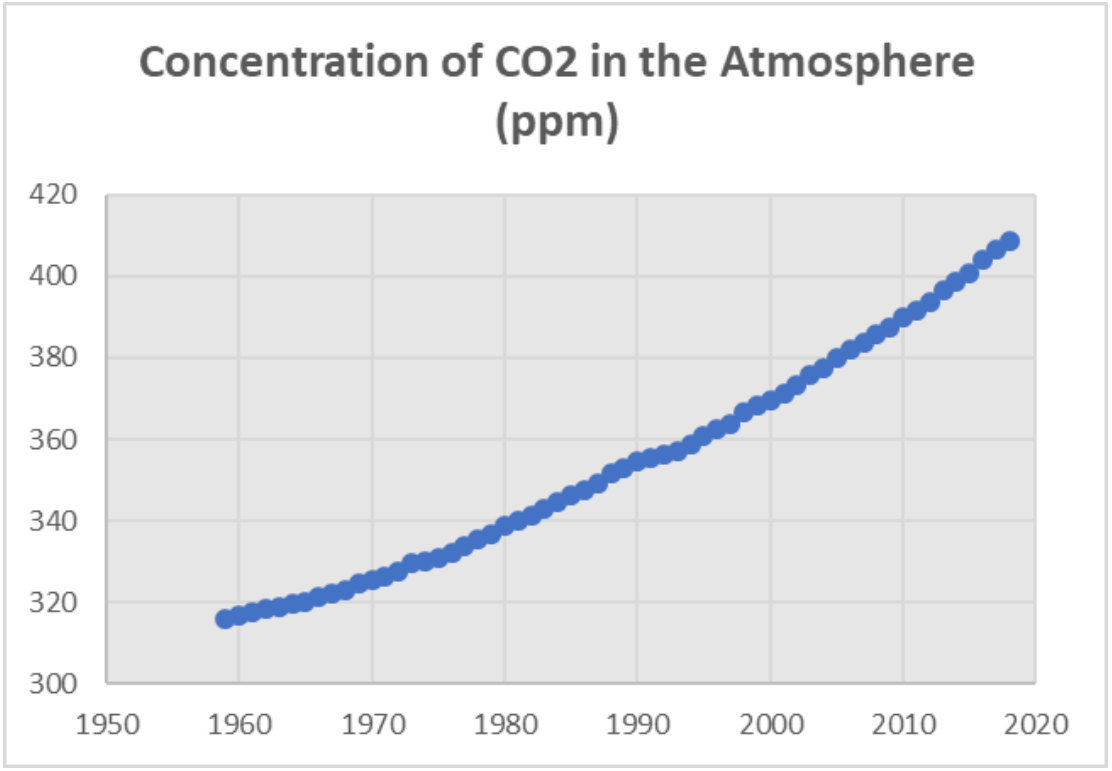
Transmittance of IR radiation depends on CO_2 content and wavelength

Measurement of CO2 concentration is based on IR-radiation



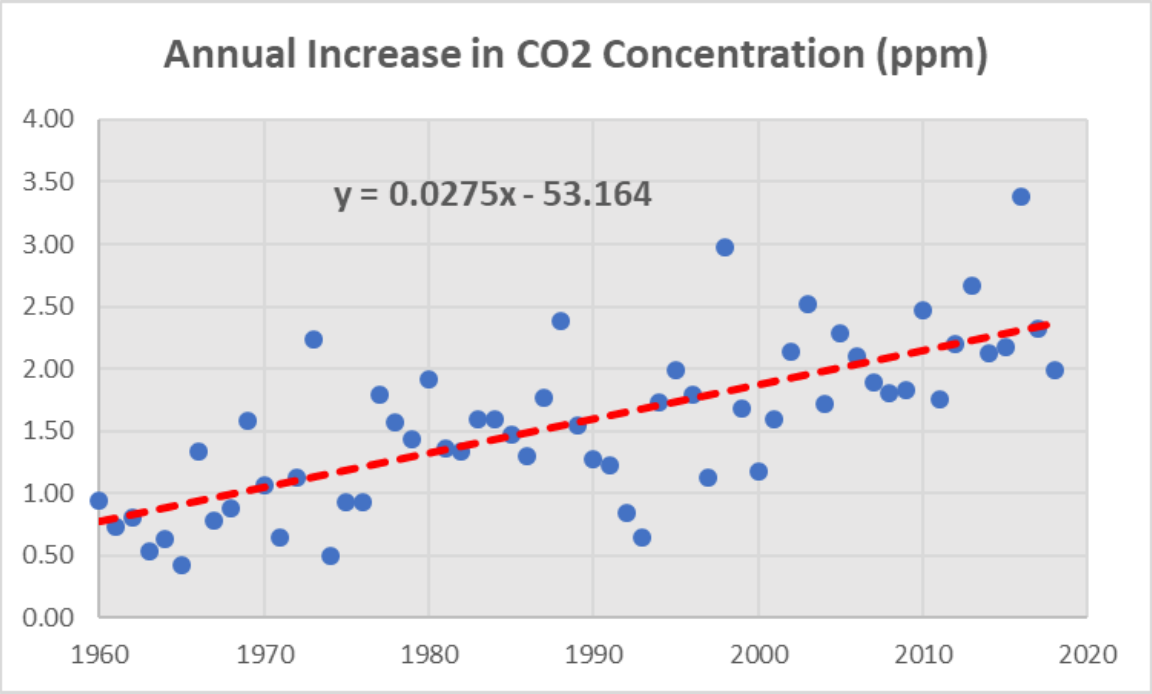
CO2 CONCENTRATION

Annual CO2 Concentration



Charles David Keeling started measurements in 1958 in Hawaii. His first measurement result was 314 ppm. The first full year was 1959, when average concentration was 316.0 ppm, but in 2018 it was 408.5 ppm.

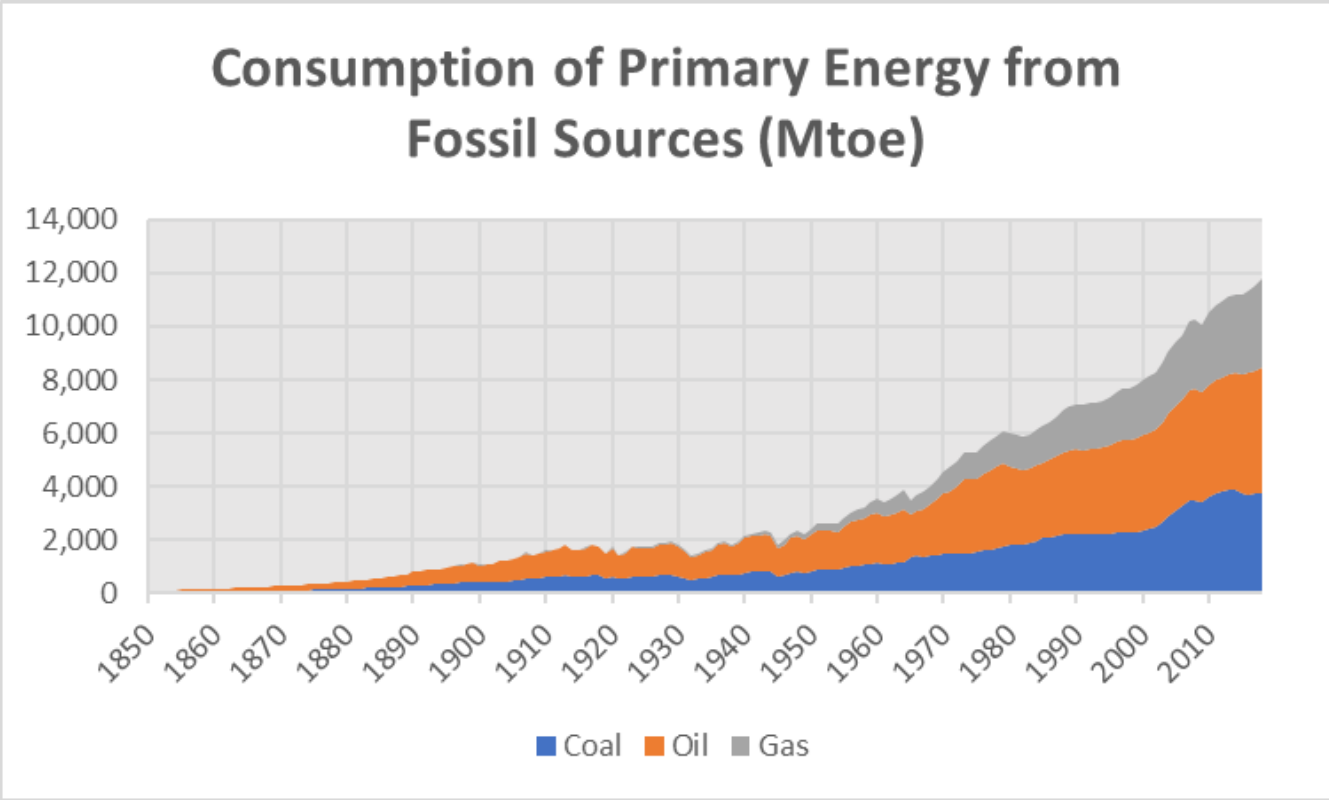
Change in annual CO2 Concentration



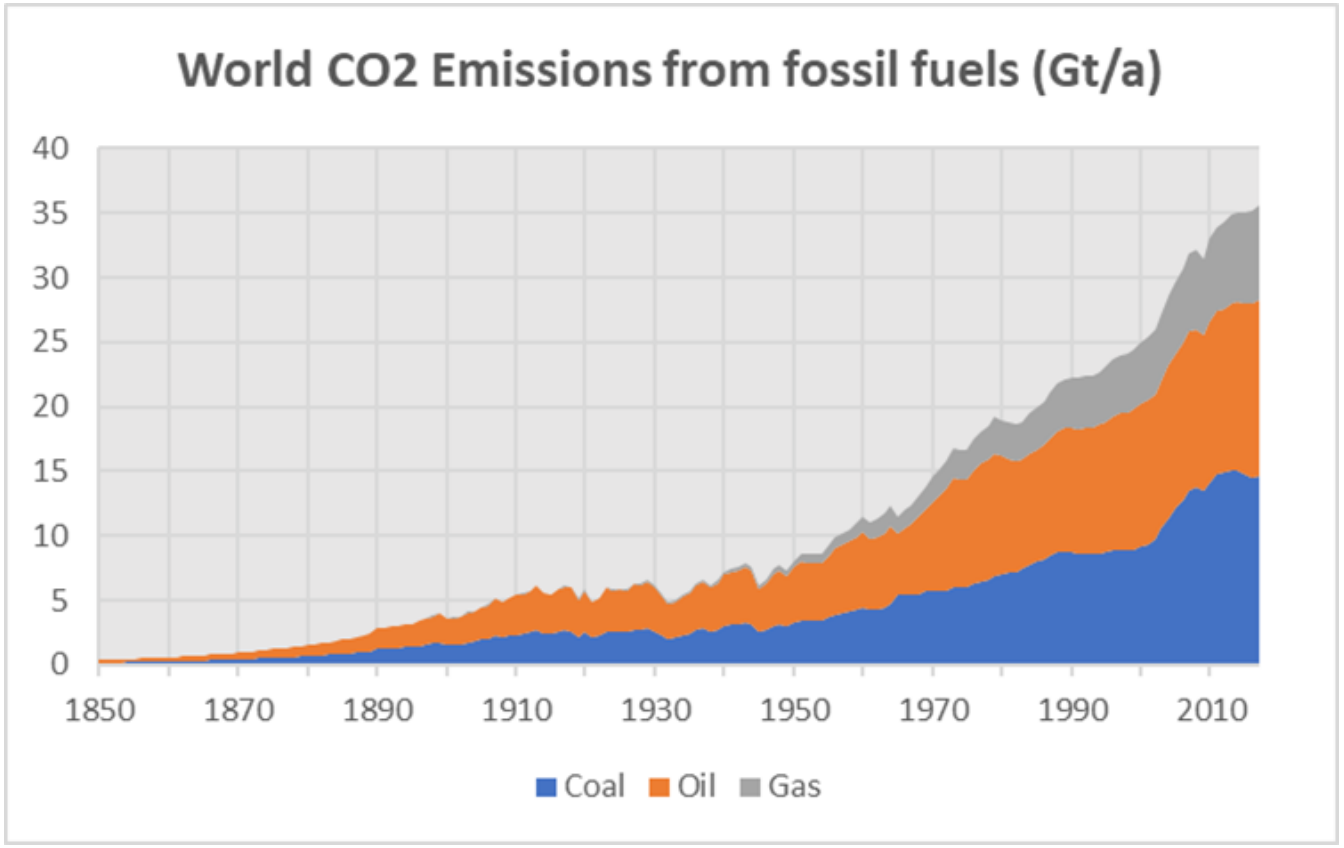
Concentration has been rising 2.3 ppm annually in 2018

CO2 EMISSIONS

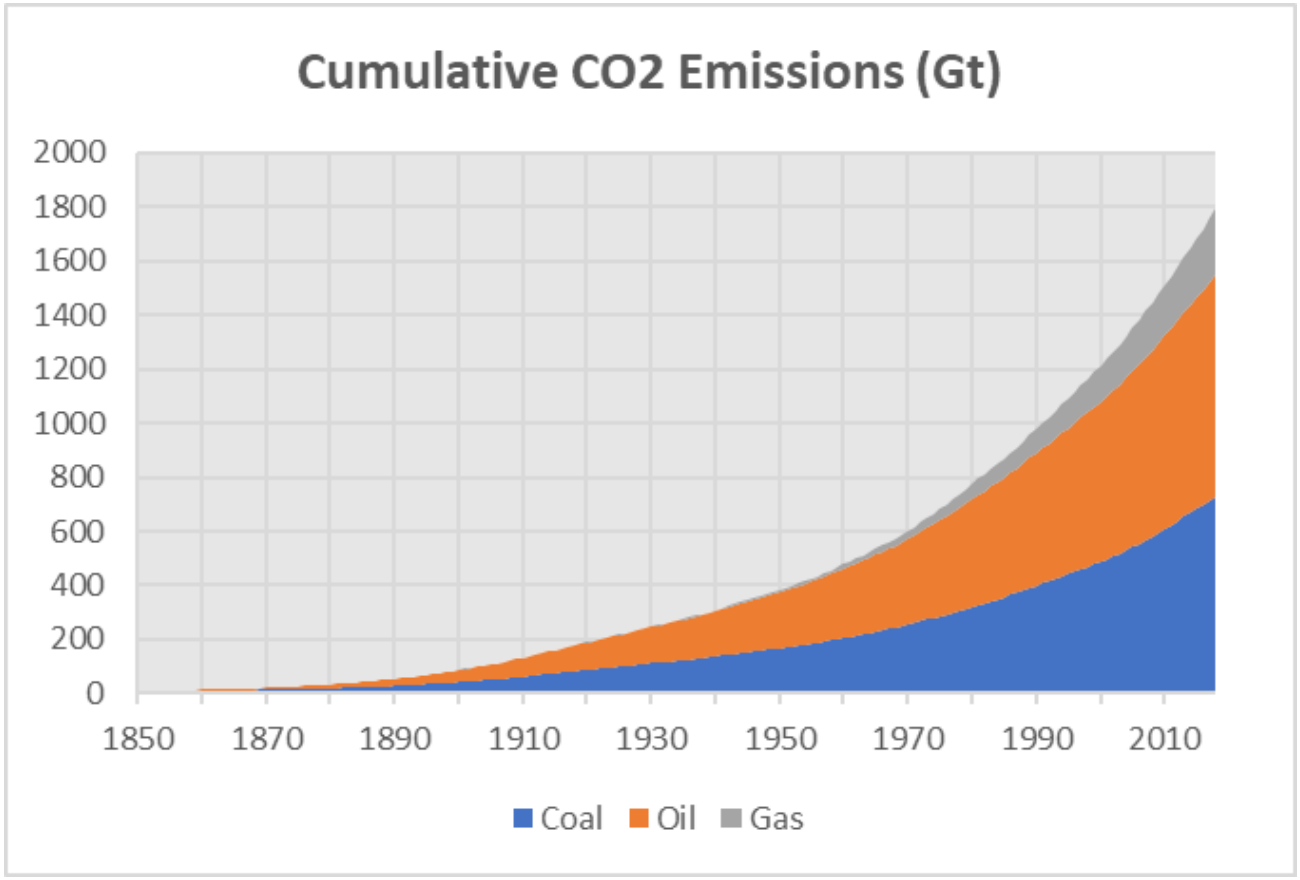
Consumption of primary energy
(German 1850-1900, EIA 1900-1965, BP 1965 - 2018)



Annual emissions of fossil fuels

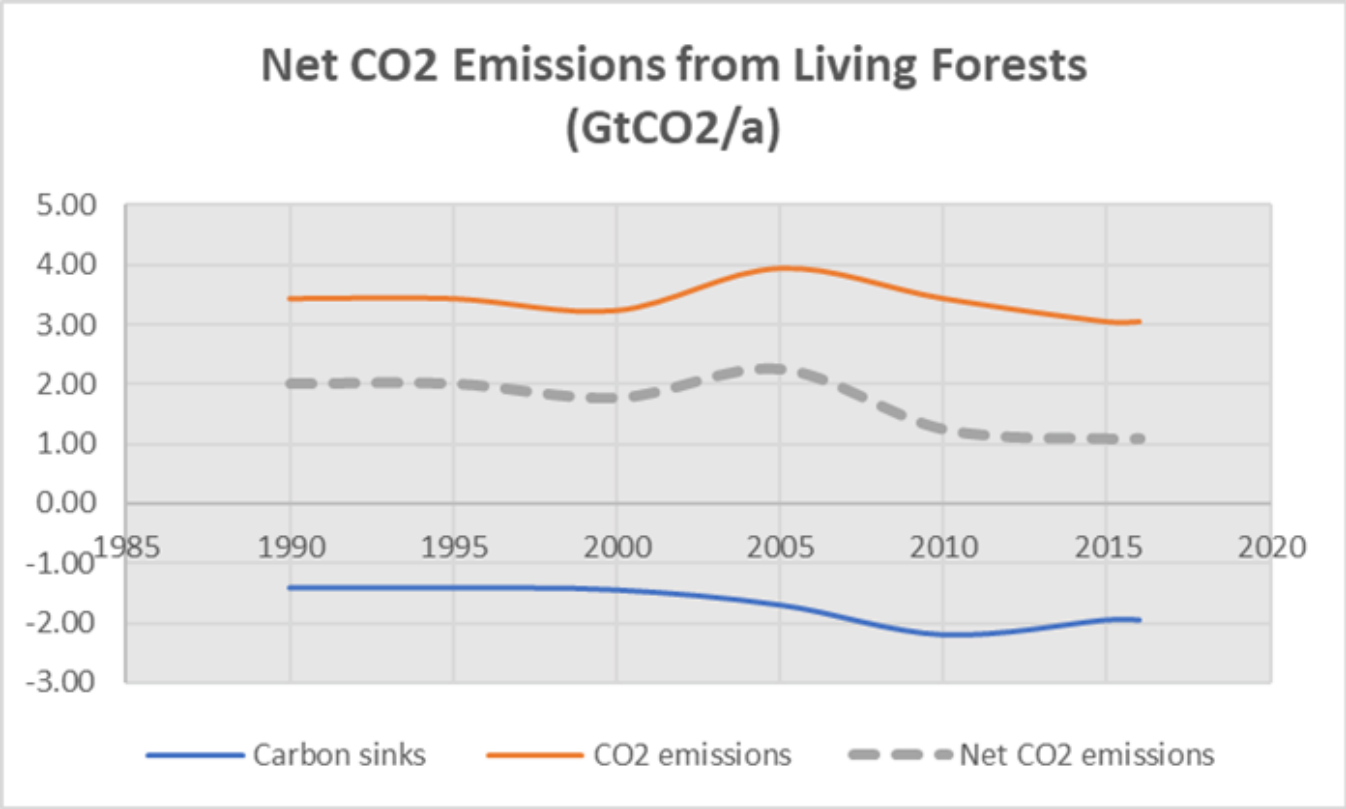


Cumulative Emissions from Fuels (Gt)



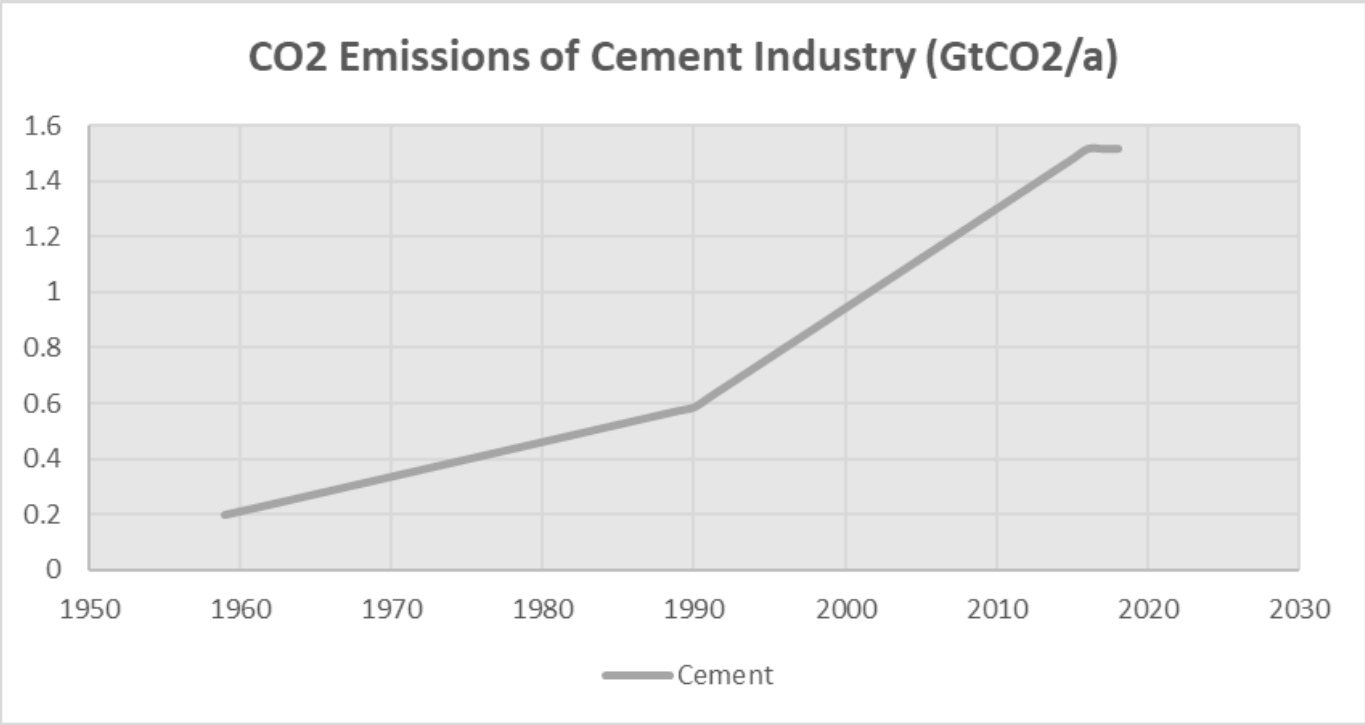
Cumulative emissions from fossil fuels since 1850 are 1790 GtCO2

Emissions from Living Forests (GtCO2/a)

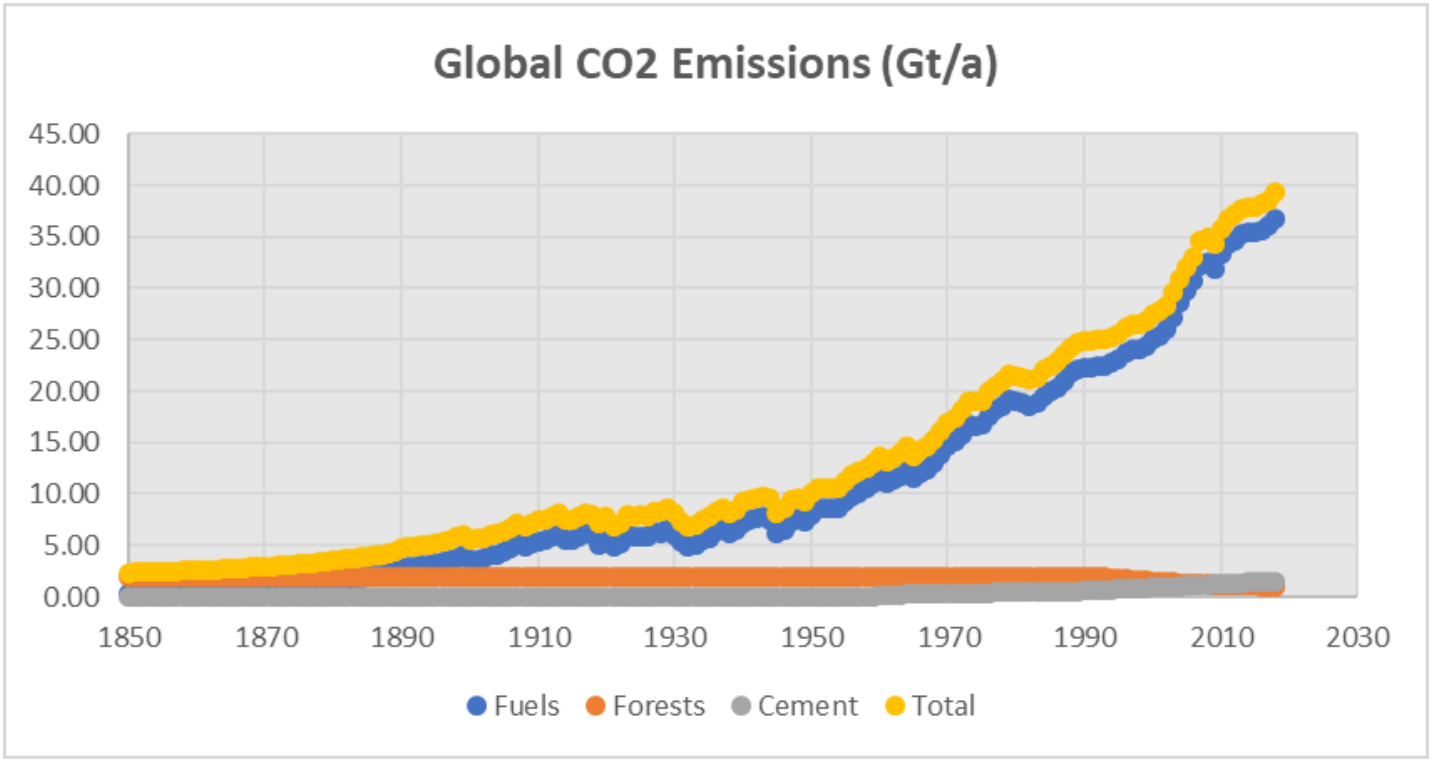


Some countries have 3 GtCO2 emissions and the other countries 2 GtCO2 sinks from living forests. The net emissions are about 1 GtCO2/a

Emissions from Cement Industry (GtCO2/a)

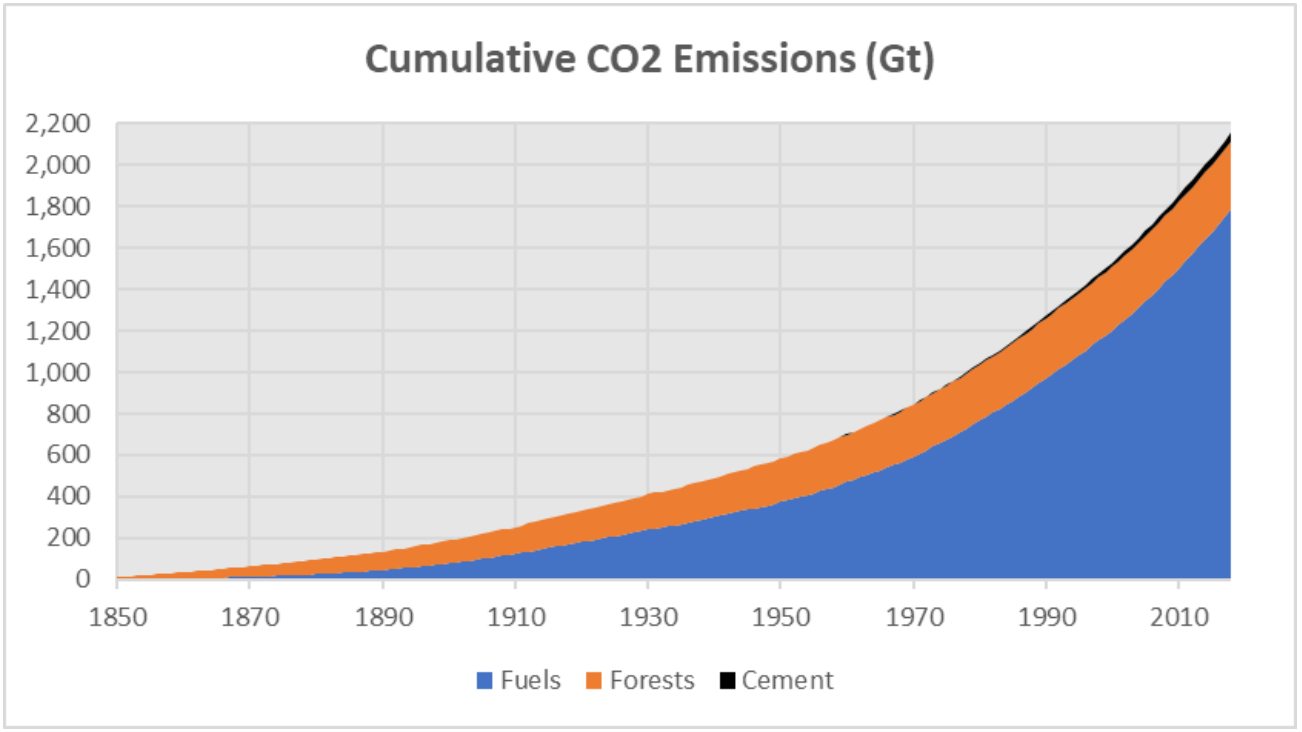


Emissions from Fuels, Forests and Cement Industry (GtCO2/a)



Forest emissions were larger than fuel emissions before 1880

Cumulative Emissions from Fuels, Forests and Cement Industry (GtCO2/a)



EMISSION REDUCTION SCENARIOS

The fossil fuel resources 2016 (Gtoe)

Countries	Coal	Oil	Gas	Total
USA	153.0	6.0	7.4	166.5
EU	46.5	0.6	1.0	48.1
Russia	97.8	14.5	29.6	142.0
Australia	88.3	0.4	3.1	91.8
China	84.7	3.5	4.6	92.8
India	59.6	0.6	1.1	61.2
Saudi Arabia	-	36.6	6.8	43.4
Rest of the world	101.3	177.1	110.3	388.7
Total	631.4	**239.3**	**164.0**	**1034.6**
Consumption 2017	**3.7**	**4.6**	**3.1**	**11.3**
R/C (Years)	**170.4**	**52.4**	**53.4**	**91.2**

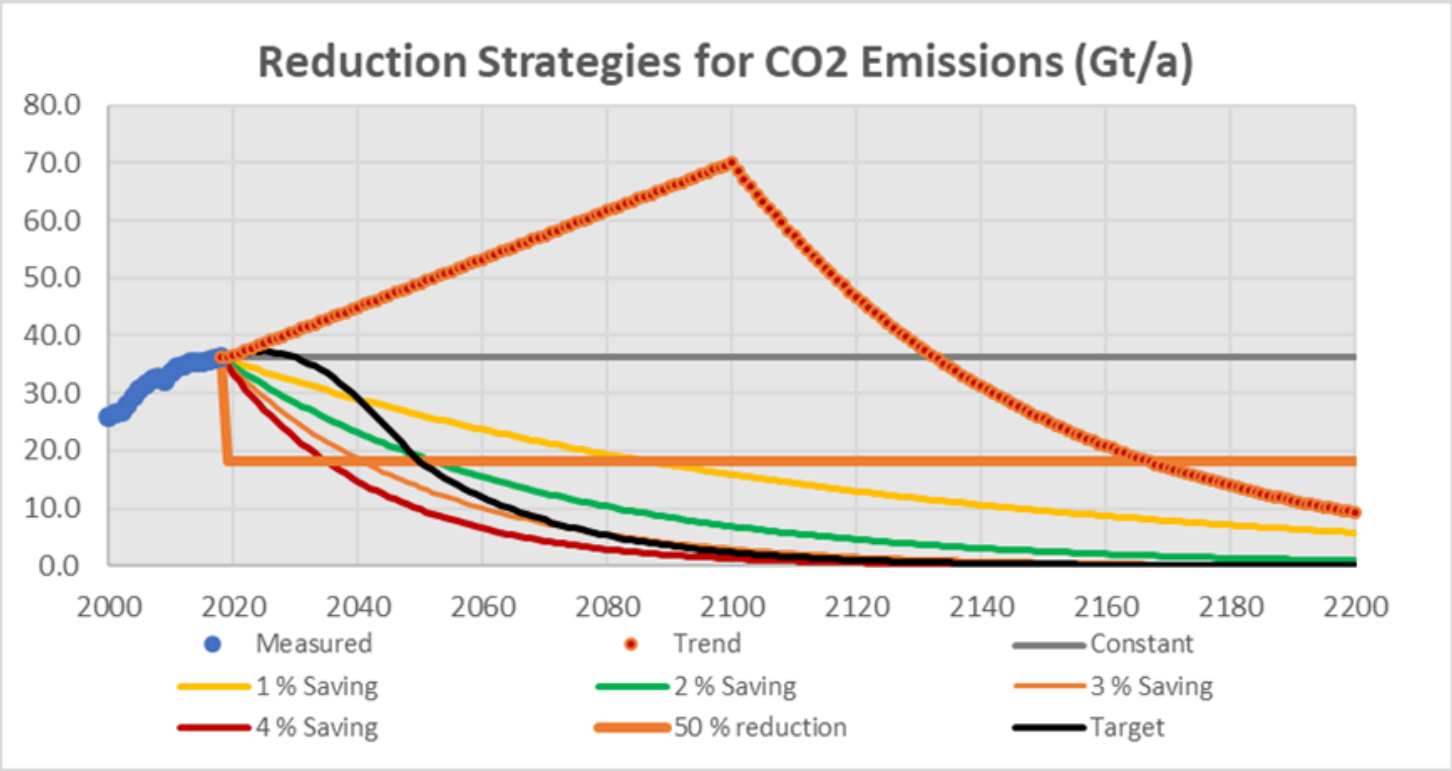
Source: BP Statistical Yearbook 2018

CO2 emissions (GtCO2), if ultimate fuel reserves will be burned, 10,000 GtCO2

Countries	Coal	Oil	Gas	Total
USA	1,799	55	52	1,907
EU	547	6	7	560
Russia	1,150	134	208	1,492
Australia	1,038	4	22	1,064
China	995	32	33	1,060
India	701	6	7	714
Saudi Arabia	0	337	48	385
Rest of the world	1,191	1,630	775	3,596
Total	**7,423**	**2,203**	**1,151**	**10,777**
Emissions until 2017	719	790	233	1,741
Total	**8,142**	**2,993**	**1,384**	**12,519**

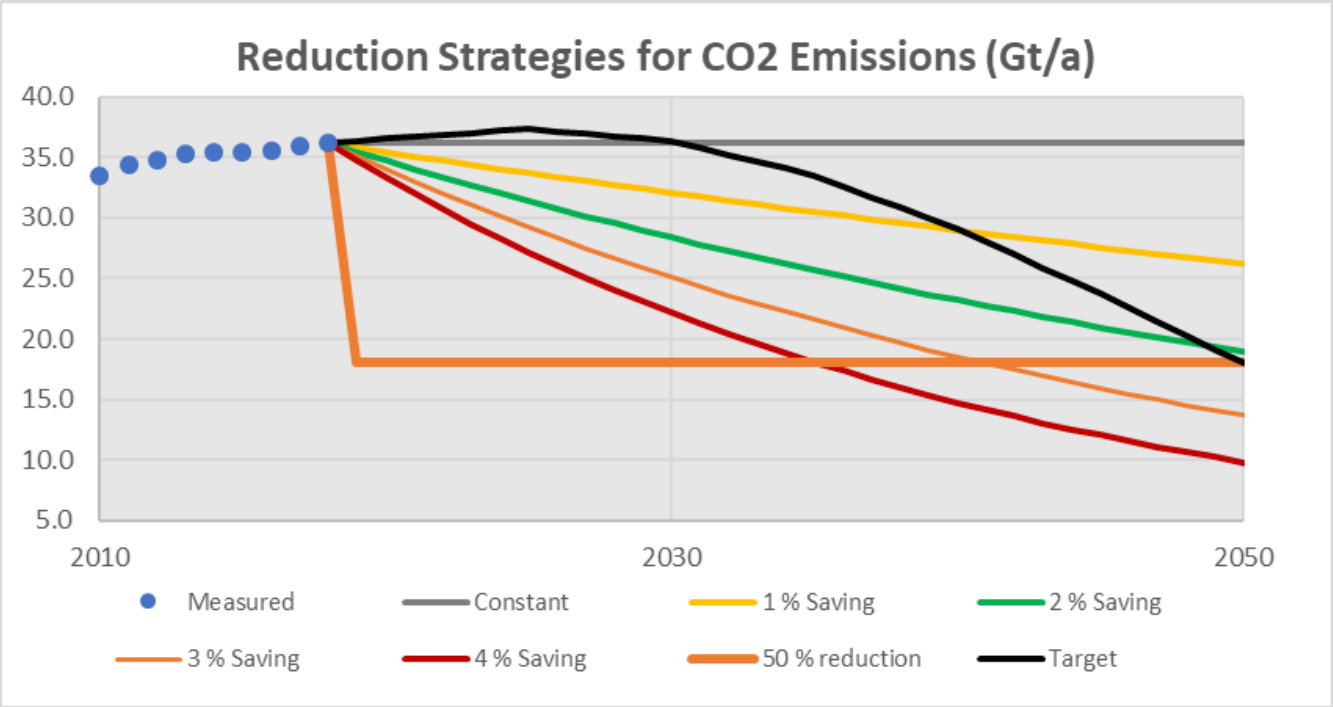
Ultimate fuel resources are at least 3 x reserves

Emission Reduction Scenarios



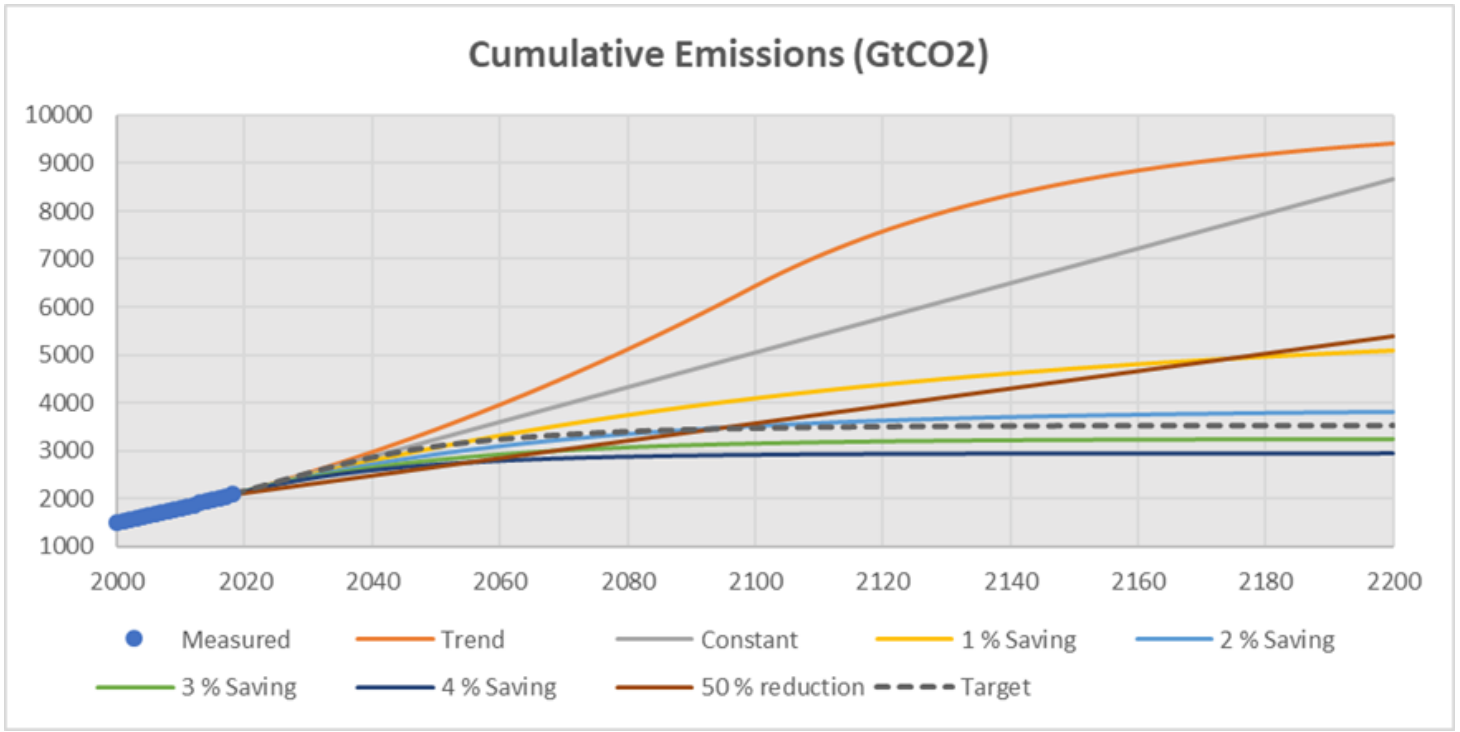
Trend will peak in 2100, when the resources will be exhousted,
Target (emissions black) is a realistic to reach 2-deg. C warming

Emission Reduction Scenarios

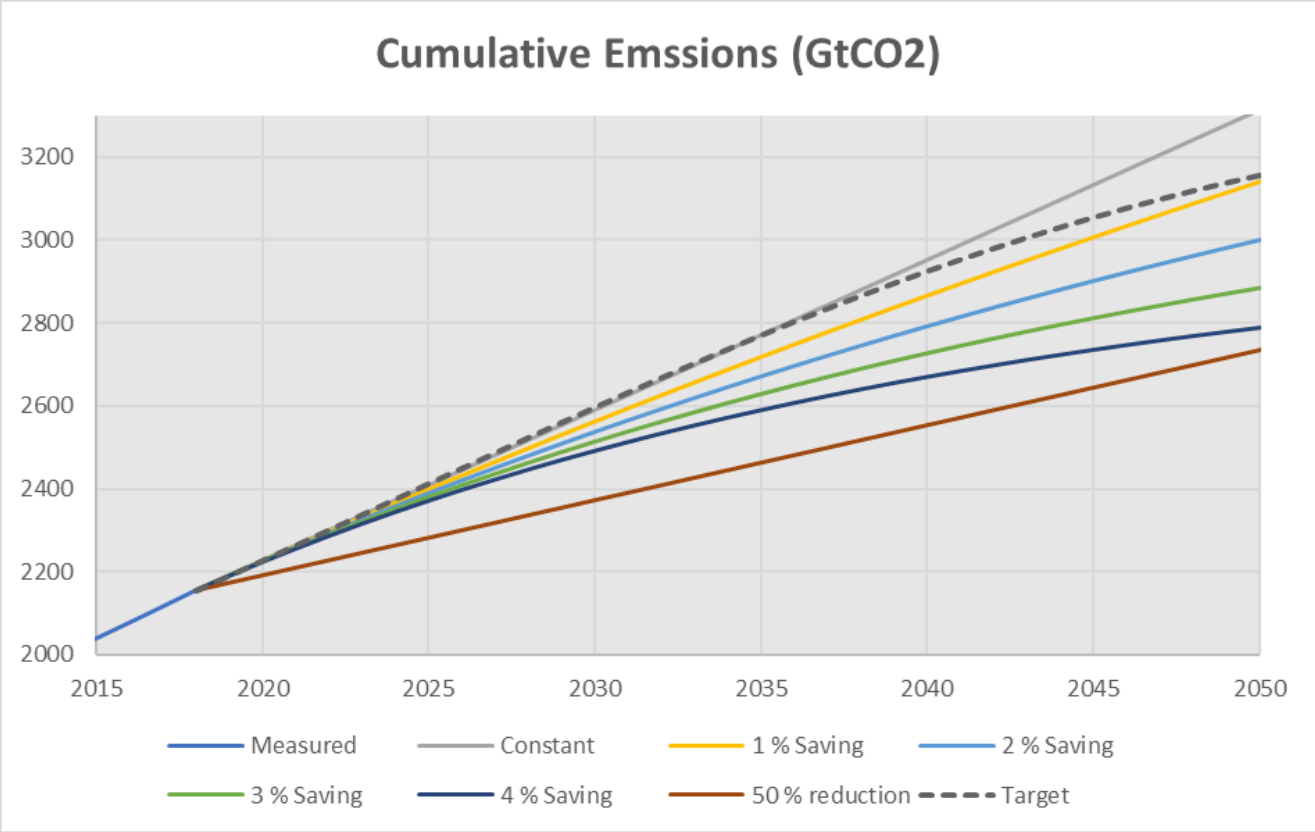


18 Gt emissions by 2050 can be achieved by 2 % saving annually, 50 % saving 2019 or with the target plan (black curve).

Cumulative emissions by 2200

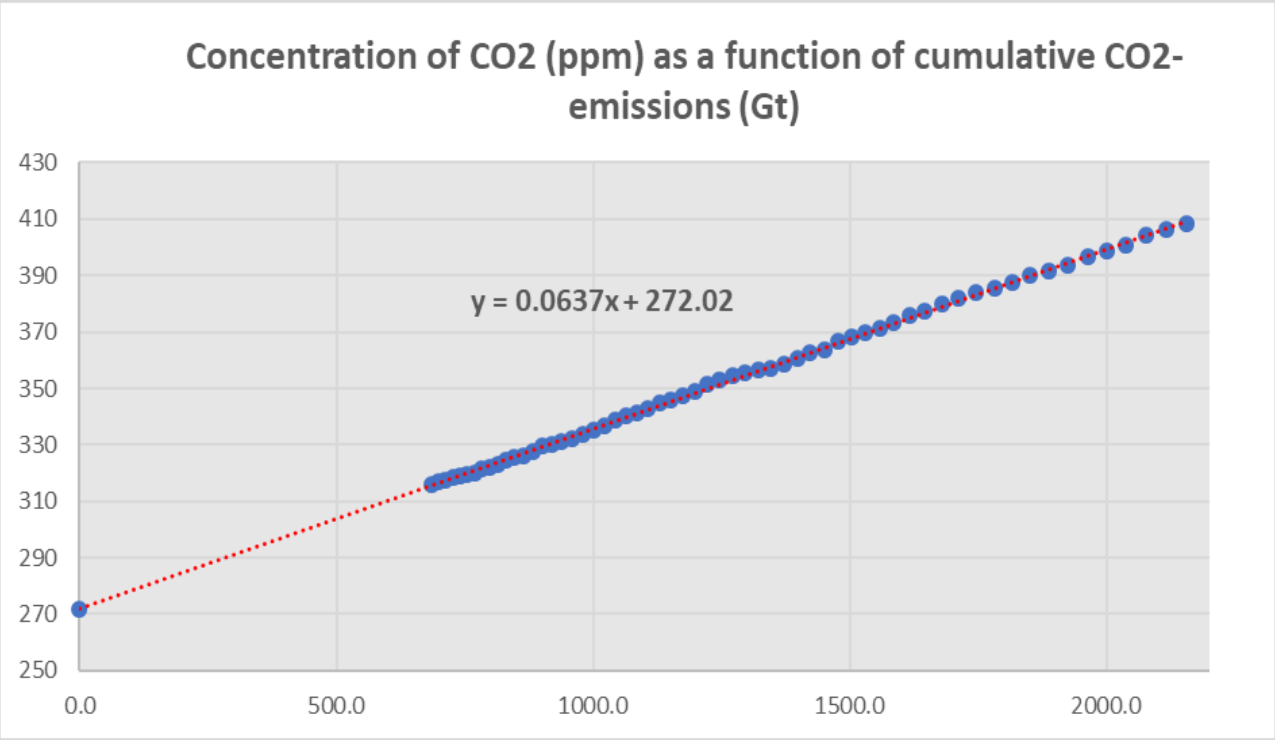


Cumulative emissions by 2050



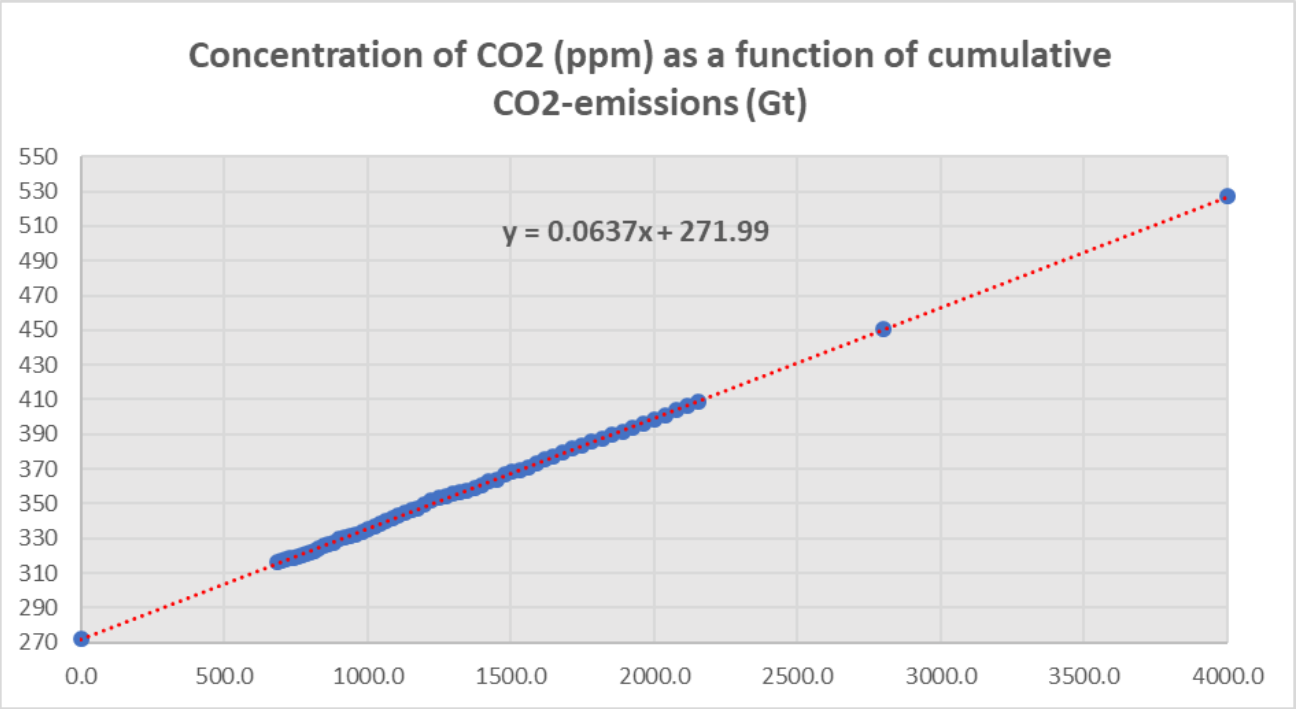
LINEAR MODEL OF CO2 CONCENTRATION

Concentration of CO2 is direct related to cumulative emissions

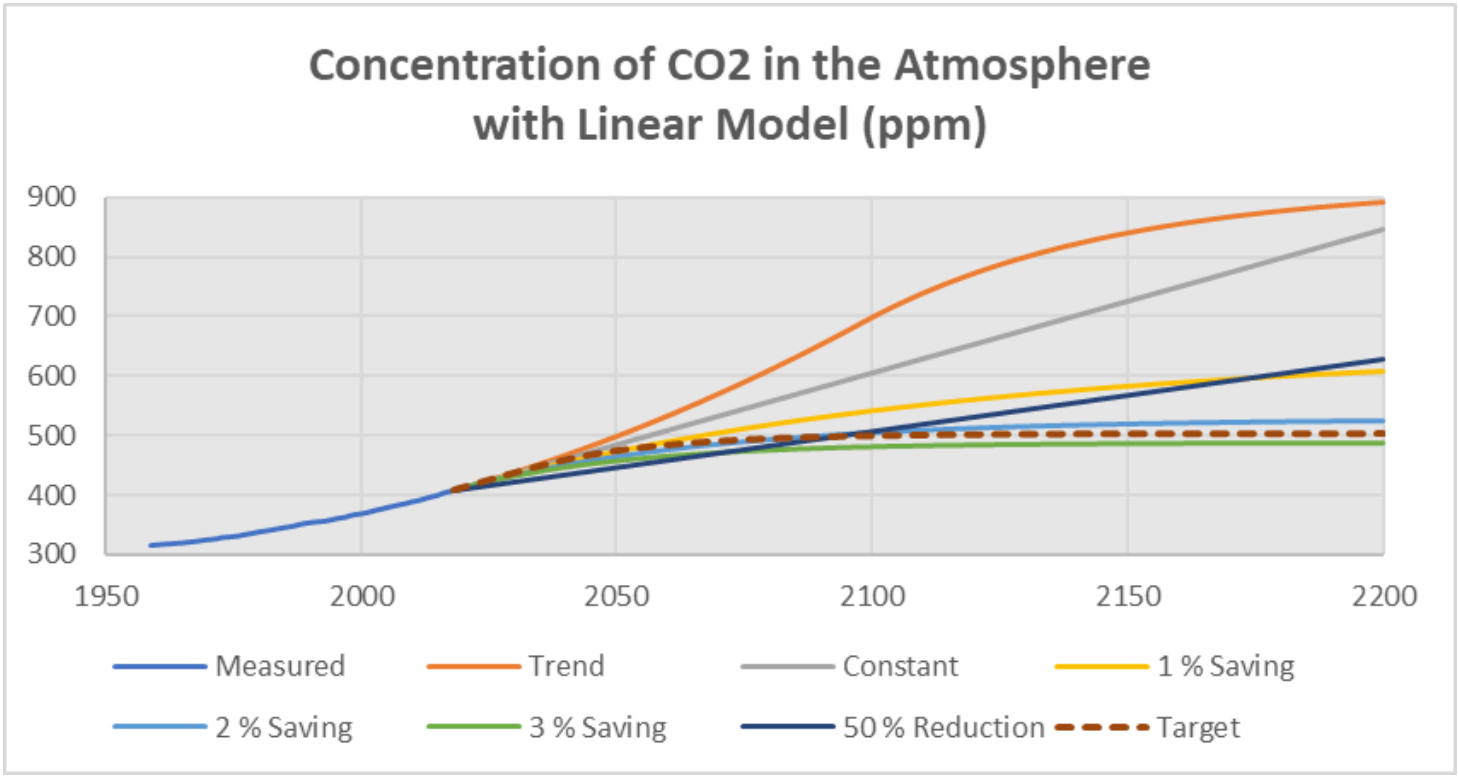


Linear model: If emissions increase with 1000 Gt, concentration will rise with 64 ppm

With linear model: CO2 concentration of 450 ppm reached at 2800 Gt emissions



Linear model: Concentration in the atmosphere



MASS BALANCE MODEL OF CO2

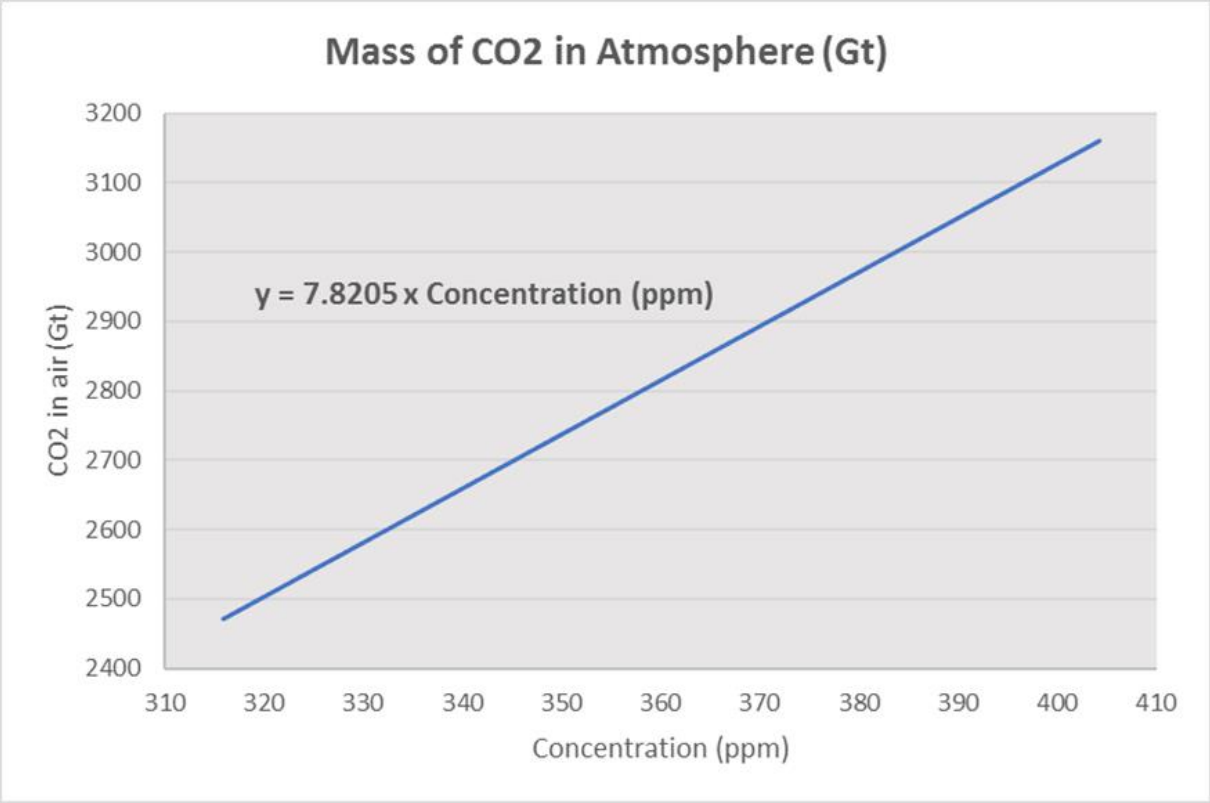
Mass balance means that emissions and changes in carbon sinks are in balance

CO2 emissions =
storage in air (dMa) and sinks dMs)

And

CO2 emissions < 3 x fuel reserves

Mass of CO2 in Atmosphere can be calculated from CO2 concentration



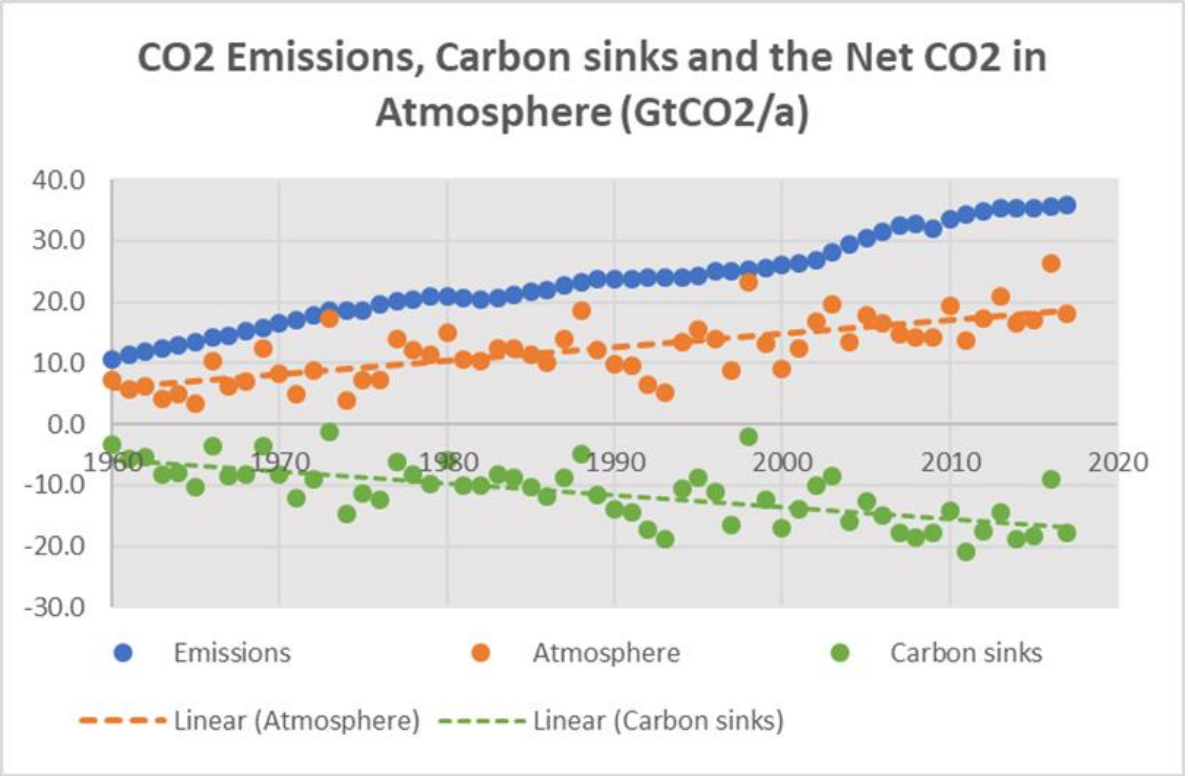
Formula: Ma = 7.8205 x concentration (ppm)

Absorbtion by the sinks dMs

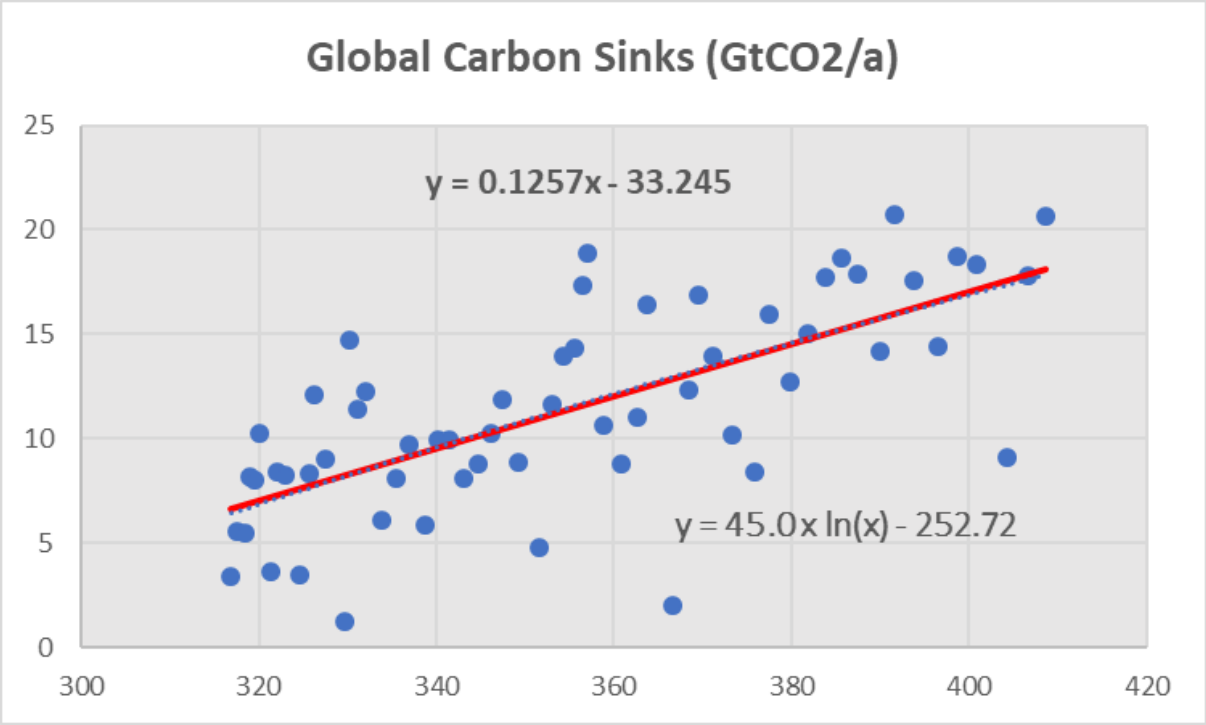
dMs = Emissions - dMa

where
dMa = change of CO2 in air

Carbon sinks are about 50 % of emissions

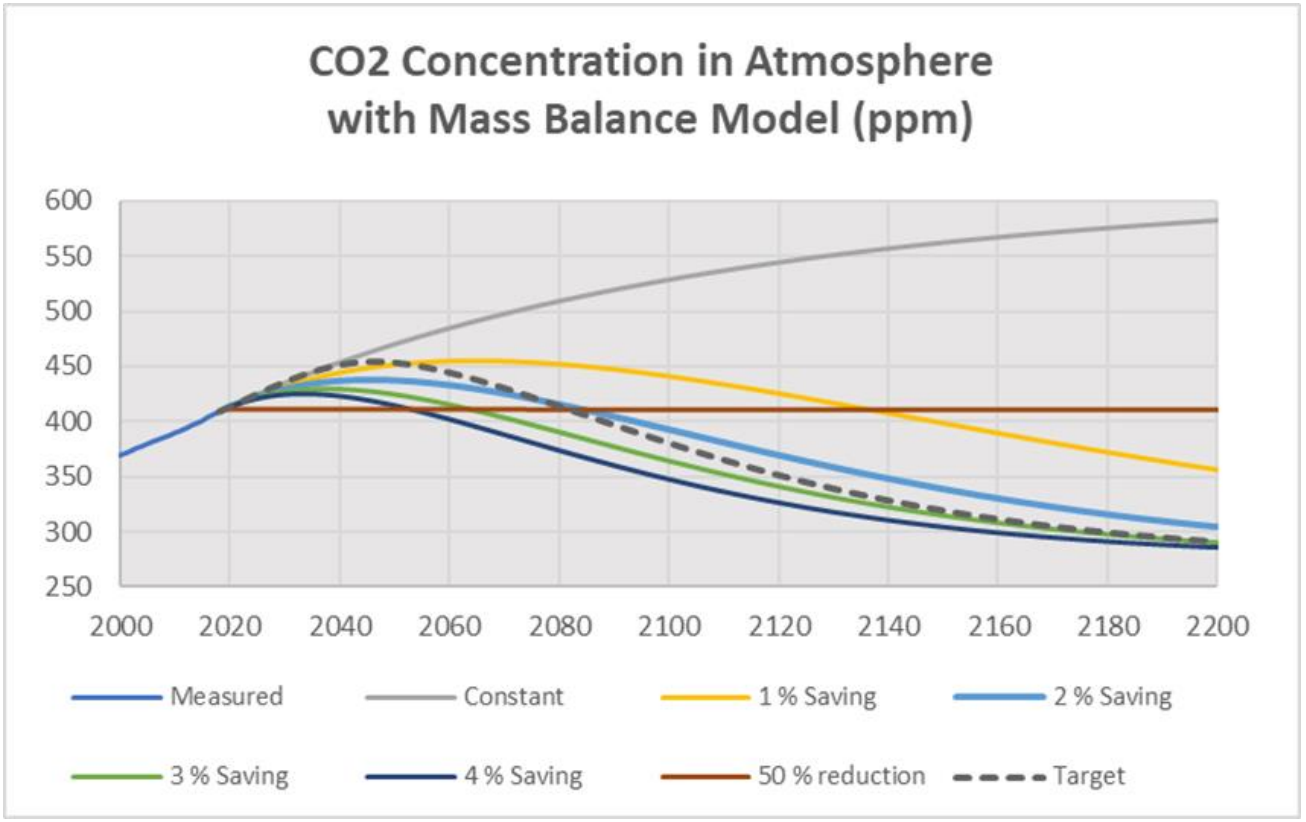


Carbon Sinks Depend on the CO2 Concentration in the Air



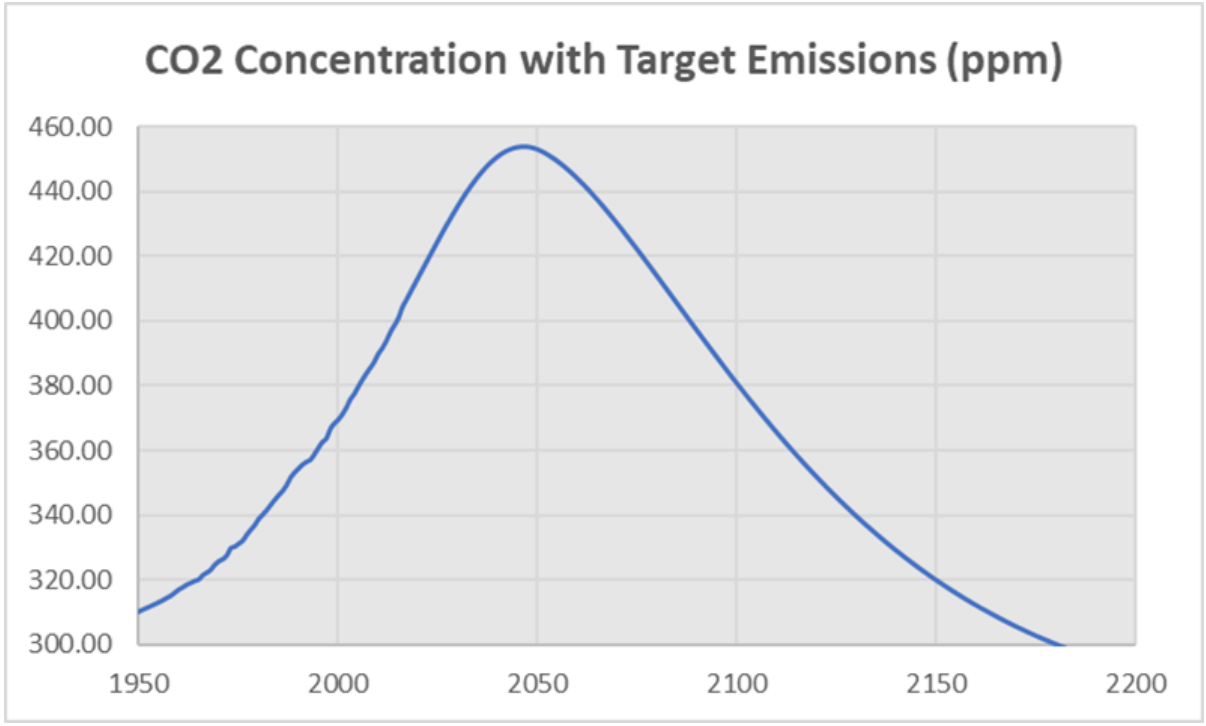
Logarithmic model: dMs = 46.0 x ln (Concentration) – 252.7

Concentration of CO2 in Atmosphere with the Mass Balance Model (ppm)



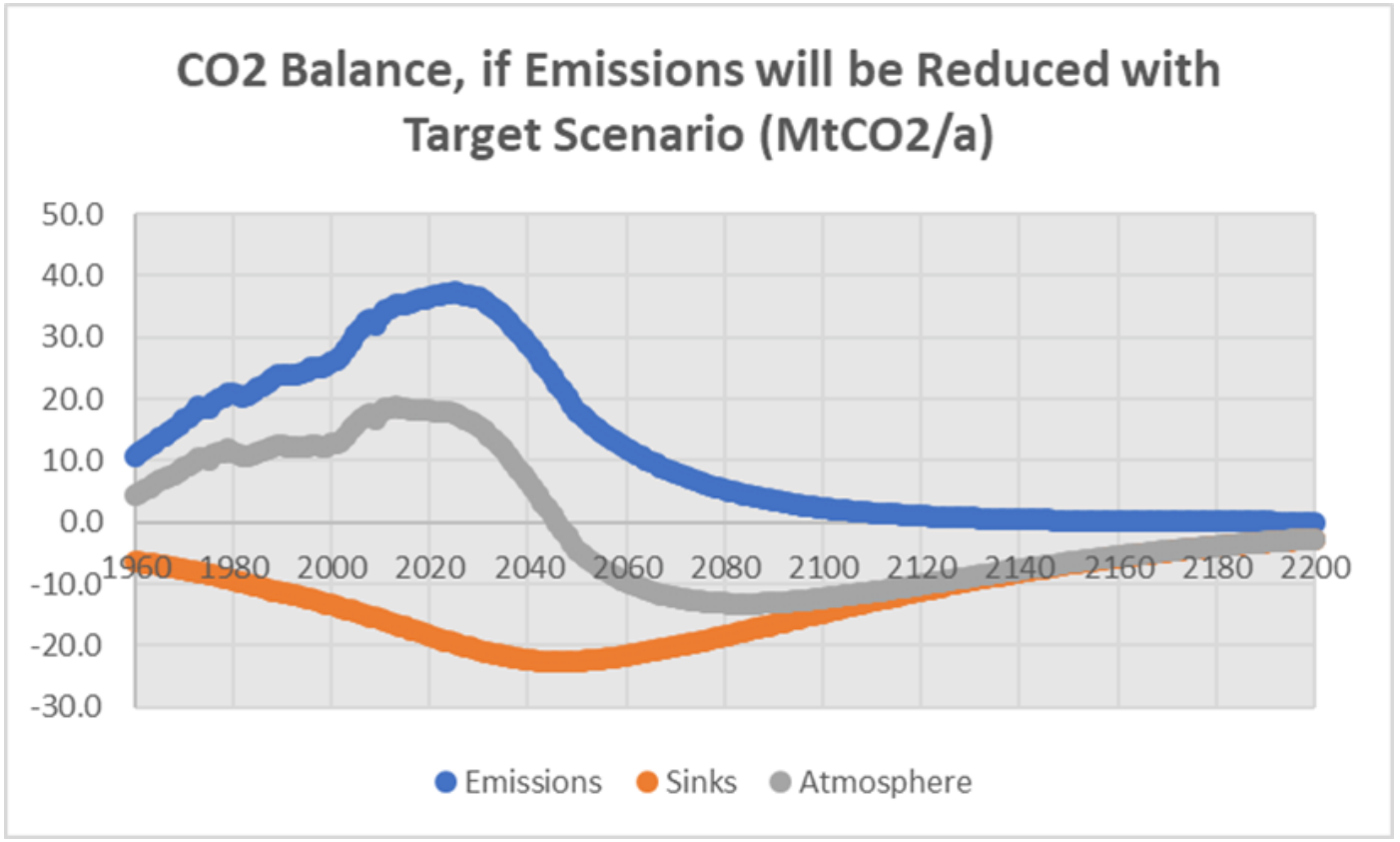
Concentration will stay below 450 ppm, if the emissions will be reduced at least 2 %/a or with the target emissions

Concentration of CO2 in Atmosphere with Reduction with the Target Plan (ppm)

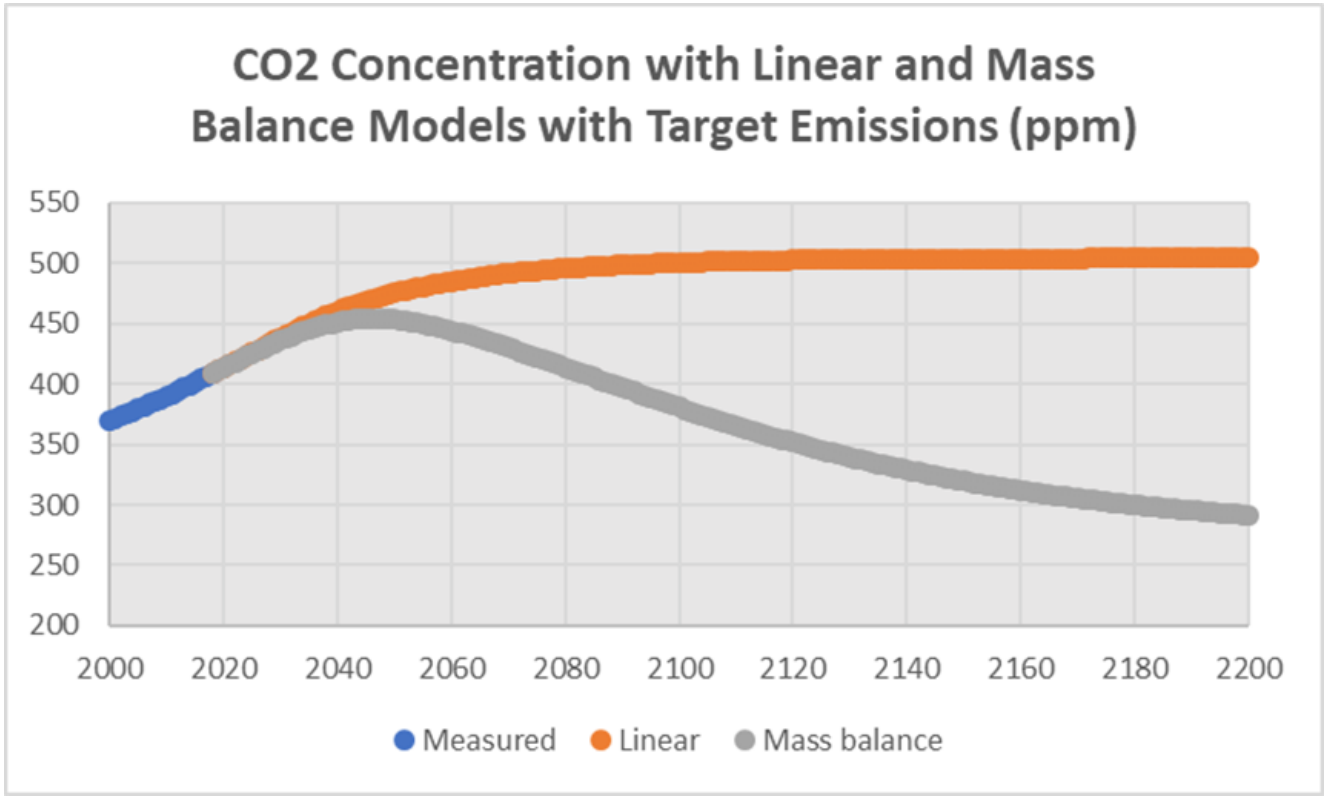


Concentration will stay below 450 ppm, if the emissions will be reduced with the target plan

With Target Emission Plan, the Sinks will be Larger than Emissions by the year 2045

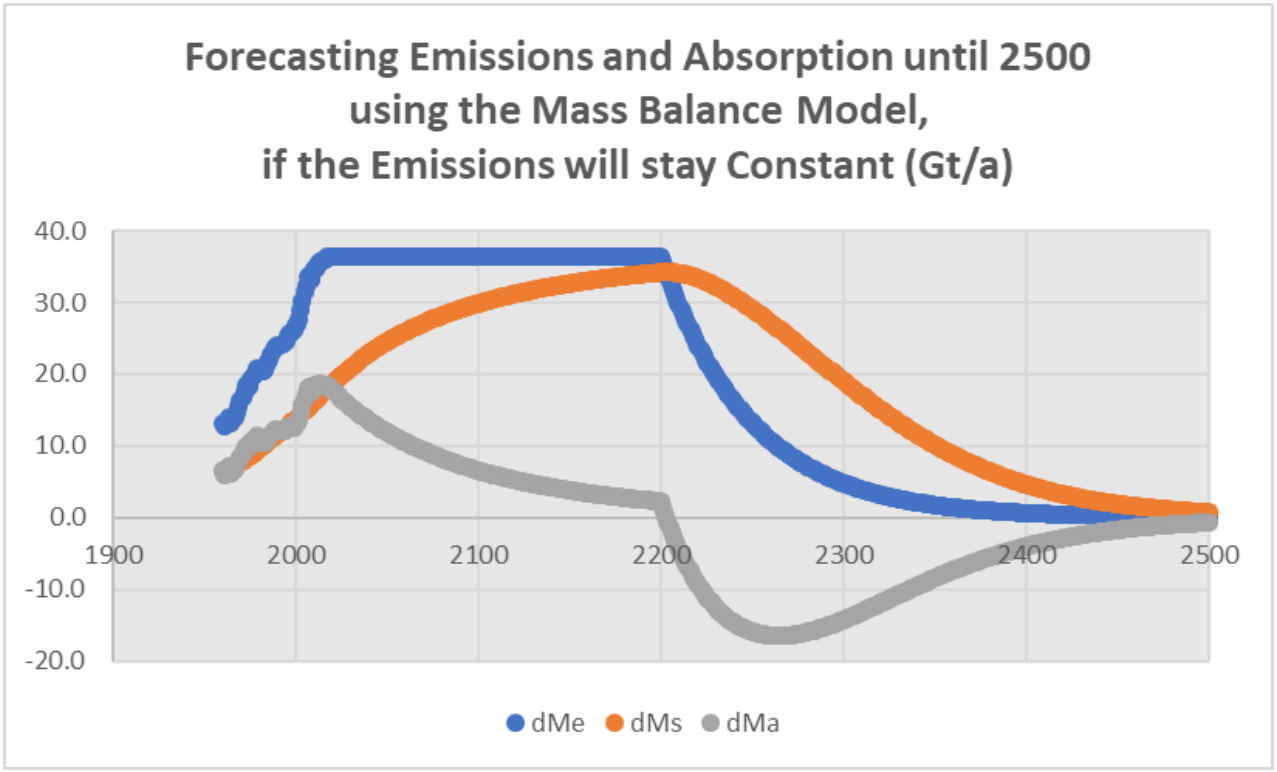


Concentration of CO2 in Atmosphere with the Mass Balance Model and Linear Model (ppm)



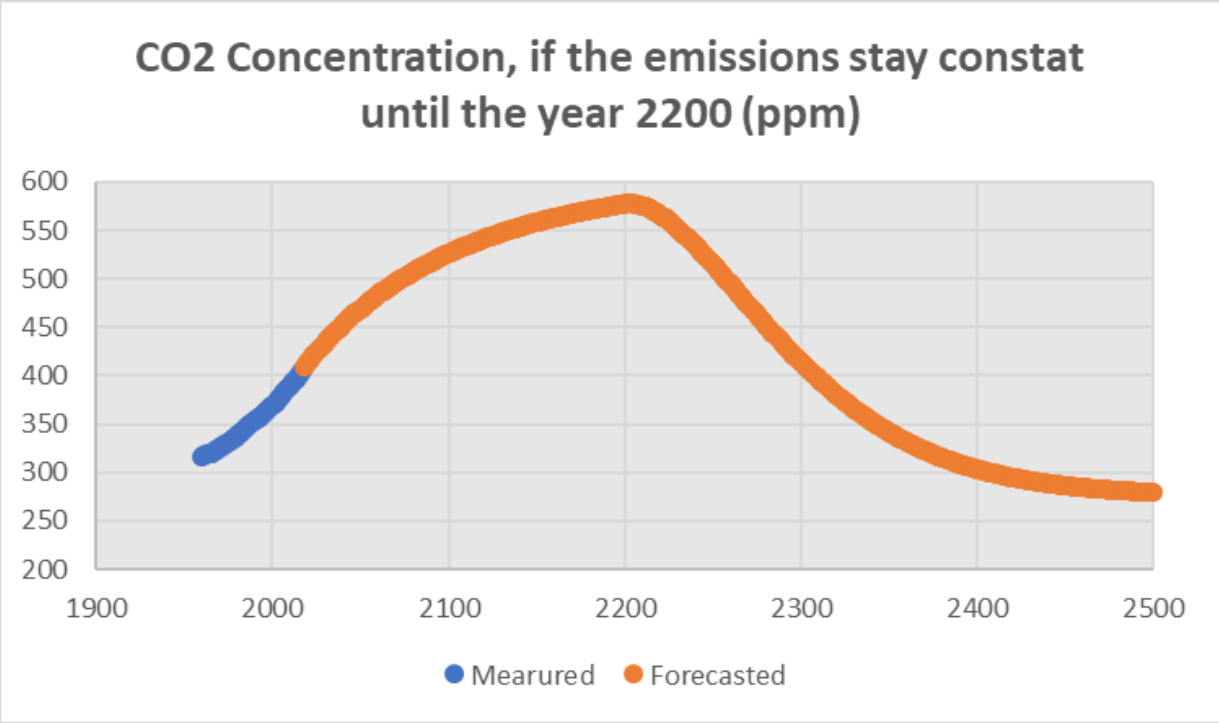
Concentration with Mass Balance Model will have peak value of 454 ppm by 2045, but with the Linear Model peak will be at 500 ppm

If emissions stay constant until the year 2200 and then decrease 2 %/a, the seas will absorb all CO2 emissions by the year 2500



Mass of CO2 in the air will stabilize by the year 2200, the emissions will start decreasing because all of fossil fuels will be burned by the year 2500

With mass balance model concentration will will peaking at 580 ppm



With constant emissions the concentration will reach peak of 580 ppm by the year 2200 and will start decreasing thereafter

Summary

CO2 concentration seems to be increasing in relation of cumulative emissions, but

The mass balance model will start to decrease concentration, when the CO2 emissions will drop 50 % from today's level

The carbon sinks (Cs) are absorbing more CO2, if concentration will rise

- **Cs = 45 x ln (Concentration) – 252**

Reference

The book
“Fundamentals of Global Warming”
can be downloaded from

www.ekoenergo.fi