Truth of Climate Change

Asko Vuorinen

The book is studying climate change facts as they really are today. It will present primary data from global warming and forecasts until the year 2200. Influence of greenhouse gases to global warming has been evaluated. But there are many other variables than CO2, which have caused the 0.9 deg. C anthropogenic global warming (AGW) until today. The analysis given in the book indicates that the emissions of the greenhouse gases will peak in the year 2030 and the AWG can be limited to less than 2.5 deg. C with 3 % saving in CO2 starting in the year 2030.

Ekoenergo Oy

www.ekoenergo.fi

5/3/2016

TRUTH OF THE CLIMATE CHANGE

Asko Vuorinen

Truth of Climate Change

Asko Vuorinen

Ekoenergo Oy

Lokirinne 8 A 25

02320 Espoo

Finland

The writing of the book was started on the 6th of December in 2015. This first draft was published in 13th of December The book is available in internet downloading at www.ekoenergo.fi. Comments to the author are warmly welcomed by e-mail to askovuorinen@gmail.com

Contents

Preword

After writing five books about energy matter, I finally decided to study climate change stories and make prediction for the future with my own judgement. One reason for many studies and books is that they have been to prove something which will benefit the sponsor. Some might support green energy because they are selling wind mills or heat pumps. Others may deny climate change because they are selling fossil power plants or petrol cars. I am neutral. I retired five years ago and do not get any money from any sponsor.

I do not like to sell this book either. This will be free as an e-book available from my publisher home page at www.ekoenergo.fi. Ekoenergo is our own small publishing company which has been publishing my books since 2007, when I wrote my first book "*Planning of Optimal Power Systems*" First edition. Thus we do not need to make any scandals to get readers and more income. I hope that my readers will be searching unbiased information from the climate change matters.

One of the biggest reasons to write the book has been the disinformation, which has been spreading from many official and commercial sources. I was really astonished, when our Finnish Meteorological Office published in 2015 figures and stated that temperature has risen here in Finland more than two degrees Celsius from the year 1850. I had published in 2011 a book "*Planning of Nuclear Power Systems to Save the Planet*", where I found that the temperature in Finland has been risen at a rate of 0.74 ^{o}C per century.

Another disinformation was spread by IPCC studies some five years ago stating that temperature curves remind hockey sticks with constantly lowering temperatures during last 2000 years. This was not true either, while the temperature was higher during middle ages than today. This was told in our history books, which said that many southern plants were growing in Finland in these high latitudes and the reason was the warmer weather during those days.

Thus I have been reading a lot of books and stories about climate change and collecting actual data from various sources and make my own judgements, how much the temperature has been risen, what are the reasons for it and how can we limit the rise to less than two degrees.

Espoo

May 3, 2016

Asko Vuorinen

www.askovuorinen.fi

www.ekoenergo.fi

1 INTRODUCTION

The temperature measurements data dates back only to the end of 19th century. However, some other marks of weather changes have been observed for more than 300 years. One of the things here in the North has been the time, when the ice cover has disappeared from the lakes and rivers.

Tornio River (in the border between Finland and Sweden) has lost its ice cover constantly earlier starting from the year 1700 (Figure 1.1.1).

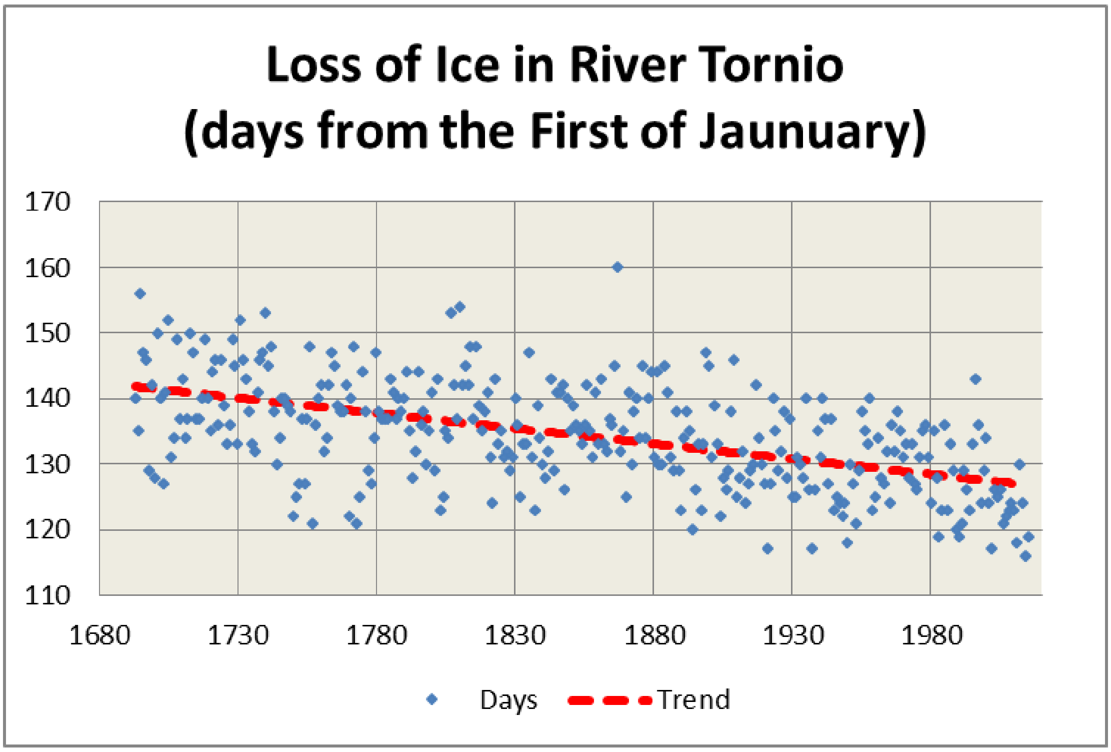


Figure 1.1.1 Days from the first of January when the ice was released from the River Tornio (Source: Esko Kuusisto, Finnish Environmental Center, SYKE).

The ice cover disappears now 14 days earlier then in the years 1700 – 1709. It is difficult to say, how large is the influence of the CO_2-emissions or any other human activity in this trend. The scientists have evaluated that the average spring temperature has increased in the Tornio area from 0.2 deg. C to 2.8 deg. C during 320-year time scale (the year 1691 to 2011). The increase has been 2.6 deg. C or 0.88 deg. C per century.

The Little Ice Age

During the Little Ice Age worse years from 1695 to 1698 about 140.000 (28 %) of the Finnish 500.000 population died for hunger and diseases caused by hunger. The summer 1695 was very cold and during the summer 1996 frost game at August 19th in 1696 and hardly any crop was achieved. During the winter 1696-1697 about all of crop has been eaten and most of the cows. After cattle people stated eating horses and dogs.

The same kind of data has been found from proxies, which do not take into account tree rings (Figure 1.1.2). The weather has been warming now 300 years from the Little Ice Age. On the other hand there was a warm period in the Middle age, when the Vikings travelled to Greenland and found America.

On the morning on 30th of January in 1658 Swedish King Charles X gave order for his troops to marc on ice over Belt in Denmark ty Island of Fyn. The march continued also over the frozen Great Belt to Zealand and the main goal was arrive to Copenhagen, which was the place Danish troop. On 11th of February King and his troops arrived to Zealand. On February 28th the Treaty of Roskilde was signed and Denmark hade to give the Swedish King many parts of Denmark as result of this march.

River Thames was also freezing during the Little Ice Age years (Figure 1.1.2). The first recorded Frost Fair was arranged in winter 1607 – 1608. The fairs were arranged until the year 1814, whenever the river was frozen.

Figure 1.1.2 Frost fair on the river Thames in the winter 1683 – 1684.

During the Medieval years about AD 500 – 1100 the weather here in the North was much warmer than today. This was found by the fact that the scientists have found seeds of the earlier flowers and trees, which have disappeared from Finland. The Greenland got settlers from Scandinavia during years 980 – 1400. The last ship sailed from Greenland to Iceland in about 1410. The Little Ice Age had started.

IPCC documents

As International Panel of Climate Change started their studies they made estimates of historical temperatures using proxies. Their studies concluded that the temperature variation was similar to Figure 1.1.3 with high temperatures during AD 600 – 1200 and lower temperatures during years 1400 – 1900.

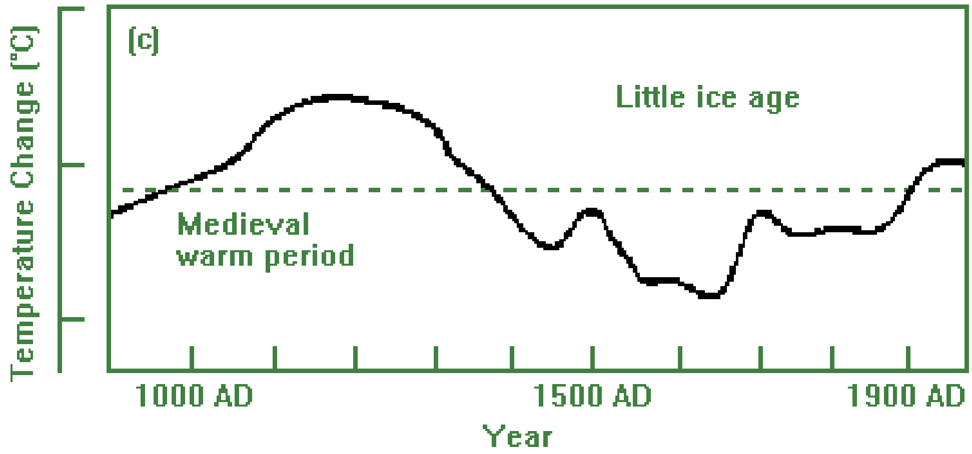


Figure 1.1.3 Temperature changes during the last 2000 years (The First IPCC report).

But in the third assessment report of IPCC from the year 2001 a hockey stick like curve was introduced (Figure 1.1.3). It indicated that the climate had becoming colder continuously until the year 1900 and after this the temperature has been rising constantly.

It seems that the hockey stick was discovered to prove the man made warming after the year 1900. It actually was man made warming as it was based on reconstructed curve by Thomas Mann et. al. Even the “instrumental data” (red curve in Figure 1.1.4) was behaving like the invented hockey stick. These curves showed to actual scientists that IPCC is a political organization which discovered its own “Inconvenient Truth” of the climate change.

Later on it was really found that so called scientists were not independent but in the control of the Governments of each country. So it was also found that this story of global warming was false. The whole story should be re-evaluated and rewritten again. The first thing to find is the real temperature records, which correspond to the history records. They should also notice the warm period during medieval years 1000 – 1300 and very cold period during Little Ice Age years 1650 – 1700.

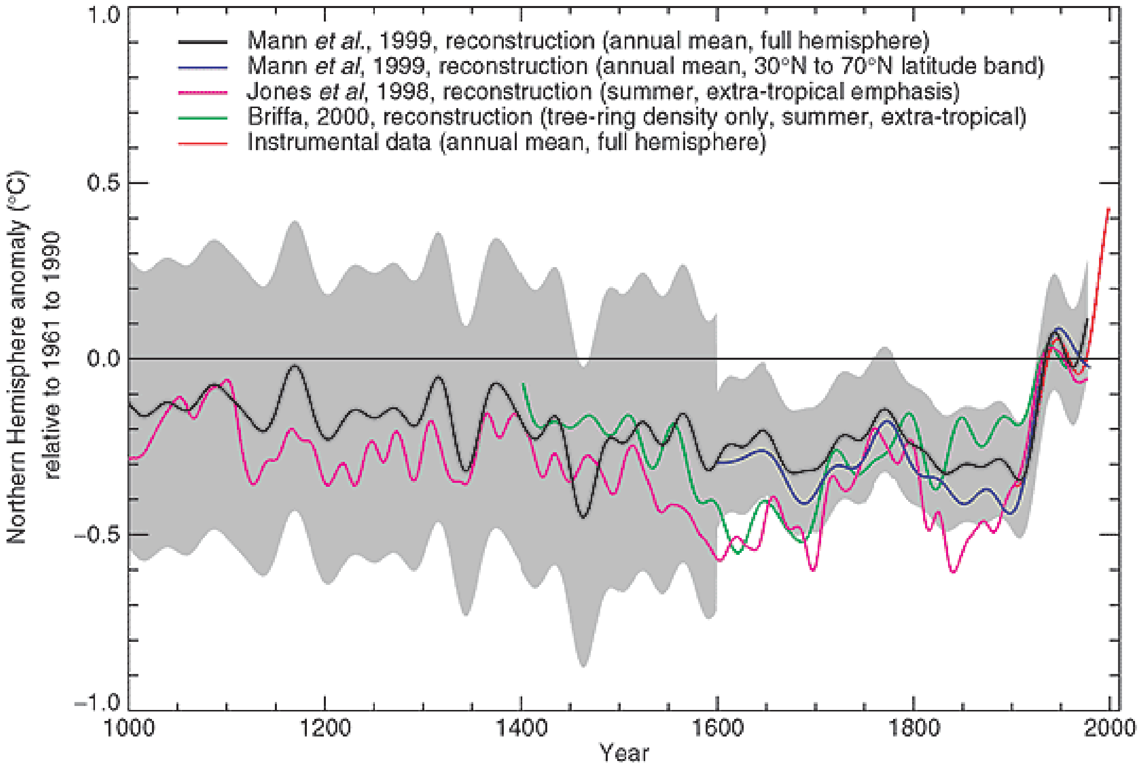


Figure 1.1.4 Hockey stick curve from IPCC third report from the year 2001. (http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm)

2 AIR TEMPERATURES

2.1 Global warming

Data from global warming has been collected and evaluated by US and UK official organizations. Their data is quite similar and thus I will use the data collected by UK Meteorological Office (MetOffice) to study global warming. Their data seems to be reliable and they have done this job many years. Additionally, their data is available without any charge for downloading from their internet site (http://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/download.html#regional_series)

I have downloaded from this site HadCRUT4, which give anomalies of land and see measurements as compared from the years 1971-2000 average data. I have calculated averages from the years 1901-1930 and corrected anomalies as compared with the 1901-1930 years average data. The result is shown in Figure 2.1.1.

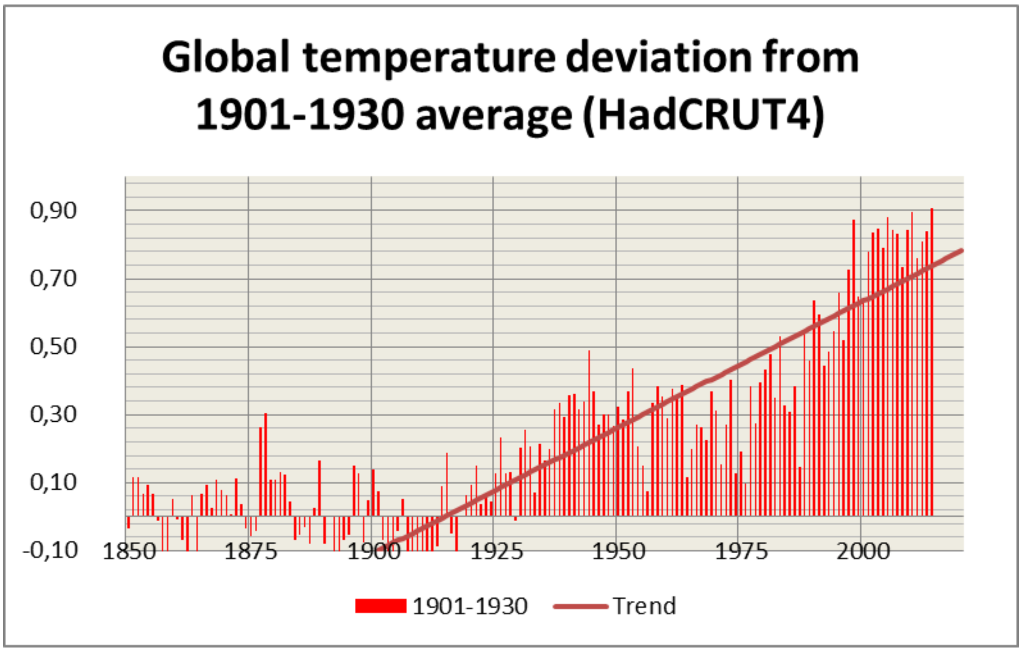


Figure 2.1.1 Global temperature deviation from 1850-1900 averages using HadCRUR4 data.

The trend from average measurements during years 1901-2014 indicates that the temperature has risen with 0.74 ^{o}C until the year 2014. Warming trend has been until today 0.65 ^{o}C per 100 years.

If we continue the global trend line to the year 2100 the increase will be 1.38 ^{o}C (Figure 2.1.2). The temperature will be lower than 1.6 ^{o}C higher than 1.2 ^{o}C during in the year 2100 with 95 % confidence (Figure 2.1.3 maximum).

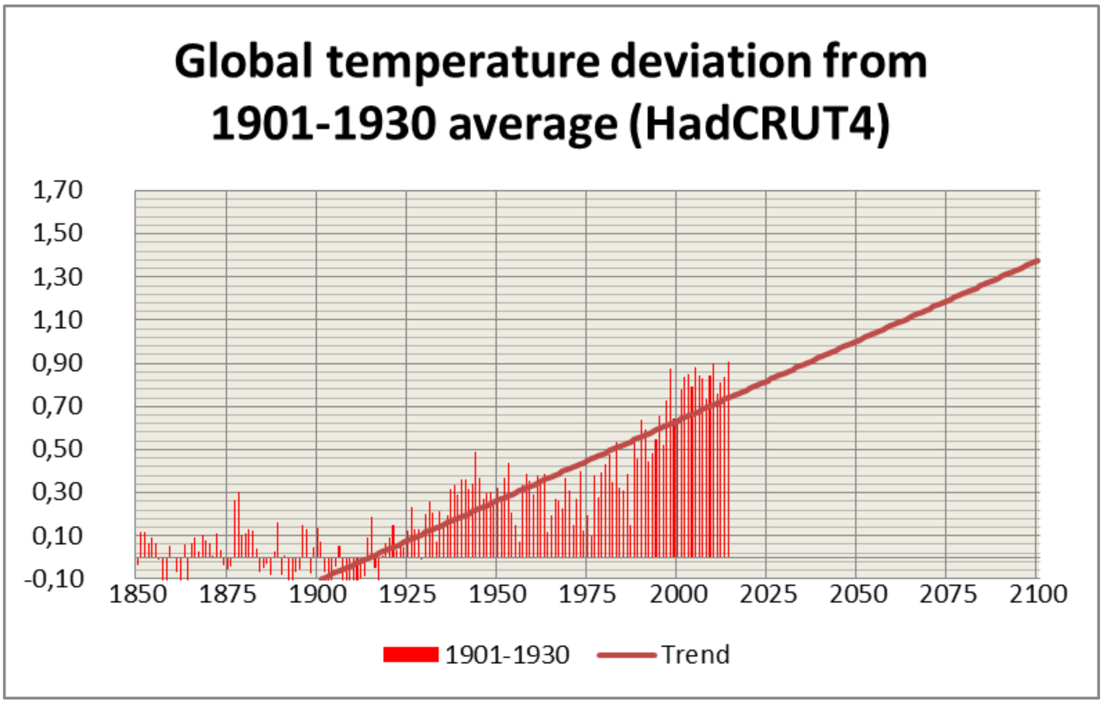


Figure 2.1.2 Global temperature trend until the year 2100.

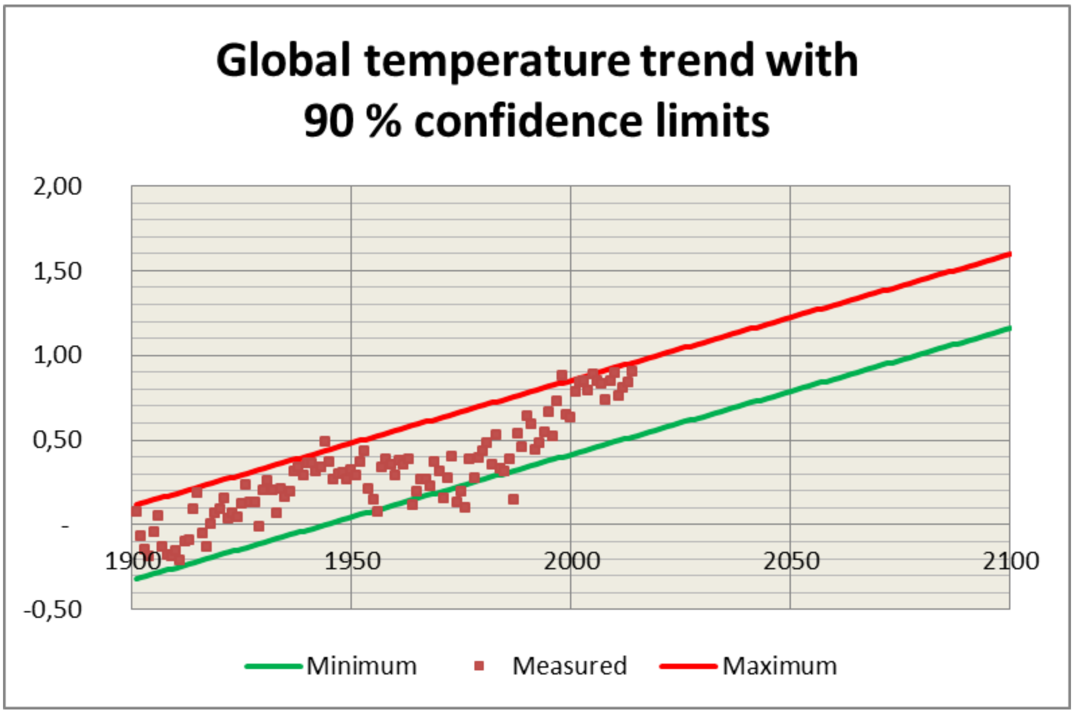


Figure 2.1.3 Global temperature trend with 90 % confidence limits.

60-year fluctuation

If we calculate deviations from the global warming trend, we will get a 60-years fluctuation curve (Figure 2.1.4). The fluctuation goes up and down. The 5-year average peaks have occurred in years 1944 and 2006. There is about 60-year fluctuation from peak to peak. Amplitude of fluctuation is +/- 0.22 ^{o}C.

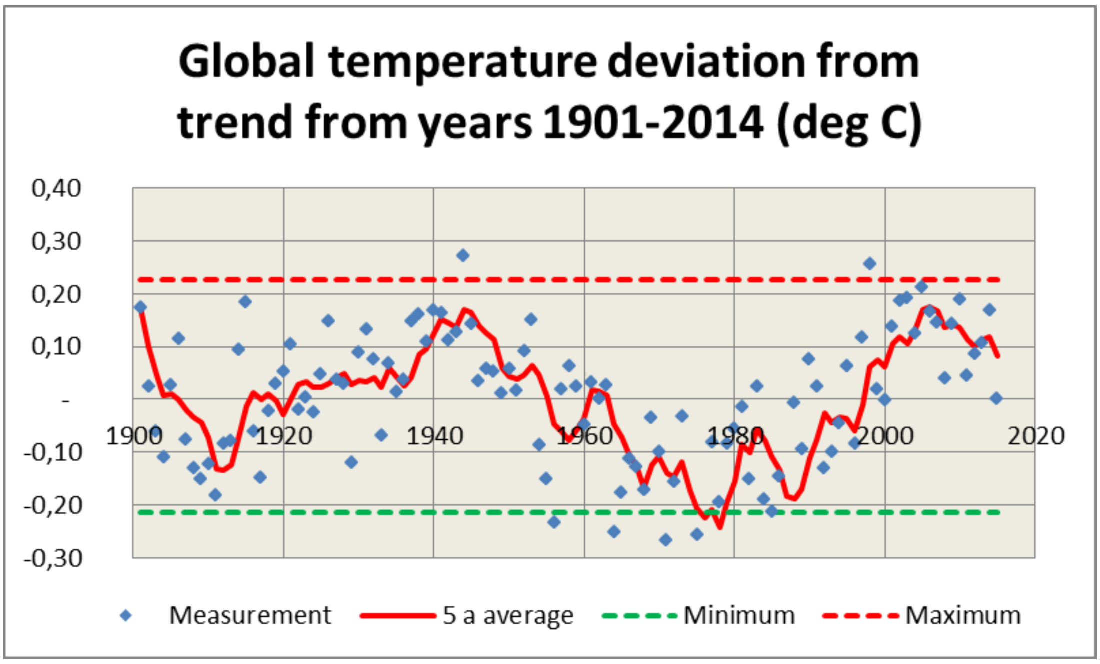


Figure 2.1.4 Global temperature fluctuation with a 60-year cycle.

30 year increases

Meteorological scientists consider that 30-year average values indicate changes in climate. The global average temperatures have risen from the years 1850-1900 to following values:

	From 1901-1930	From 1931-1960	From 1961-1990
to 1931-1960	0,29	-	-
to 1961-1990	0,33	0,04	-
to 1991-2014	0,74	0,45	0,41

The increase from 1901 – 1930 to years 1991 – 2014 has been 0.74 deg. C. This corresponds to 0.65 deg. C per hundred years. The increase of 0.45 deg. C from 1931-1960 to 1991 – 2014 corresponds to 0.75 deg. C increase in hundred-year time (Figure 2.1.5). This 60-year increase eliminates also influence of the found 60-year cycle.

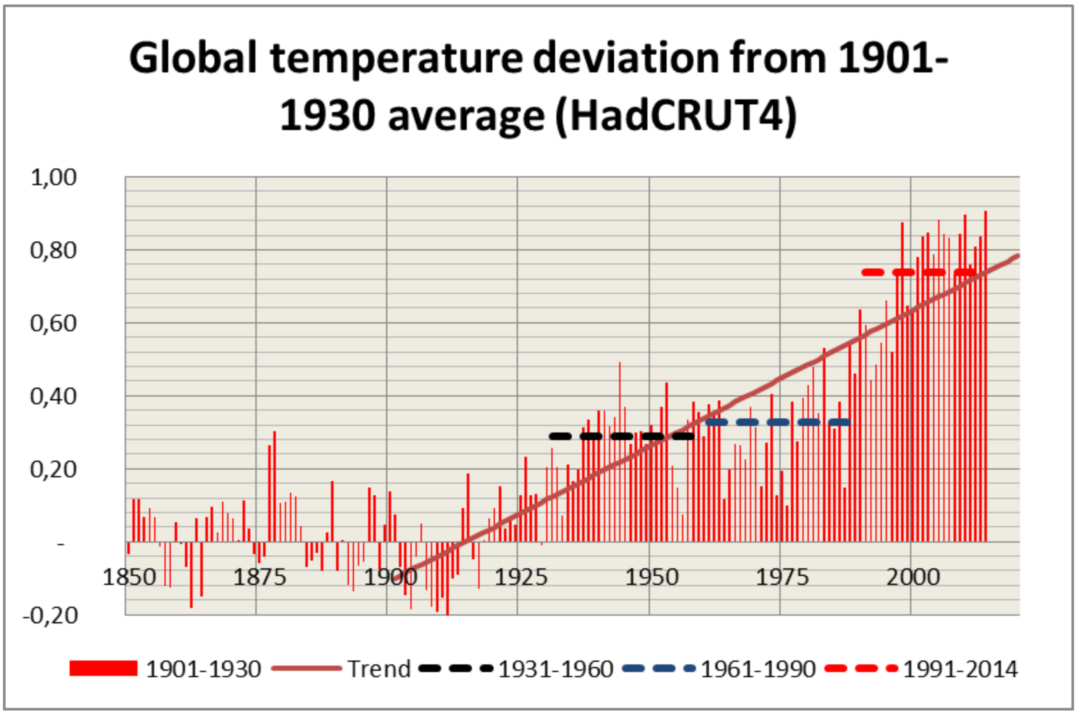


Figure 2.1.5 Temperature deviation from years 1850-1900 including averages values from years 1921-1950, 1951-1980 and 1981-2010.

The latest increase of 0.41 deg. C from the years 1961-1990 to 1991-2014 corresponds to 1.37 deg. C increase in hundred years. This happens in upward phase of the 60-year cycle and is not relevant. The increase from 1931-1960 to 1961-1890 is only 0.04 degrees because this happens in the downward phase in the 60-year cycle.

Thus if the temperature will be increasing with the 0.65 deg. C trend from the years 1901-1930, the rise until the years 2085-2115 (184 years) will be 1.2 deg. C. The increase before 1930 could not be caused by human influence.

Conclusion:

Global temperature has been risen from the years 1901-1930 with a trend of 0.65 degrees C per 100 years. If the trend continues until the year 2100, the global temperature will be about 1.3 degrees C higher than in the years 1901-1930. The 90 % confidence limits for warming until the year 2100 are +1.1 and +1.6 degrees C.

2.2 Air temperatures in USA

Air temperatures in USA have been down loaded from NASA Goddard Institute for Space Studies pages (http://data.giss.nasa.gov/gistemp/station_data/) for four sites. Anomalies to 1901 – 1930 average data has been evaluated in Washington (East coast, Figure 2.2.1), Lamar (Colorado Figure 2.2.2), Headworks Portland (West coast, Figure 2.2.3) and Anadyr (North, Figure 2.2.4).

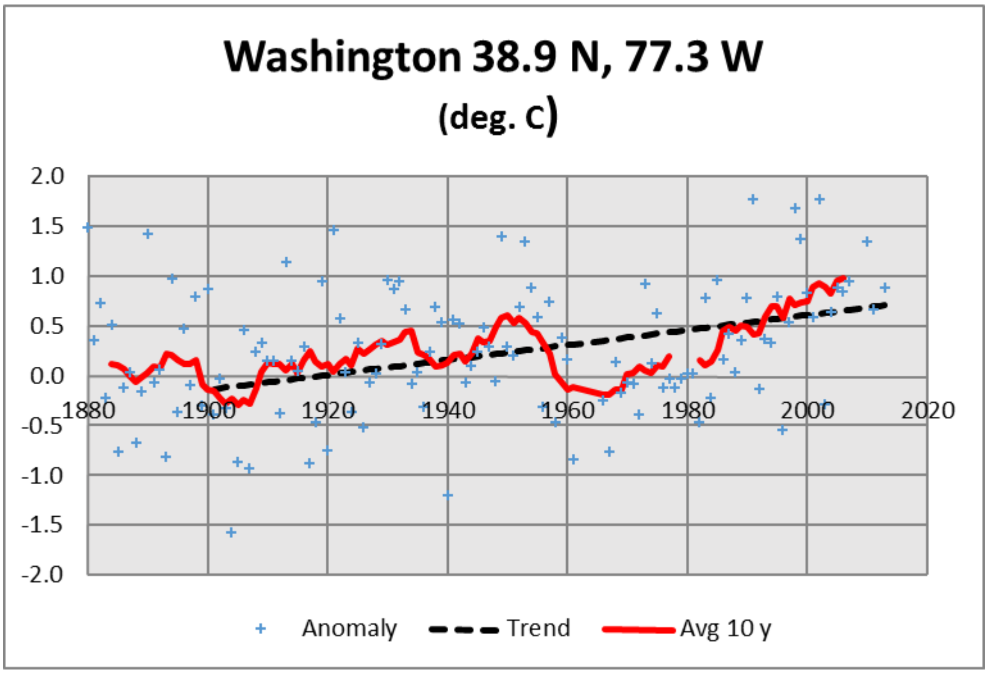


Figure 2.2.1 Temperature trend in Washington (NASA)

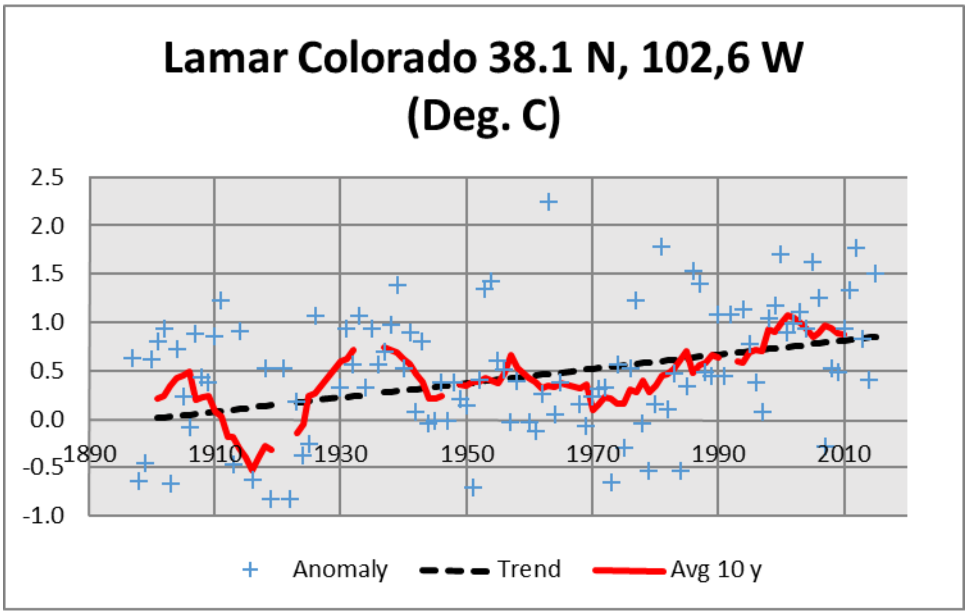


Figure 2.2.2 Temperature trend in Lamar Colorado (NASA).

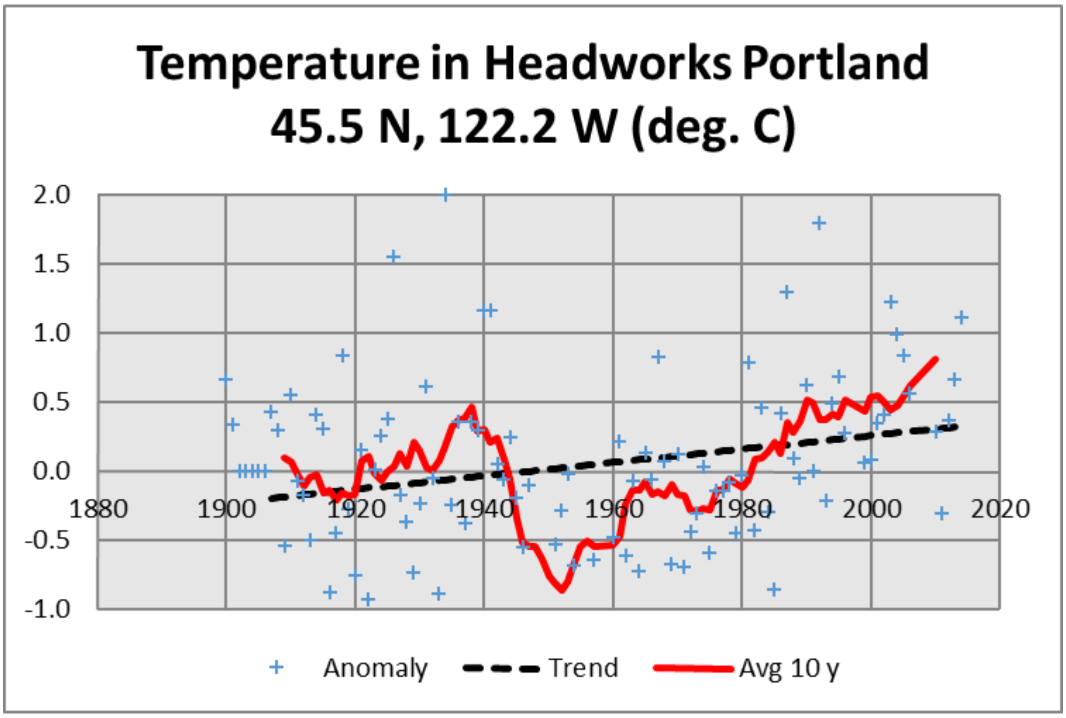


Figure 2.2.3 Temperature trend in Headworks Portland (NASA).

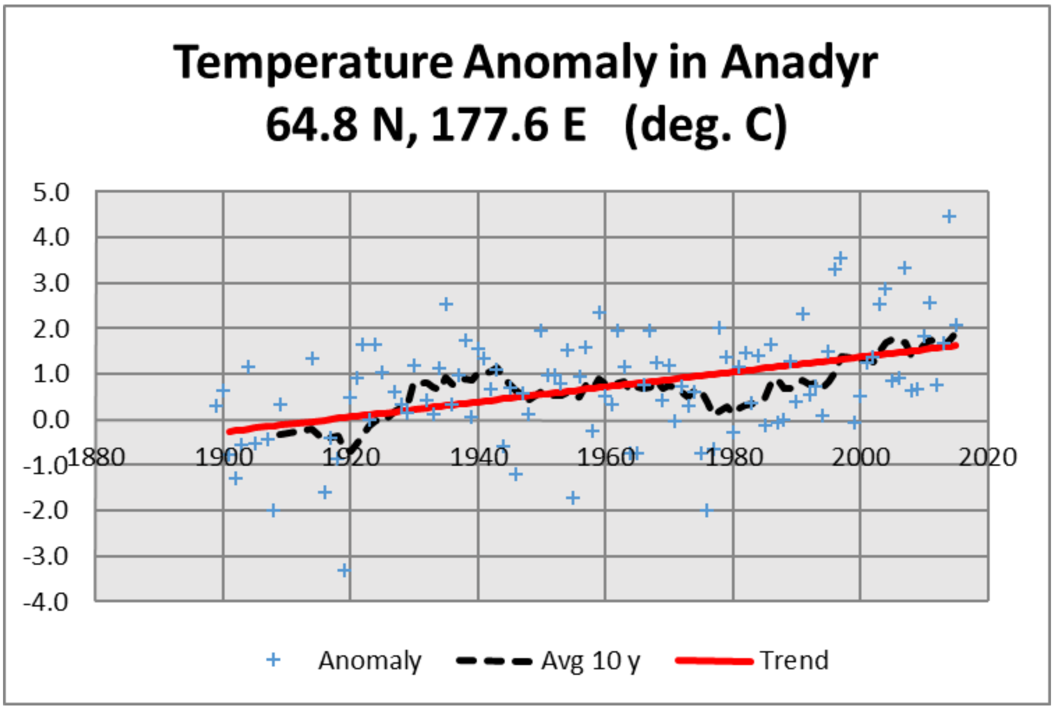


Figure 2.2.4 Temperature trend in Anadyr (NASA).

The measurement trends show highest warming in Anadyr (1.6 deg. C/century). Warming has been lowest in Headworks (0.45 deg. C/century). The highest warming has happened in Anadyr (in the North at 64.8 N latitude) as expected.

The trend of deviations from 1901 – 1930 average values shows average (of four sites) warming with 0.9 deg. C in hundred years (Figure 2.2.5). This analysis shows that warming is happening at different speed at different sites depending on the location.

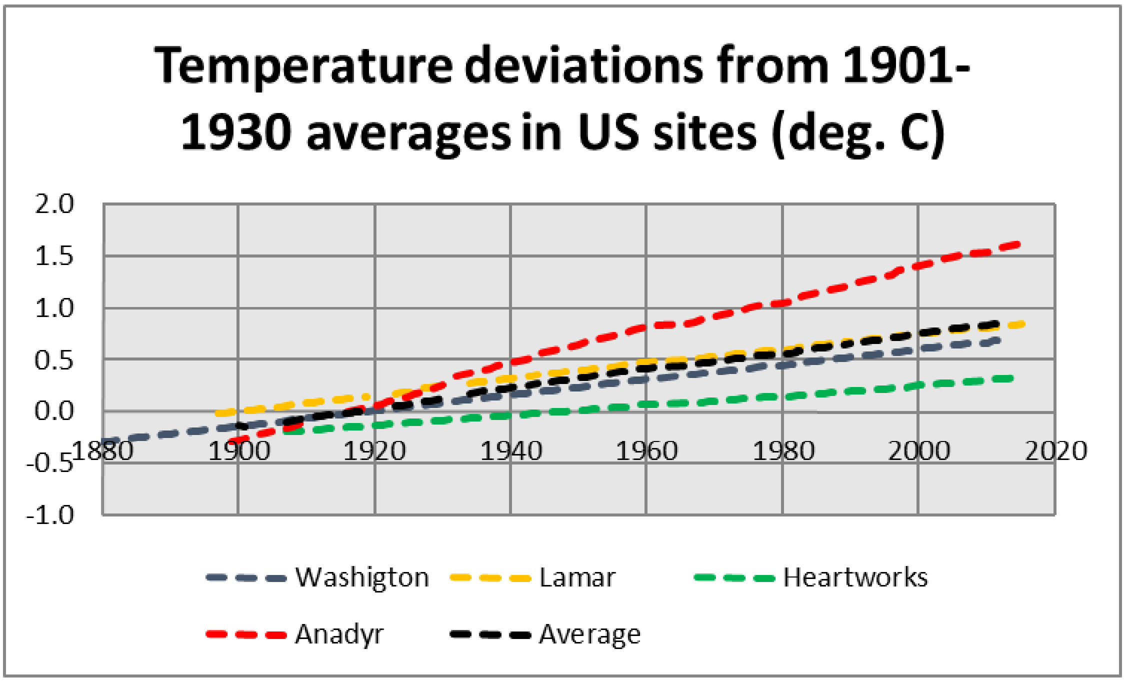


Figure 2.2.5 Temperature deviations from 1901 – 1930 averages in three sites (Washington, Lamar, Headworks).

2.3 Air temperatures in UK

Temperature measurements started in UK about 150 years ago. I have selected three sites from MedOffice files to present UK. One site in Oxford presents inland (Figure 2.3.1). Another site in Stornoway presents Atlantic weather in the north island (Figure 2.3.2). Third site is from the east coast of UK Durham (Figure 2.3.3).

The trend in warming from the year 1900 has been highest in Durham (1.4 deg. C/115 y) and Oxford (1.26 deg. C/115 y) and lowest in Stornoway (0.72 deg. C/115 y). The average warming trend in these three sites has been 0.94 deg. C in a century if we start counting from the year 1901 (Figure 2.3.4)

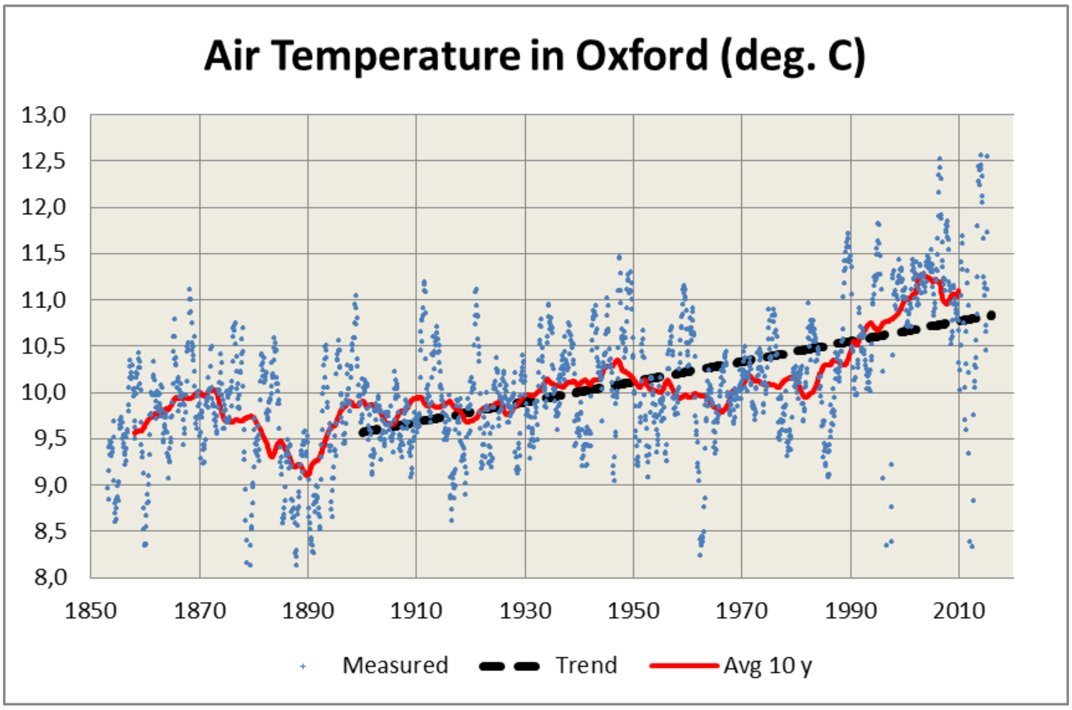


Figure 2.3.1 Air temperature in Oxford (MetOffice).

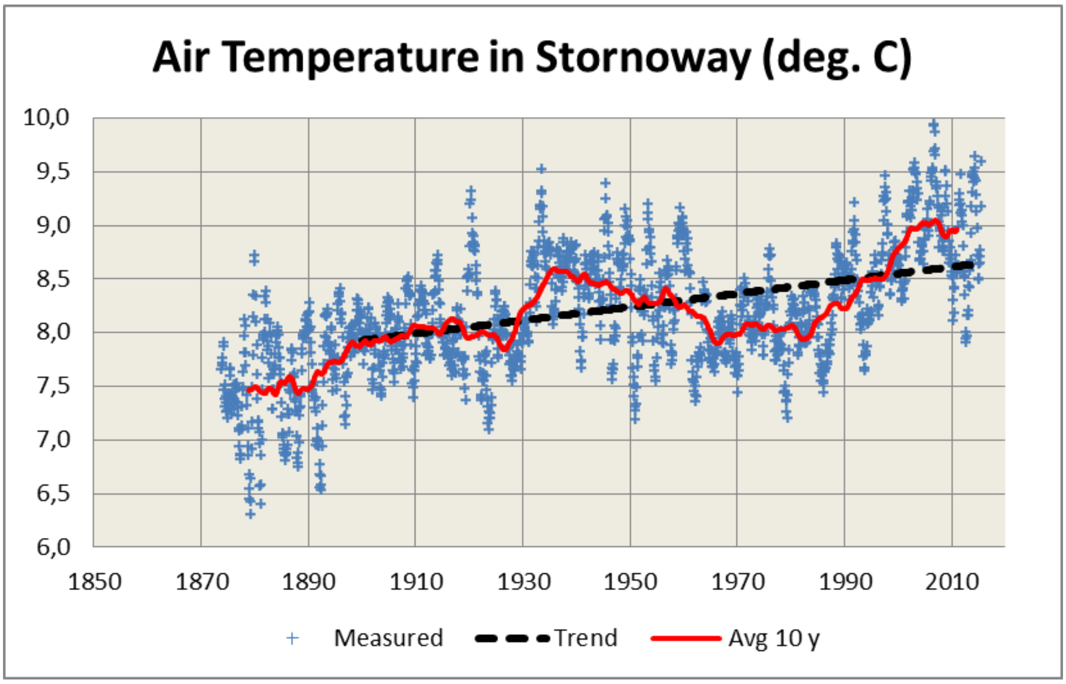


Figure 2.3.2 Air temperature in Stornoway (MetOffice).

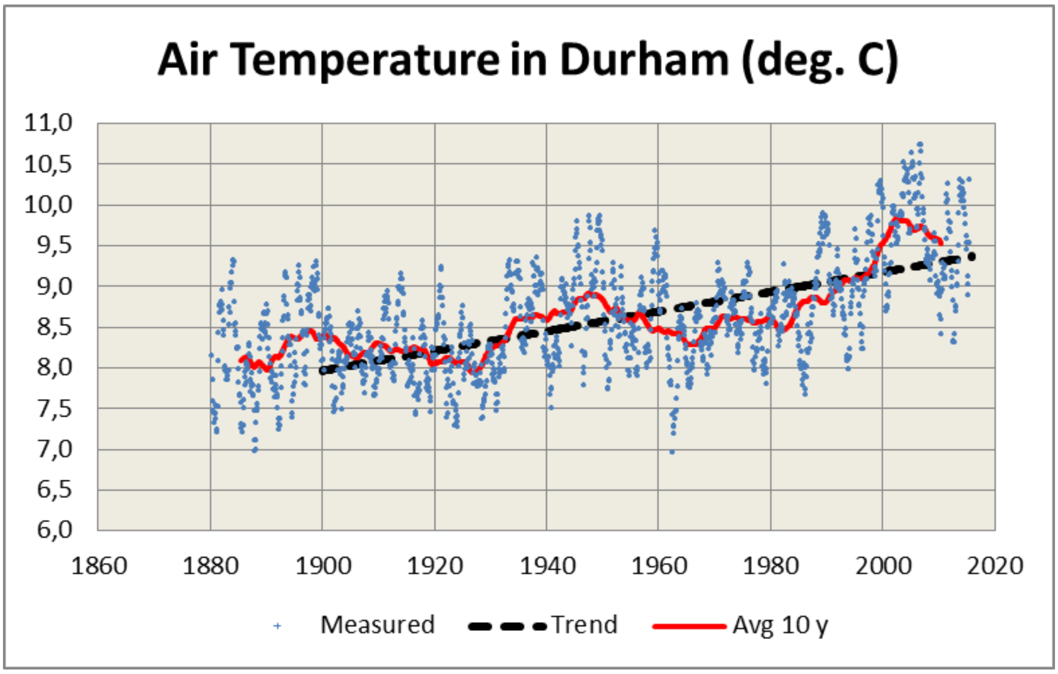


Figure 2.3.3 Air temperature in Durham (MetOffice).

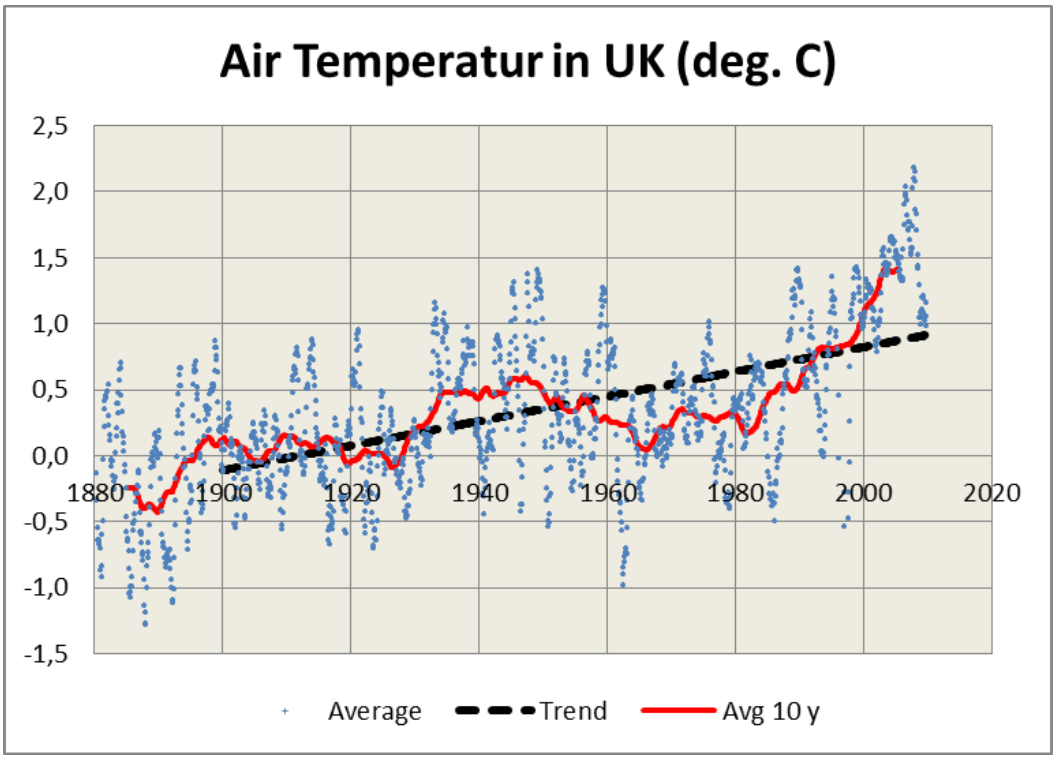


Figure 2.3.4 Air temperature in UK sites (Oxford, Stornoway, Durham).

2.4 Air temperatures in Finland

Measured temperature data dates back to 1850, but there are very few places, where the temperature was measured during early years. The measurements were made mostly on land on Northern latitudes and in cities, but not in South and wilderness.

One place which is far from cities is Sodankylä Observatory in Finland (67° 22' N, 26° 38' E, 180 m). The place is in Lapland where in Sodankylä municipality are less than 1 people per square kilometer. The temperature measurements were started in 1900 and they show annual average temperatures fluctuations from -3.5 to +2.5 °C (Figure 2.4.1). The ten year average temperatures in Sodankylä peaked in 1939 at 0.39 °C and had lowest value of -0.80 °C in the year 1960.

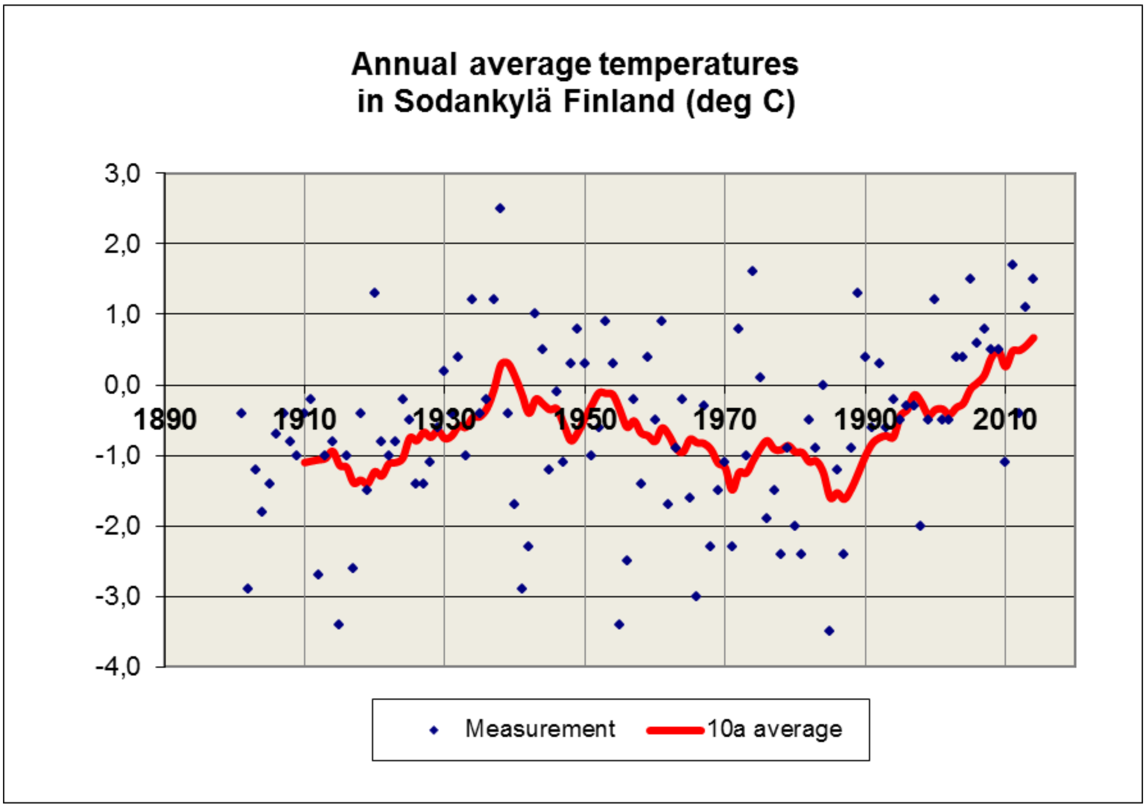


Figure 2.4.1 Measured temperatures in Sodankylä (67° 22' N, 26° 38' E, 180 m).

We can find there both warming and cooling. Warming happened from 1910 to 1939 and cooling from 1939 to 1960. In 1960 warming started again and we do not know it the peak value will be in 2015.

The trend of temperature increase in Sodankylä from 1900 to 2014 is showing the increase of 0.98 deg. C within 114 years (Figure 2.3.2). The increase is then 0.86 deg. C in 100 years. If the trend continues with the same rate, the temperature will be 1.73 deg. C higher in 2100 than in 1900. The 90 % confidence limits are +0.2 and +3.1 deg. C.

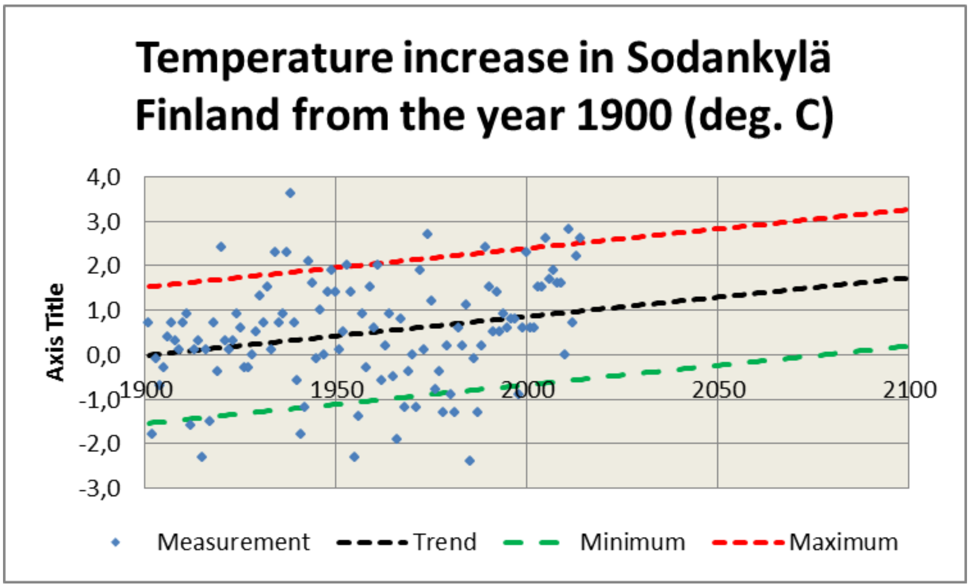


Figure 2.4.2 Temperature increase in Sodankylä from the year 1900 (deg. C).

Ten year average warming

We can also make a trend analysis based on ten year annual averages. The ten year average trend (Figure 2.4.3) indicates that the temperature has risen with about one degree from the year 1905, which was the first ten year average. If the trend continues until 2100 the temperature in Sodankylä will be 1.77 °C higher that in 1905. The warming will be about 0.91 °C in 100 years. We can also find the 90 % confidence limits, which indicate that warming will be less than 2.6 °C with 95 % confidence.

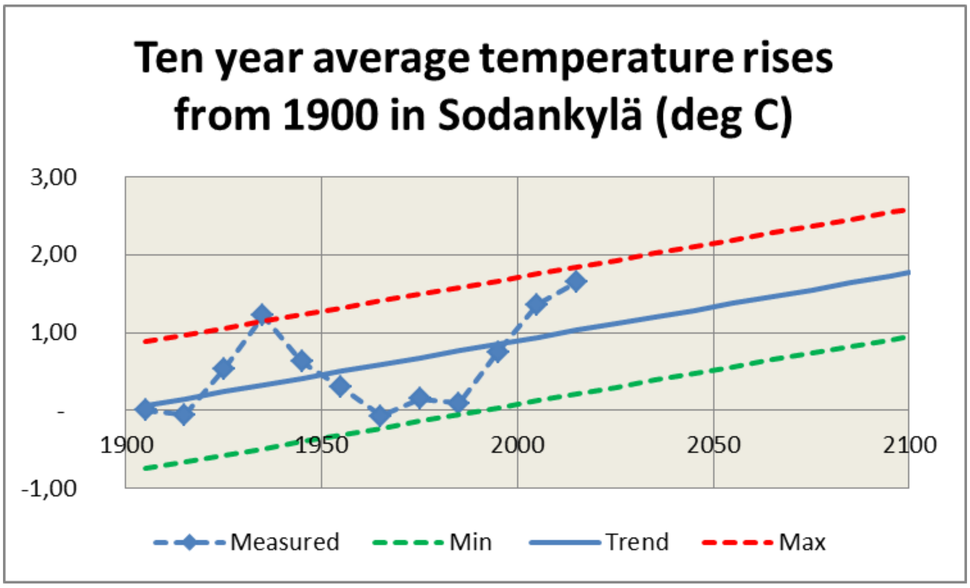


Figure 2.4.3 Warming trend in Sodankylä using ten year average measurements.

30-year warming

Climatologists consider, however, that 30-year average temperatures are showing where climate is going to. If we look at 30-year average temperatures (Figure 2.4.4), they show a peak at 1940 and another peak in about 2000 and lowest points at 1910 and 1970. The fluctuation has about 60 years cycle and range of about one degree.

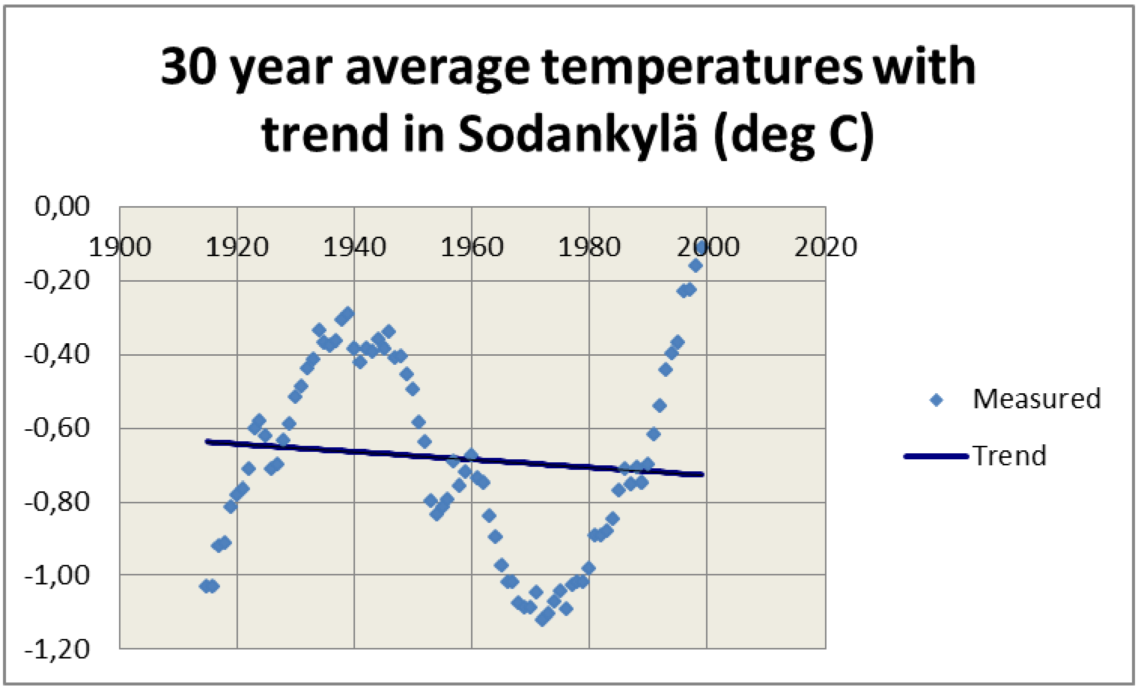


Figure 2.4.4 Thirty years average temperatures in Sodankylä with trend.

Temperature from peak to peak has risen from -0.3 to -0.1 °C or with 0.2 °C during one 60-year cycle. However, we do not know, if there will be a peak in the year 2015, which is the highest measurement today as the average has not yet going down..

If the trend will be calculated using the 30 year values, the climate in Sodankylä seems to be cooling from the value of -0.64 deg. C in 1915 to value of -0.73 deg. C in the year 2000 (Figure 2.4.4). Thus it is difficult to say from these trends is the weather coming warmer of colder in 100-year perspective.

However, this 30-year average difference from the years 1901-1930 indicated cooling during the years from 1968 to 1977 (Figure 2.4.4). During these years scientist were speculating that the world was cooling and a new ice age is coming.

I think that one cannot compare trends from averages to predict future. The best is to measure the difference from 30 base years (1901-1930) to the present. If we compare 30-year average value -0.11 °C from the years 1985-2014 to the average value of -1.03 °C from the years 1901-1930, then temperature has risen with about 0.92 °C within 85 years. The increase corresponds to increase of 1.10 deg. C within 100 years.

Warming since years 1901 - 1930

I found old Statistical Yearbooks of Finland, which has the monthly temperature measurements during years 1901-1930 at five sites (Helsinki, Tampere, Maarianhamina, Oulu and Sodankylä) and in which the measurements are made still today (Table 2.4.1).

Table 2.4.1 Monthly average temperatures during years 1901 – 1930 and 1981 – 2010 and temperature rise from the years 1901 – 1930 to years 1981 – 2010 (deg. C).

Years 1901-1930	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	-5,5	-5,8	-2,7	2,2	8,2	13,0	16,8	15,0	10,6	5,3	0,5	-3,4	4,57
Tampere	-6,7	-7,2	-3,4	2,1	8,6	13,5	16,9	14,4	9,8	4,2	-0,9	-4,9	3,93
Maarianhamina	-2,4	-3,4	-1,6	2,2	7,0	11,7	15,6	14,8	10,5	6,1	2,0	-0,9	5,18
Oulu	-9,0	-10,0	-5,7	0,0	5,9	11,8	15,7	13,2	8,2	2,0	-3,3	-7,4	1,85
Sodankylä	-13,5	-13,8	-8,9	-2,5	4,0	10,6	13,8	10,8	5,7	-1,2	-8,0	-11,9	-1,18
Average	-8,3	-9,1	-5,4	-0,1	5,6	11,4	15,0	12,9	8,1	2,3	-3,1	-6,7	1,95
Years 1981-2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	-3,9	-4,7	-1,3	3,9	10,2	14,6	17,8	16,3	11,5	6,6	1,6	-2,0	5,94
Tampere	-6,4	-6,9	-2,8	3,3	9,7	14,1	16,9	15,0	9,8	4,6	-0,6	-4,5	4,41
Maarianhamina	-2,1	-3,1	-0,6	3,7	9,1	13,3	16,7	15,8	11,4	6,9	2,6	-0,4	6,16
Oulu	-9,6	-9,3	-4,8	1,4	7,8	13,5	16,5	14,1	8,9	3,3	-2,8	-7,1	2,72
Sodankylä	-13,5	-12,7	-7,5	-1,3	5,3	11,6	14,5	11,7	6,2	0,1	-7,1	-11,7	-0,30
Average	-8,4	-8,4	-4,3	1,3	7,4	12,8	15,9	13,9	8,8	3,4	-2,4	-6,4	2,86
Rise to 1981-2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	1,6	1,1	1,4	1,7	2,0	1,6	1,0	1,3	0,9	1,3	1,1	1,4	1,37
Tampere	0,3	0,3	0,6	1,2	1,1	0,6	0,0	0,6	0,0	0,4	0,3	0,4	0,48
Maarianhamina	0,3	0,3	1,0	1,5	2,1	1,6	1,1	1,0	0,9	0,8	0,6	0,5	0,98
Oulu	-0,6	0,7	0,9	1,4	1,9	1,7	0,8	0,9	0,7	1,3	0,5	0,3	0,87
Sodankylä	0,0	1,1	1,4	1,2	1,3	1,0	0,7	0,9	0,5	1,3	0,9	0,2	0,87
Average	-0,1	0,7	1,1	1,4	1,8	1,4	0,9	0,9	0,7	1,1	0,7	0,3	0,91

We can find that the annual temperatures have risen more than others in Helsinki and less than others in Tampere. This has been caused by urbanization effect in Helsinki and by the fact that the measurement site was changed in Tampere to the airport.

If we omit Helsinki and Tampere, we can find that the annual temperature has been risen with 0.91 deg. C to years 1981-2010. The increase of 0.91 degrees C from year 1915.5 (average 1901-1930) to 1995.5 (average 1981-2010) has happened during 80 years. Thus the trend is then 1.14 deg. C per. 100 years. This is more than the calculated 100 year trend of 0.86 ^{o}C in Sodankylä (Figure 2.4.2).

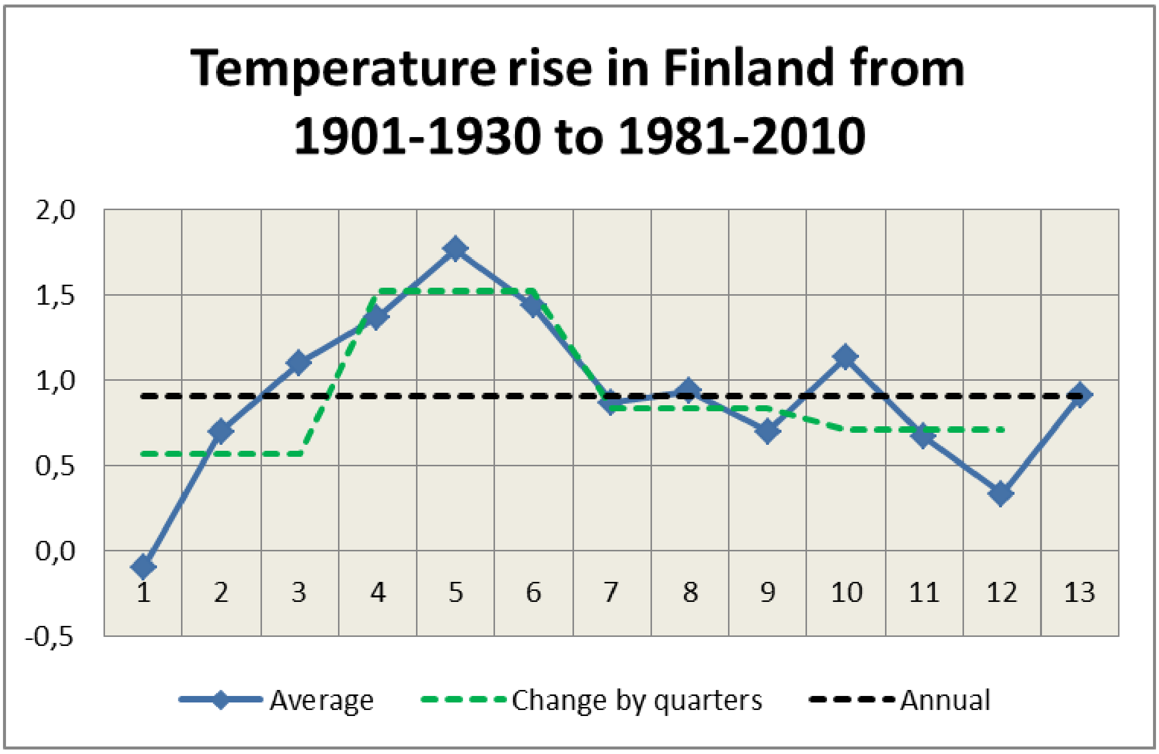


Figure 2.4.5 Warming in Finland from 1901 – 1930 to 1981 – 2010 (deg. C).

We can notice that the warming has been the highest during spring from March to June and lowest in December and January (Figure 2.4.5). Rising of the temperatures in the spring of the year is an indication of warmer seawater temperatures. Warmer seawater brings more heat with the wind to Finland. This causes also more rain and snow, which have filled the water reservoirs in the Nordic countries.

Conclusion:

The temperature has been risen in Finland for 300 years. Warming in Finland has been 1.14 deg. C per 100 years after years 1901-1930. If trend continues at the same rate as before, the Finnish climate will be about 2.3 deg. C warmer in the year 2100 than during years 1901-1930.

2.5 Sunspots and solar influence

We have found that temperatures have been risen more than 300 years almost constantly from the times of Little Ice Age (LIA). LIA was happening from 1300 to 1750 during which times also River Thames was frozen and people were walking on the ice (Figure 2.5.1).

Figure 2.5.1 Frozen River Thames.

Figure 2.5.2 Invention of telescope was a key to find sunspots.

Sunspots are black points in sun, which were found because Italian scientist **Galileo Galilei** (1564 – 1642) developed better telescope. He and others found the sunspots with the better telescope which could magnify objects with factor 30. In 1610 he published a small book titled "*Starry Messenger*", where he described his findings.

Later it was found that sunspot numbers were extremely low during years 1645 - 1700 (Figure 2.5.3). This era was called as Mounder Minimum according to its inventors **E. Walter Mounder** (1851-1928) and his wife **Annie Russel Mounder** (1868-1947), who studied sunspots by this time. Number of sunspots was only less than 10 in each decade during those years.

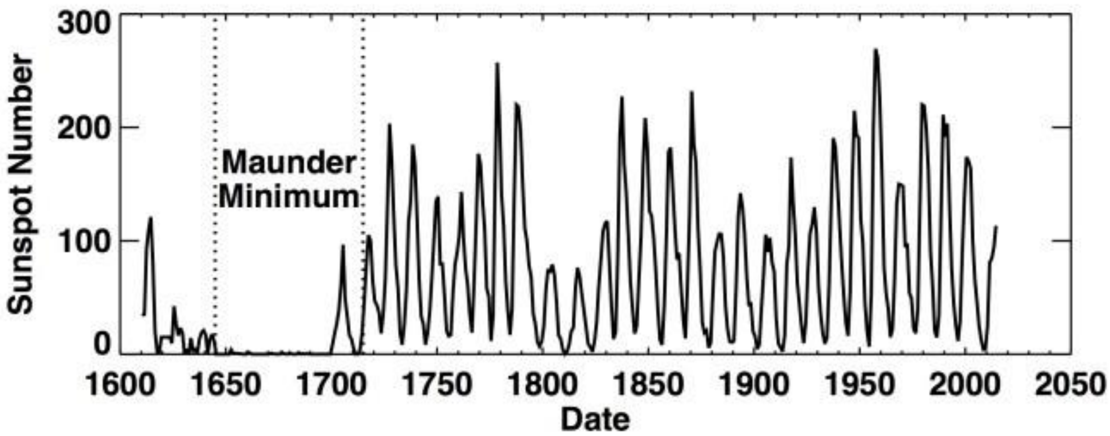


Figure 2.5.3 Mounder minimum and sunspots Numbers.

The sunspot data can be downloaded from the year 1700 (Figure 2.5.4) and analyzed with temperature records given in chapter 2.1. Assuming 150 spots corresponds to temperature deviation of 1.0 deg. C, the influence of sunspots are given in Figure 2.5.4. Then trend in global temperature rise caused by sunspots is 0.58 deg. C in 350 years or 0.17 deg. C per hundred years.

We can use the sunspot caused temperature data (Figure 2.5.4) to extrapolate measured temperature data to years 1650 – 1850 and get set of temperature data for years 1650 – 2014. These extrapolated temperatures from the year 1650 have been rising with a trend of 0.75 deg. C in 350 years or 0.21 deg. C in hundred years (Figure 2.5.5).

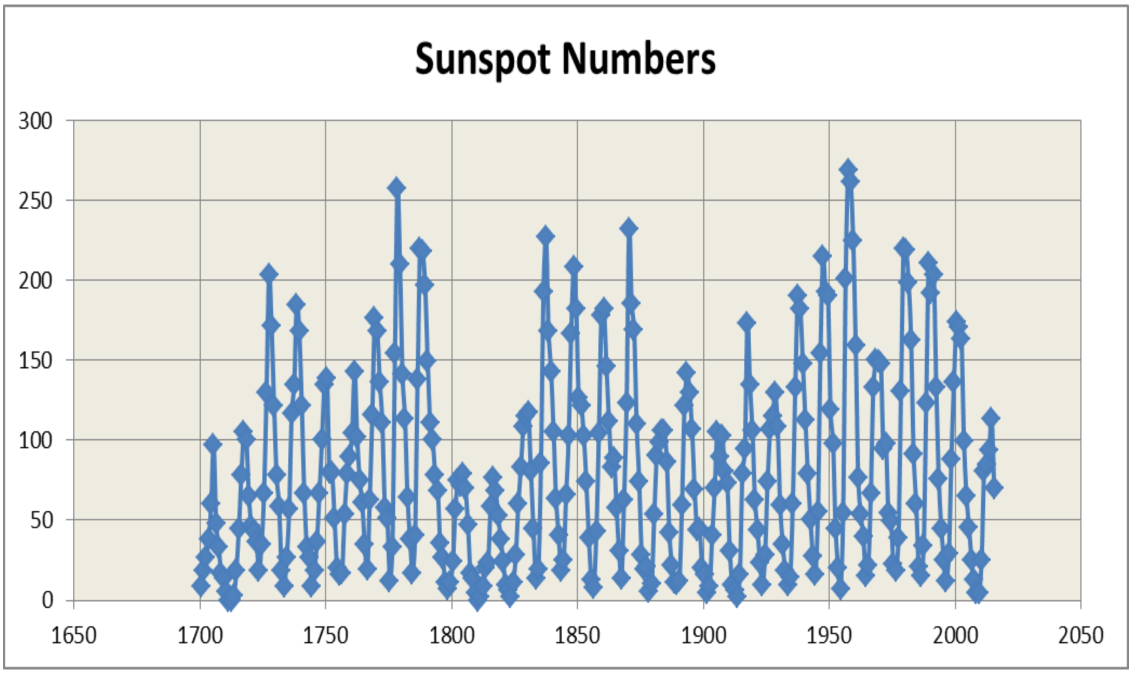


Figure 2.5.4 Sunspot data as downloaded from the file (http://www.sidc.be/silso/datafiles).

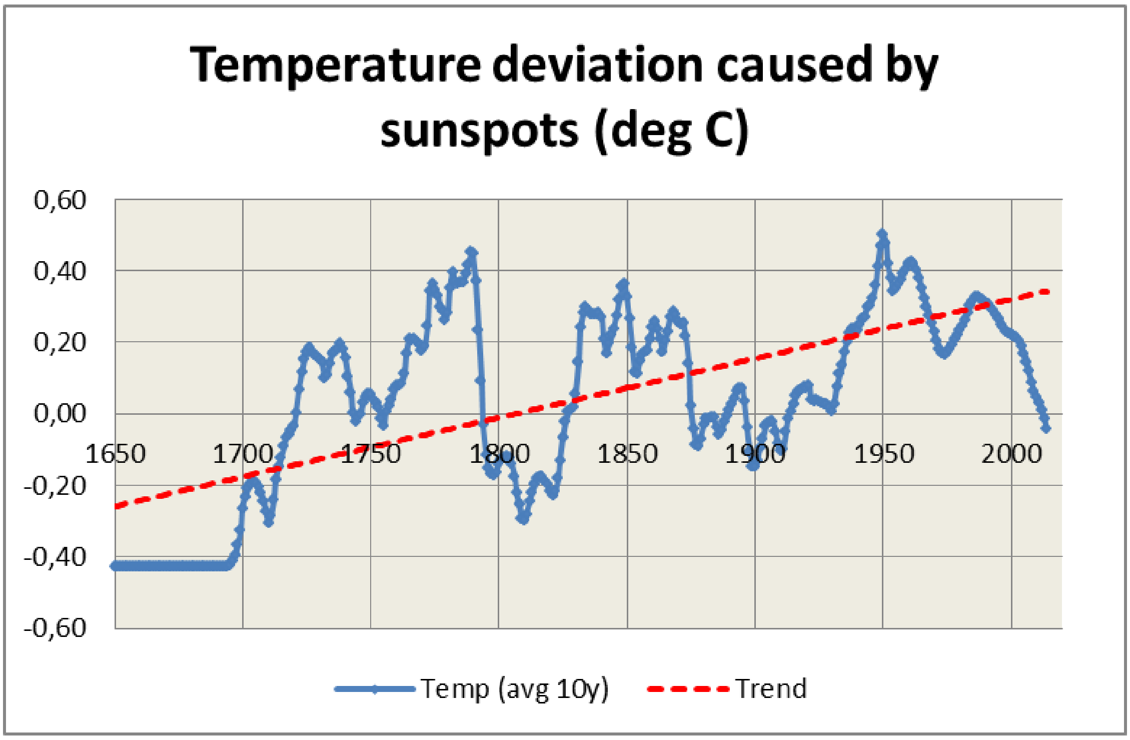


Figure 2.5.5 Influence of sunspots to global temperature.

If we eliminate the influence of sunspots from the temperature data, the corrected global temperatures have been evaluated in Figure 2.5.7. The temperature has been rising about 0.57 deg. C during 160 years or 0.36 deg. C per 100 years.

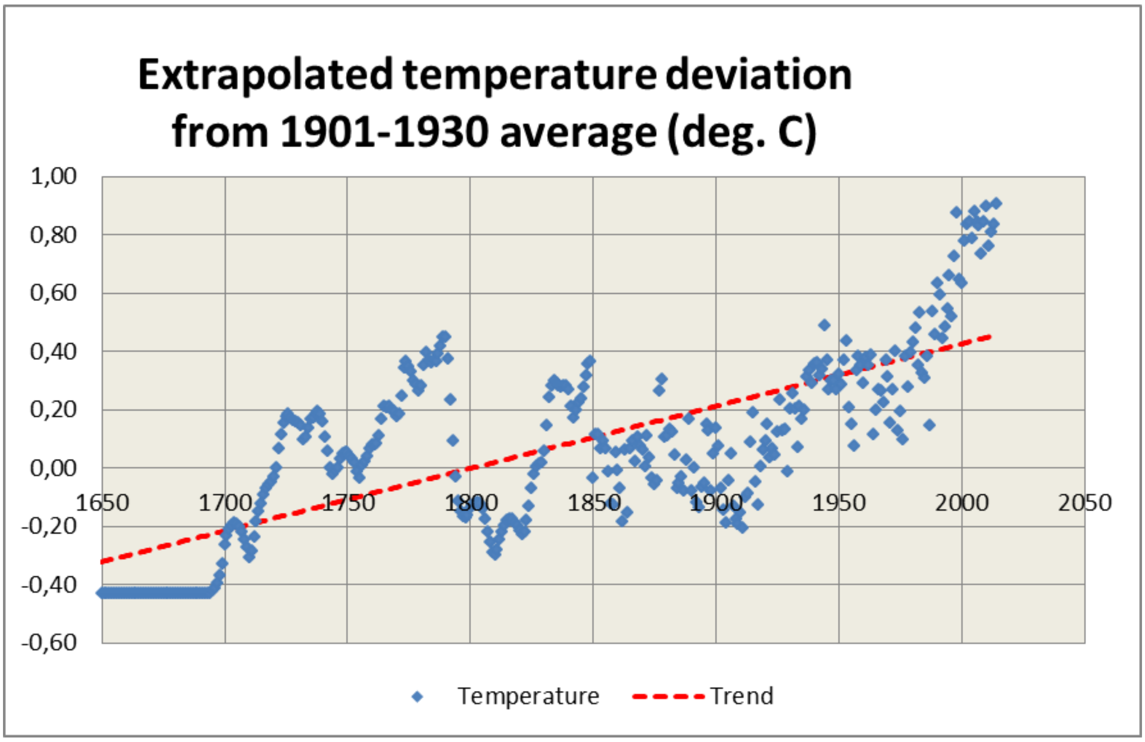


Figure 2.5.6 Extrapolated temperature using sunspot correction for years 1650-1850 (from Figure 2.5.5).

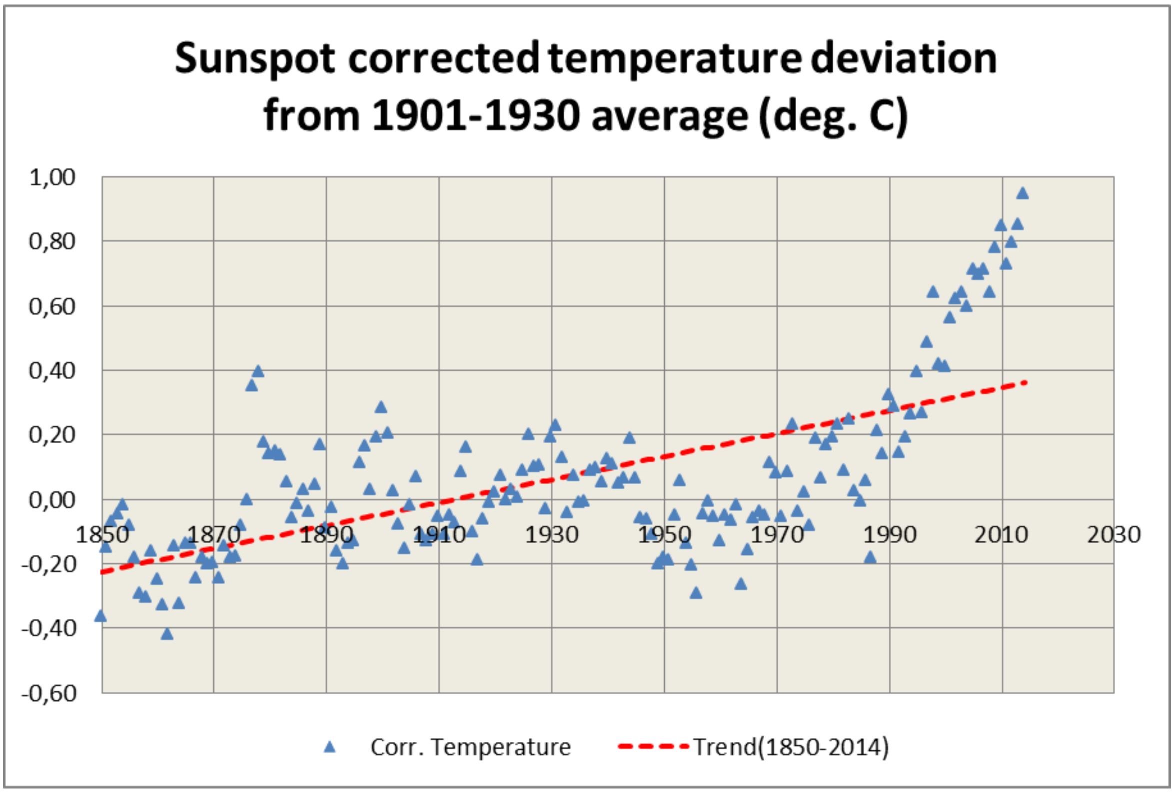


Figure 2.5.7 Sunspot corrected temperature deviation which eliminates the influence of sunspots given in Figure 2.5.4.

It can also be said that this rise has been caused by man or it is anthropogenic global warming (AGW). We can now separate global warming caused by man (AGW) and caused by the sunspots. Thus the global warming was mainly caused by the sunspots until the year 1970 and by AGW since then (Figure 2.5.8).

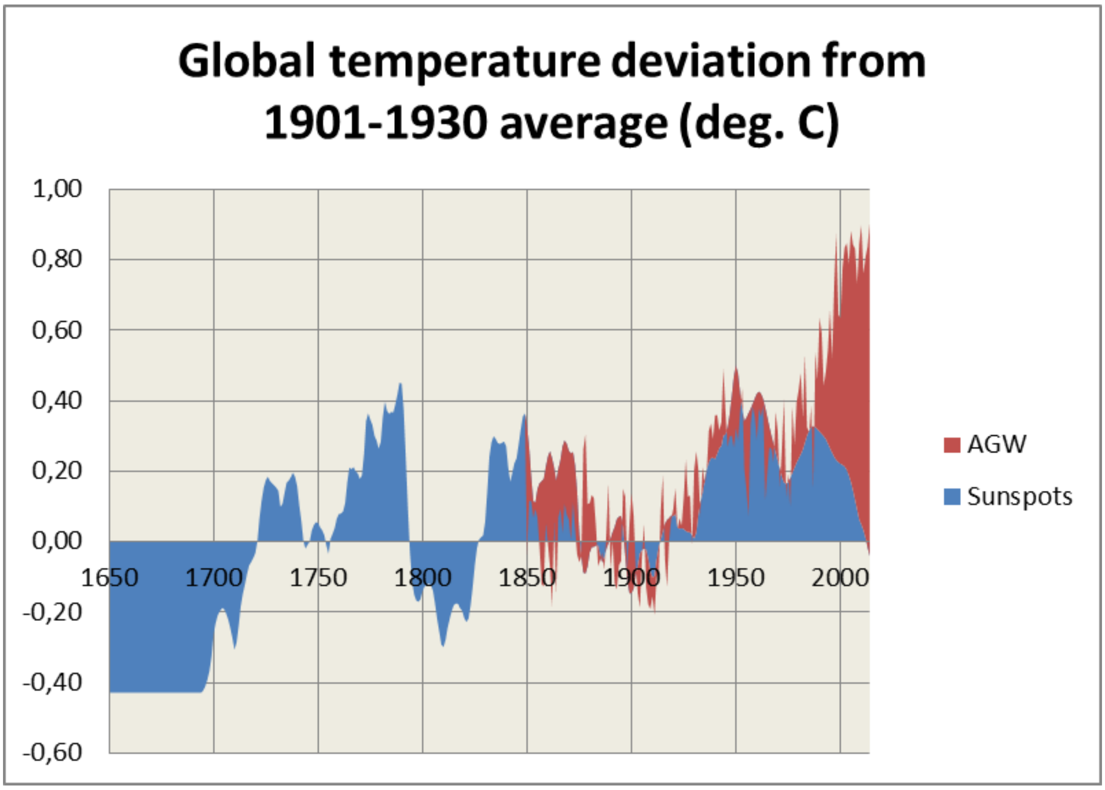


Figure 2.5.8 Global temperature deviation from average from years 1901 – 1930.

We can find from Figure 2.5.9 that the sunspot corrected temperature trend has been quite stable until the year 1980. However, after 1981 the trend is indicating rise of 0.9 deg. C within 34 years or 2.6 deg. C per 100 years. If this trend continues, the temperature in 2100 will be 2.2 deg. C higher than in the year 2014 or 3.1 deg. C higher than in the years 1901 – 1930.

The sunspot corrected 30-year average temperature has been rising about 0.57 deg. C from the years 1901-1930 to years 1991 – 2014 or 0.63 deg. C in 100 years (Figure 2.5.10). However, there increase until 1961 – 1990 has been only 0.05 deg. C.

The 30-year average trend shows that the sunspot corrected temperature will rise with 2.8 deg. C (Figure 2.5.11) from the average level of years 1901 – 1930. This will happen, when the sunspot levels will be coming back to level as it was during years 1901 – 1930.

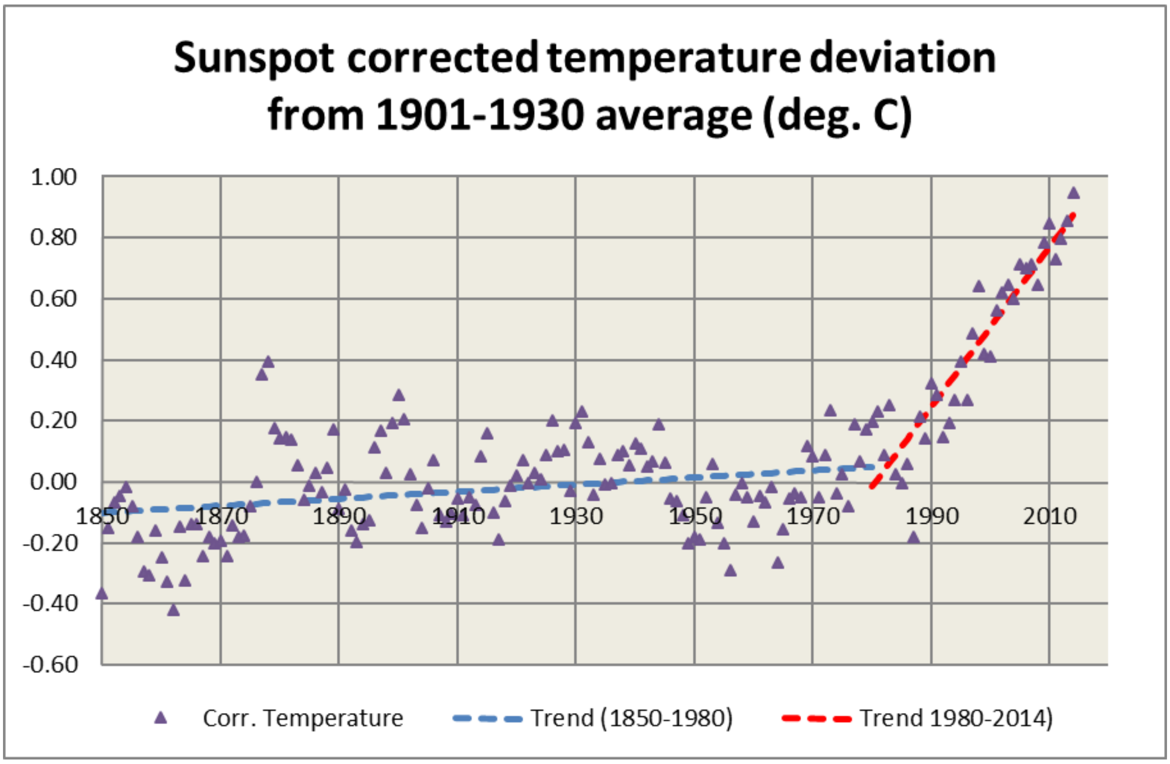


Figure 2.5.9 Sunspot corrected temperature deviation (AGW) which eliminates the influence of sunspots given in Figure 2.5.4.

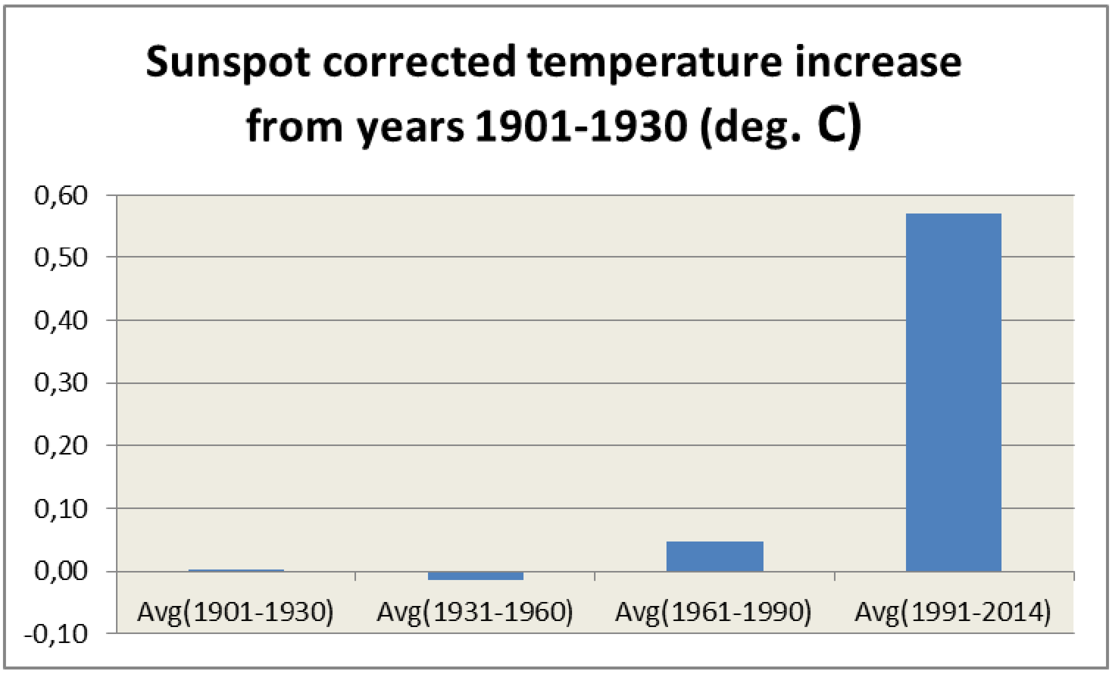


Figure 2.5.10 Sunspot corrected temperature has risen with 0.5 deg. C from 1901-1930 to years 1991-2014.

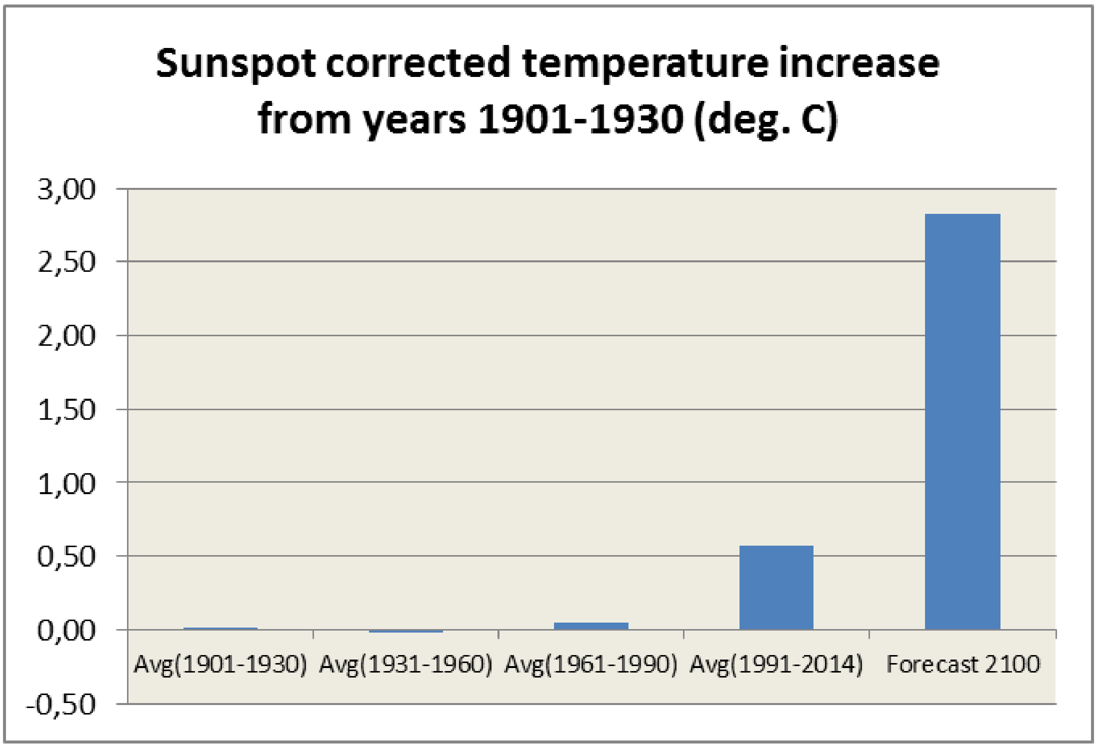


Figure 2.5.11 Sunspot corrected temperature has risen with 0.5 deg. C from 1901-1930 to years 1991-2014 and will rise with 2.8 deg. C by 2100, if the present trend continues.

Conclusion

The temperature increase of 0.63 deg. C in 100 years indicates that the temperature will be 1.3 deg. C higher in the year 2100 than in years 1901 – 1930. However, the latest trend after the year 1980 has been 2.6 deg. C in 100 years. If this trend continues, the global temperature in the year will be 3.1 deg. C higher than in the years 1901-1930.

3 AEROSOL COOLING

3.1 Emissions of sulfur dioxide

Aerosols in the atmosphere cause cooling of climate by formatting clouds, which reflect the sun radiation back into the space. One of the most significant aerosols is sulfur oxide, which is mostly emitted by the coal and oil power plants (Figure 3.1.1). The emissions peaked in about 1980, when the global temperature started to increase. Thus many claim that the rise in temperature after 1980 is caused by cleaning the emissions of the power plants.

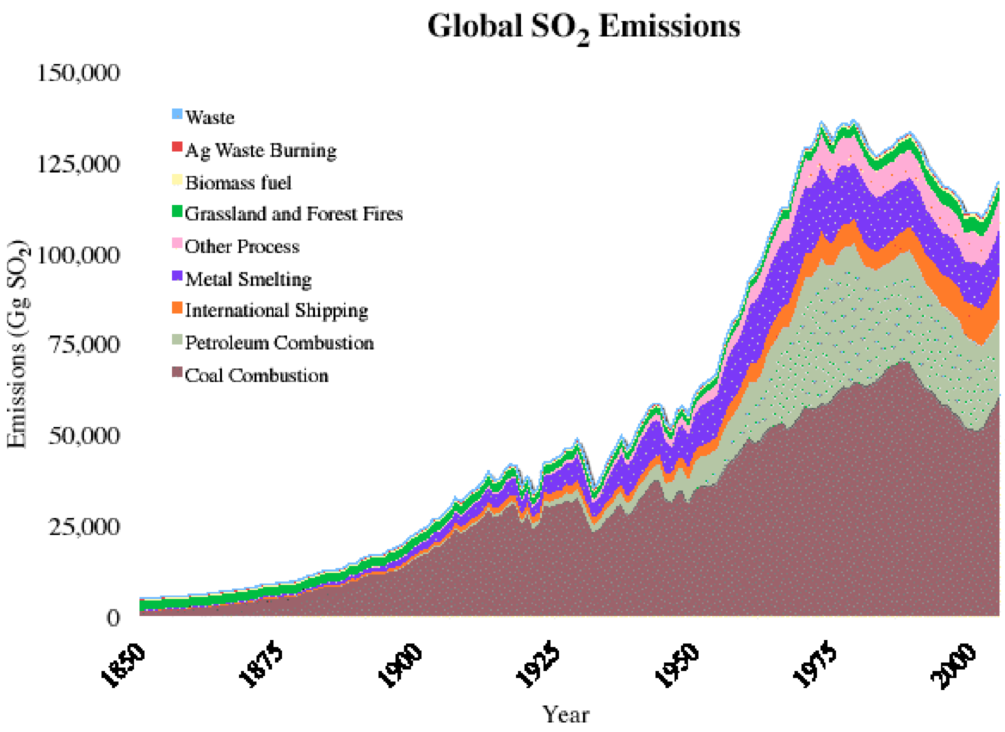


Figure 3.1.1 Global SO_2 emissions (Steve Smith, July 8. 2010)

Main source of SO_2 emissions are coal fired power plants, which were built without sulfur removal systems until 1970 in most parts of the world. The 70 % of the produced coal has been used in power plants, 15 % in industry and 15 % in other applications like generating heat.

In 2015 the coal power capacity was about 2000 GW in the world and coal power plant generated about 10,000 TWh of electricity. About 880 GW of capacity was in China, which has started to install Flue Gas Desulfurizing system only after 1996. Today the new coal plants should meet the 200 mg/m3 emission standard. China generated about 4300 TWh of electricity with coal fired plants in 2015, which had about 30 million tons of SO_2 emissions.

North America, EU and Japan have about 600 GW of coal power capacity and these countries generated 3000 TWh with coal. About 70 % them have FGD systems and thus the SO_2 emissions were about 6 million tons.

The rest of the world generated about 2800 TWh without FGDs. Thus the SO_2 emissions of these countries were about 20 million tons in 2015. Thus the total SO_2 emissions of coal fired power plants in the world were about 56 million tons (Figure 3.1.2).

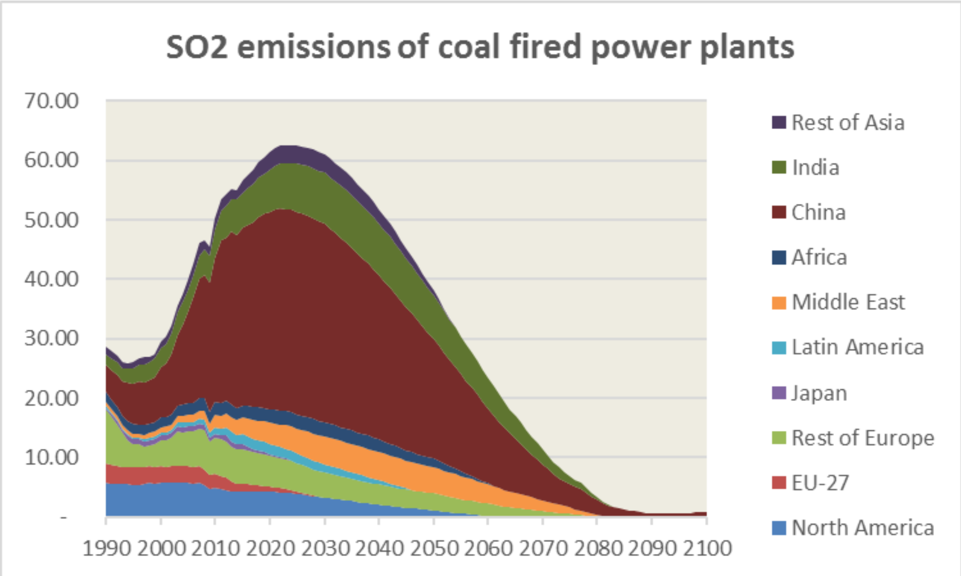


Figure 3.1.2 SO_2 emissions of coal fired power plants.

The reduction of emissions has happened since 1975 because desulfurization systems were installed in coal power plants and use of oil was decreased in oil fired power plants. However, China has started to build new coal fired power plants after the year 1990 and the emissions have been rising again (Figure 3.1.2). This may have caused the increase in SO_2 emissions and the slowdown of temperature rise after the year 2000.

It has been estimated that the coal fired power generation will peak at 11,000 TWh in the year 2025 and will decrease to 5000 TWh by 2060 (Figure 8.2.2). SO_2 emissions of coal fired power plants will peak at 43 million tons in 2025 (Figure 3.1.2).

The global SO2 emissions including electricity generation, industries and the other sectors by countries can be found in Figure 3.1.3, where East Asia (China) is now leading emitter. North America is in the second place with South East Asia (India) and the Middle East increasing their emissions constantly.

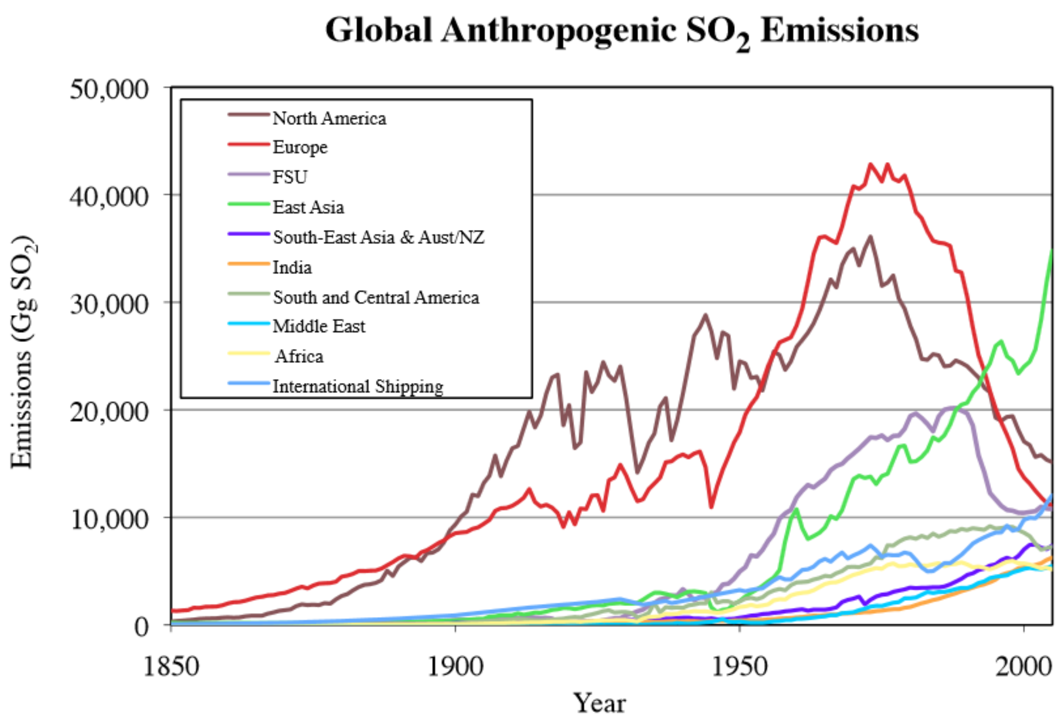


Figure 3.1.3 Emissions of SO_2 by country groups.

Forecasts of SO_2 emissions of power plants, industries and other sectors until the year 2200 have been evaluated in Figure 3.1.5. If saving starts in the year 2030 with 1 % rate, the emissions will be 20 Mt in the year 2200.

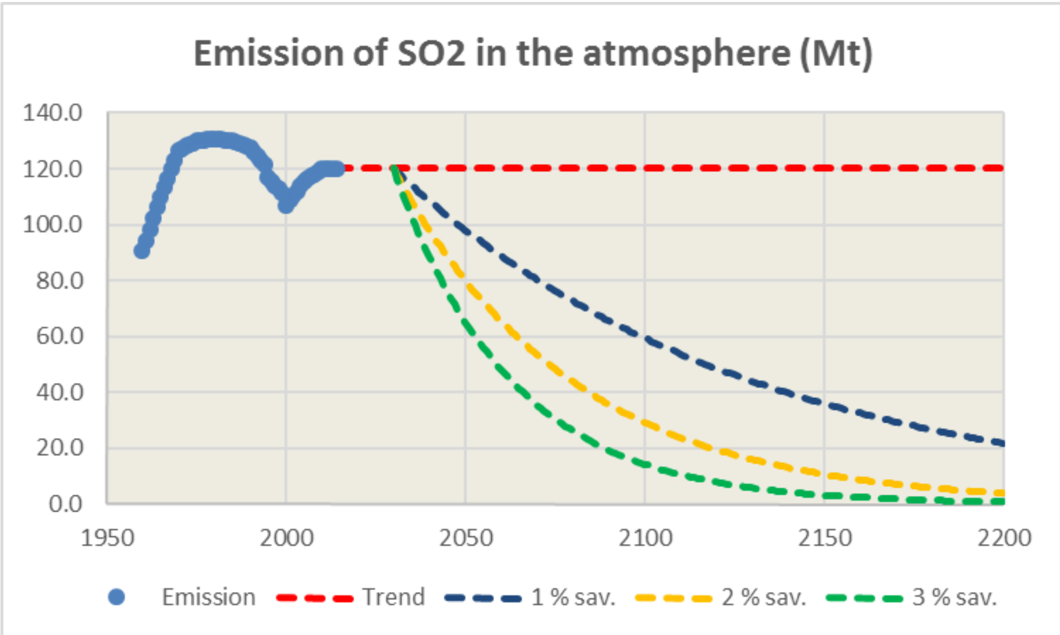


Figure 3.1.4 Forecast of SO_2 emissions with alternative saving scenarios.

3.2 Cooling influence of SO_2

When the SO_2 emissions decline, the concentration in the air will follow it very closely with about one year lagging. Thus the SO_2 concentration in U.S. has been declining from the year 1980 constantly (Figure 3.2.1).

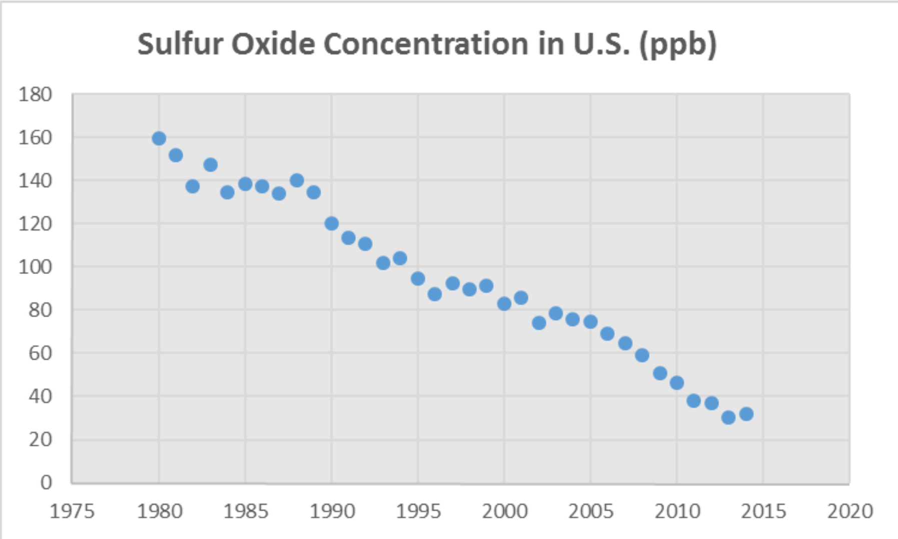


Figure 3.2.1 Concentration of SO_2 in U.S. air (source: EPA).

SO_2 emissions have caused about 0.3 deg. C cooling global temperature in 2014 compared with the average values from the years 1901 – 1930. (Figure 3.2.2, red dots). The warming caused by the greenhouse gases (GHG= green dots) can then be evaluated by the difference of the anthropogenic global warming (AWG=blue dots) figures and cooling caused by sulfur oxide (Sulfur).

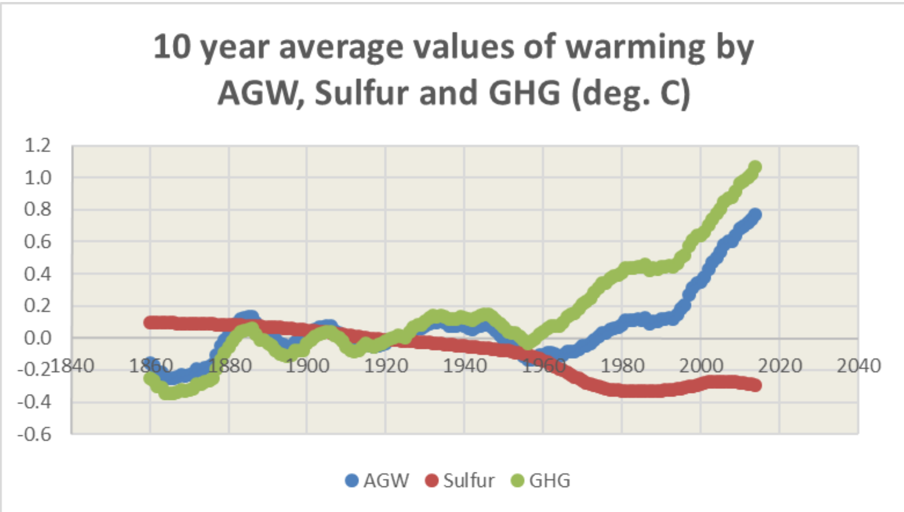


Figure 3.2.2 Ten year averages of anthropogenic warming (AWG), sulfur caused cooling (Sulfur) and greenhouse gas warming (GHG).

If look the GHG figures more closely, we can find that GWG have caused 0.1 deg. C warming until the year 1960 (Figure 3.2.3). After the year 1961 warming has been risen from 0.1 to 1.1 deg. C or with 1.0 deg. C in 53 years or at rate of 1.9 deg. C in hundred years.

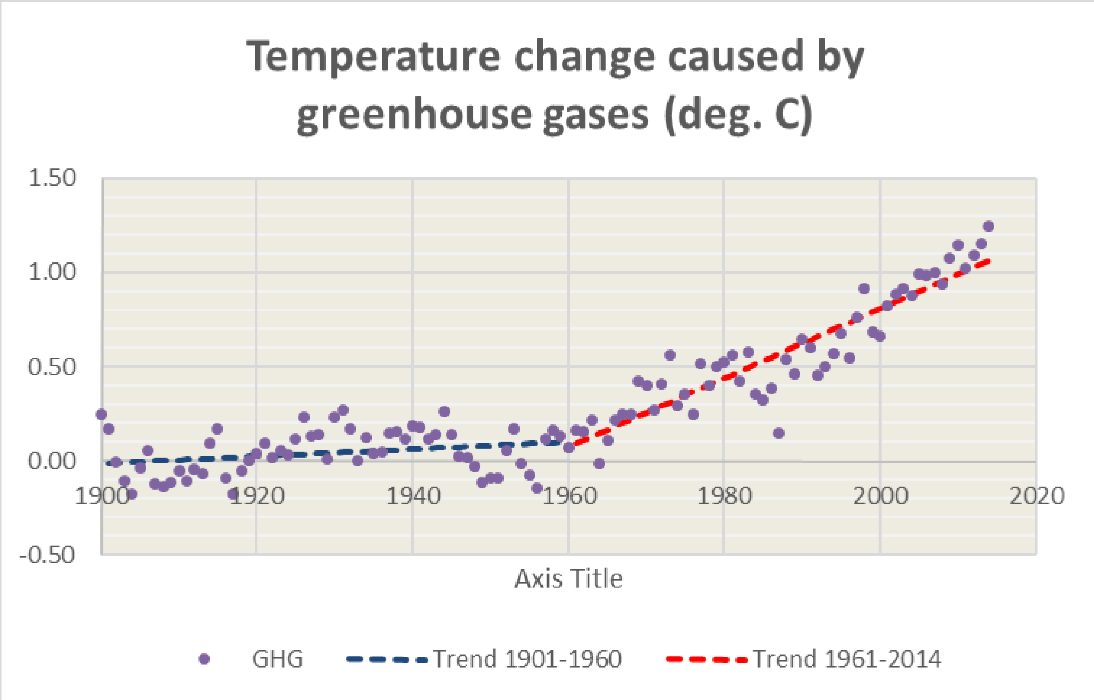


Figure 3.2.3 Trends of greenhouse gas generated warming.

3.3 Volcanic eruptions

Every now and the volcanic eruptions emit millions of tons of SO_2 into the atmosphere. The latest last eruption happened in Mount **Pinatubo** in Philippines in 1991, when 20 million tons of SO_2 and 10,000 tons of magma were emitted. It was noticed that global temperature dropped by 0.5 deg. C for two years.

Even greater eruption happened in Indonesia in 1883, when mount **Krakatoa** erupted releasing 25 cubic kilometers of rock. At least 36,000 people was killed mostly from tsunami followed by the explosion.

The next notable large eruption happened in **Mount Tambora** in Island of Sumbawa in Indonesia in April 1815. It has been estimated that between 20 – 100 million tons of sulfur oxide was emitted into the atmosphere. This caused 10,000 acute deaths and temperature drop in the area and about 38,000 people died in Sumbawa 4,000 and people were died in island of Lombok due to starvation.

It was said that 1815 was a year without summer. In global temperature has dropped with 0.51 deg. C in 1816, 0.44 deg. C in 1817 and with about 0.29 deg. C in 1818 (*Briffa, K.R.;*

*Jones, P.D.; Schweingruber, F.H.; Osborn, T.J. (1998). "Influence of volcanic eruptions on Northern Hemisphere summer temperature over 600 years". **Nature 393** (6684): 450–455).* Additionally, colored sunsets were seen in London during the summer of 1815.

The largest eruption during historical times happened in the Andes, Peru, in **Mt. Hyaunaputina** in February 19, 1600, when about of 30 million cubic meters of lava and sulfur gases were emitted. This caused temperature drop in the whole world and the summer 1600 was said to be cold. Famine was affecting Russia during the years 1601 – 1603.

4 CARBON DIOXIDE

4.1 CO_2 concentration

Continuous measurements of concentration of CO_2 in the air were started in the year 1958 in Mauna Loa observatory in Hawaii by an American Dr. **Charles David Keeling** (b. 1928). The first figure in his measurements was 314 ppm (parts per million). Since then the concentration has been constantly increasing to about 400 ppm today. The annual figures are available since 1959 (Figure 4.1.1).

The annual increase of CO_2 concentration has been increasing constantly from the year 1930, when there seems to be some kind of stable condition. Today concentration is increasing with trend of 2.2 ppm annually (Figure 4.1.2). There has been great variation because of forest fires and other causes. Because the trend of annual increase seems to be approaching zero in the year 1930, this year can be considered as a starting year of studies.

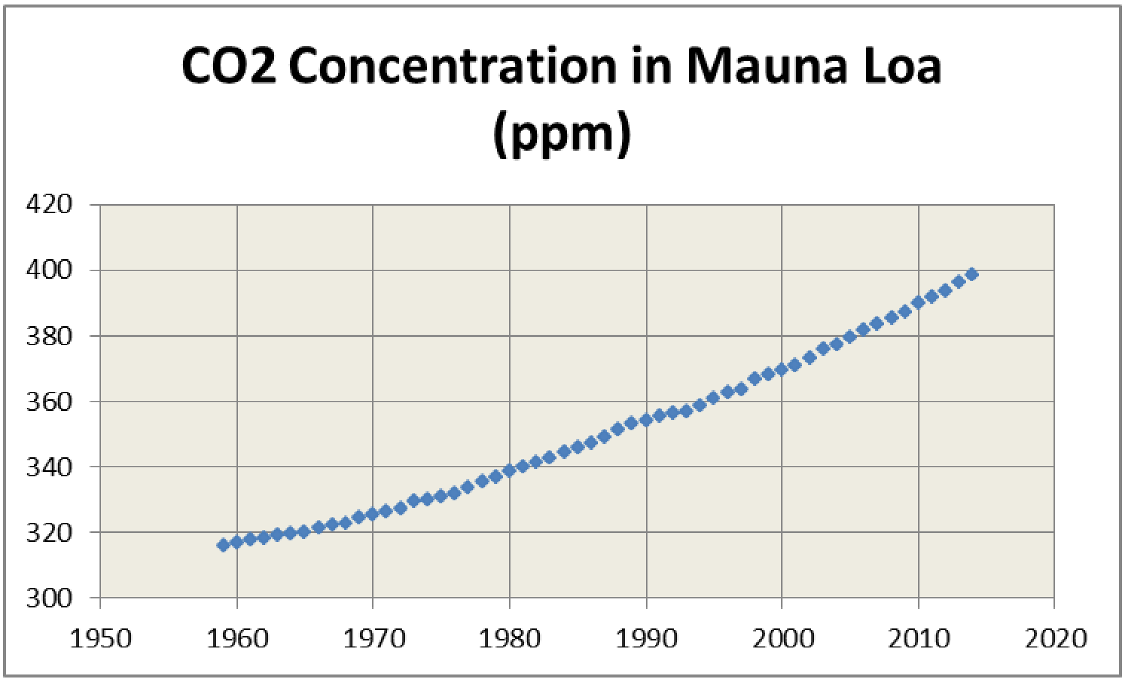


Figure 4.1.1 CO_2 concentration in Mauna Loa as measured by National Oceanic& Atmospheric Administration (NOAA). (The measurements have been downloaded from: http://www.esrl.noaa.gov/gmd/ccgg/trends/).

As was already found in chapter 1 that global warming was caused by other unknown reasons before the year 1930. It can be concluded from the Figure 3.2.3 that warming caused by greenhouse gases (GHG) has been really increasing after the year 1960.

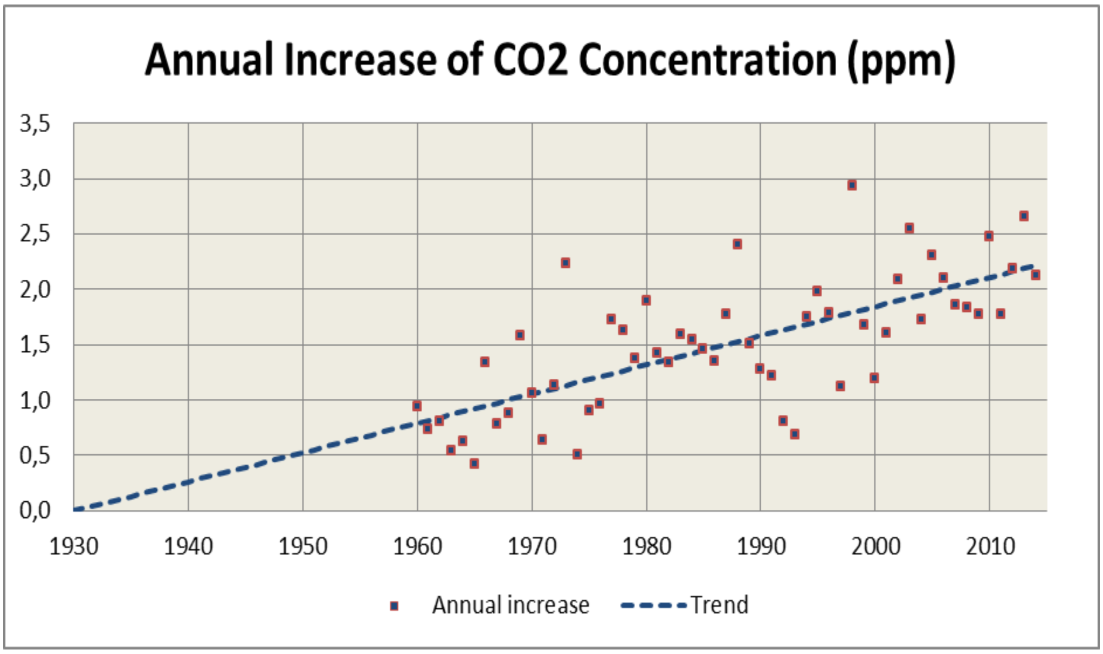


Figure 4.1.2 Annual increase in CO_2 concentration (ppm).

4.2 CO_2 emissions

The main reason for increase has been the fossil fuels, which started to give energy for traffic and industries and heating of buildings. CO_2 emissions were increasing from less than 10 Gt/a rate in 1960 to about 35 Gt/a today (Figure 4.2.1).

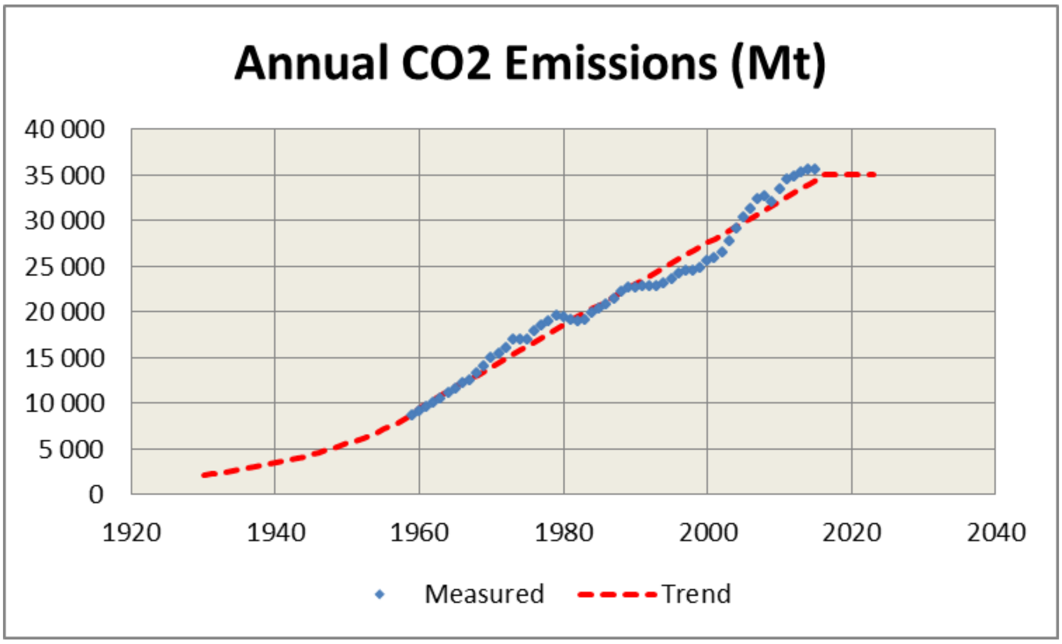


Figure 4.2.1 Annual CO_2 emissions (Source BP Energy Statistics).

There seems to be some kind of stabilization after years 2010 – 2015, because the emissions have not been increasing. Before 1960 it has been assumed that the emissions have been increasing 5 % annually.

The cumulative CO_2 emissions since 1930 have been increasing exponentially until 2014, but it has been assumed that the present level of 35 Gt continues in the future (Figure 4.2.2). The cumulative CO_2 emissions are about 1410 Gt today, but they will reach 4400 Gt until the year 2100.

CO_2 concentration in the air seems to be dependent from the cumulative emissions very closely. At 200 Gt emissions CO_2 concentration was 318 ppm in the atmosphere. At 1400 Gt emissions (year 2015) the CO_2 concentration was 400 ppm (Figure 4.2.3).

This relation can be used to extrapolate the cumulative emissions to future and forecast then CO_2 concentration (Figure 3.2.4). The figure indicates that two times pre industrial level concentration (2 x 280 ppm) will be reached at 3690 Gt of cumulative emissions. On the other hand the two times of the concentration of 300 ppm in 1930 will be achieved when the cumulative emissions will be 4250 Gt.

Assuming that the cumulative CO_2 emission will stay at 35 Gt level then the 560 ppm level will be reached in the year 2080 and the 600 ppm level in the year 2096 (Figure 4.2.5).

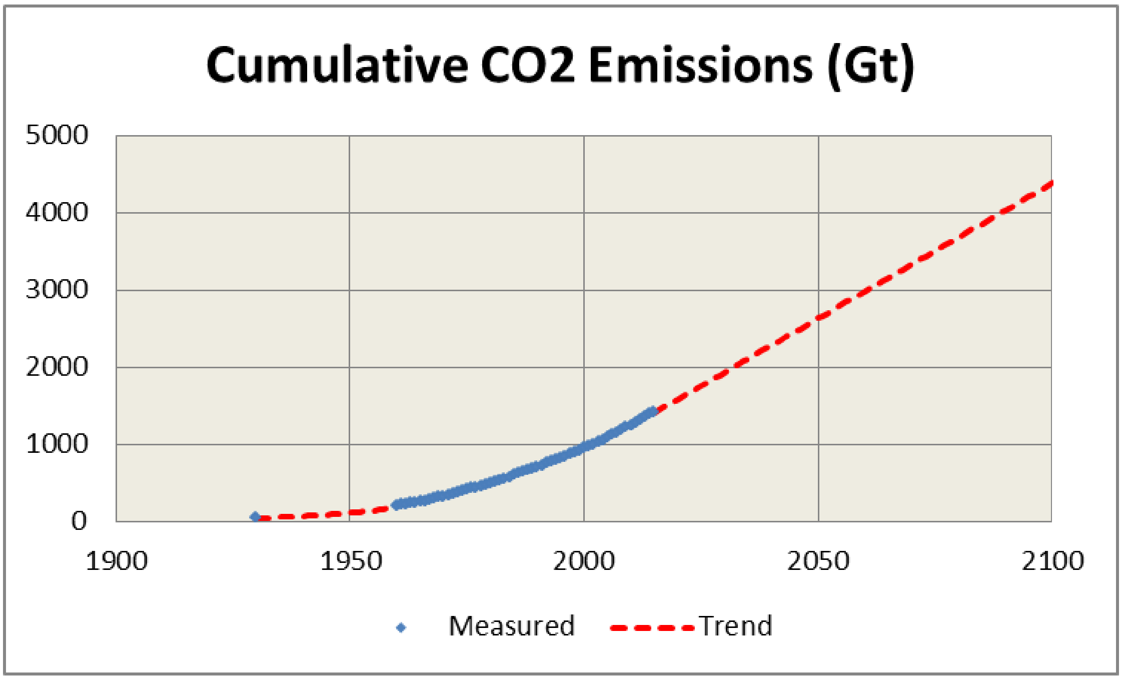


Figure 4.2.2 Cumulative CO_2 emissions (Gt) with constant 35 Gt trend.

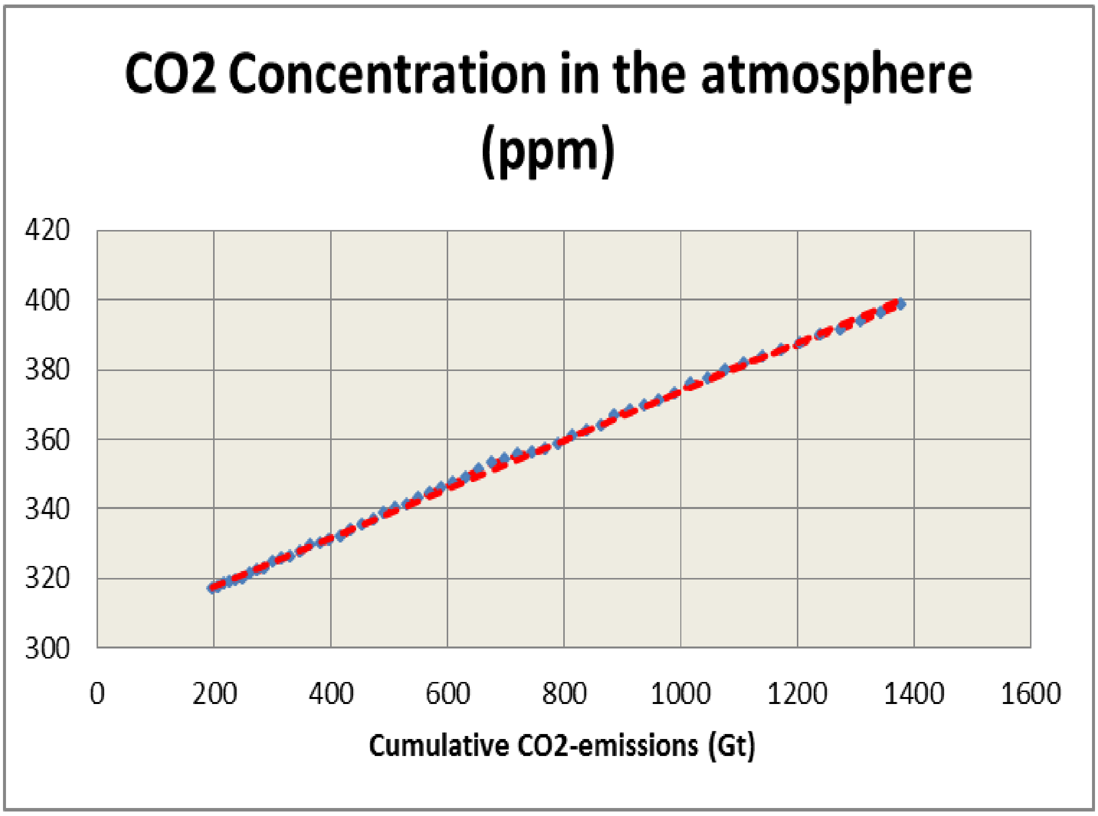


Figure 4.2.3 CO_2 concentration (ppm) dependence on the cumulative emissions (Gt)

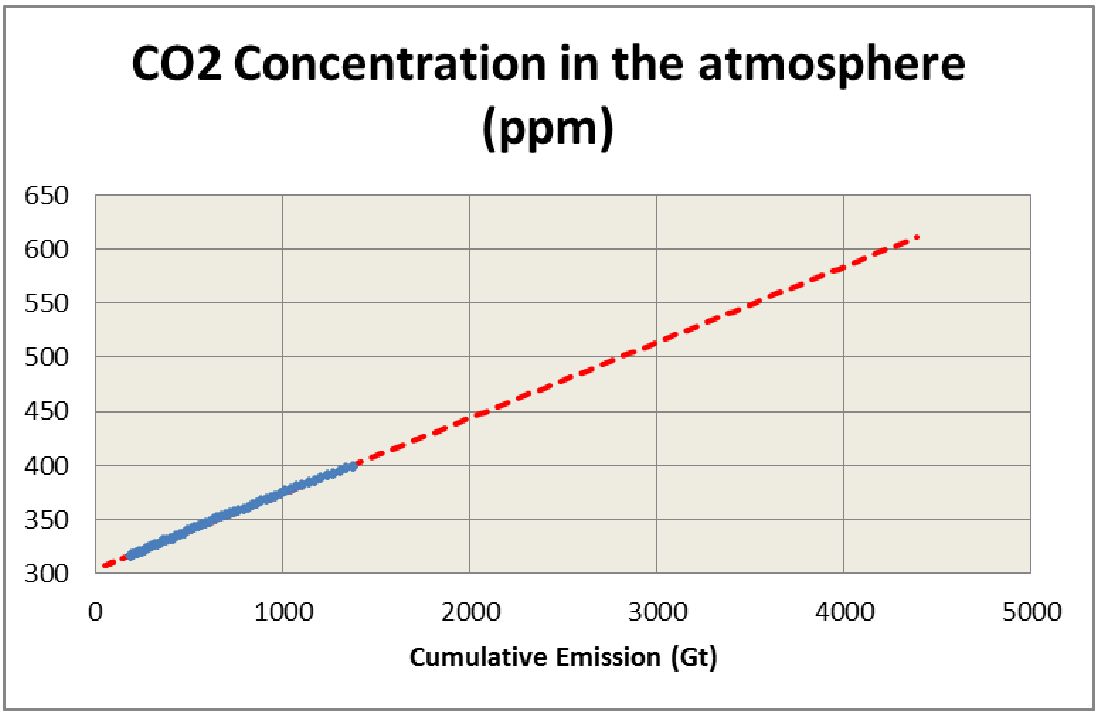


Figure 4.2.4 Extrapolation of CO_2 concentration (ppm) dependence on the cumulative emissions (Gt).

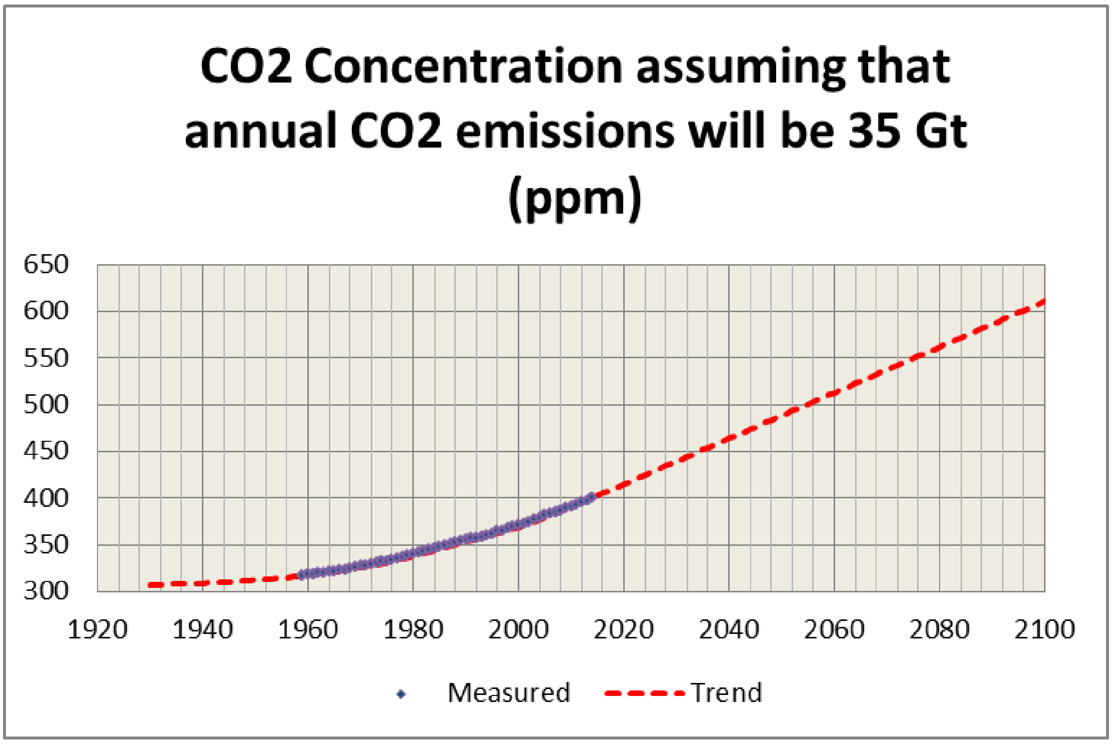


Figure 4.2.5 Forecast of future CO_2 concentration, if the emission will remain at 35 Gt level in the future.

4.3 CO_2 reduction plans

CO_2 emissions can be reduced using several emission reduction strategies. If the reductions are started after the year 2030 with rate of 0 %, 1 %, 2 % or 3 % annually, then the emissions will be following the red, blue and green curves correspondingly in Figure 4.3.1.

Cumulative emissions will be approaching 5000 Gt by the year 2200 with the 1 % annual emission reduction plan, 3700 Gt with the 2 % annual reduction plan and 3000 GT with 3 % annual reduction plan (Figure 4.3.2).

The CO_2 concentration will be increasing constantly, if reductions are not made. Concentration will stabilize at 650 ppm level with 1 % reduction plan, 560 ppm level with 2 % emission reduction plan and 520 ppm with 3 % annual reduction plan (Figure 4.3.3).

The two times the preindustrial period level of CO_2 concentration (560 ppm) has been the target for many environmentalists already for several decades. This corresponds to the 2.5 deg. C rise in temperature (see chapter 4.5).

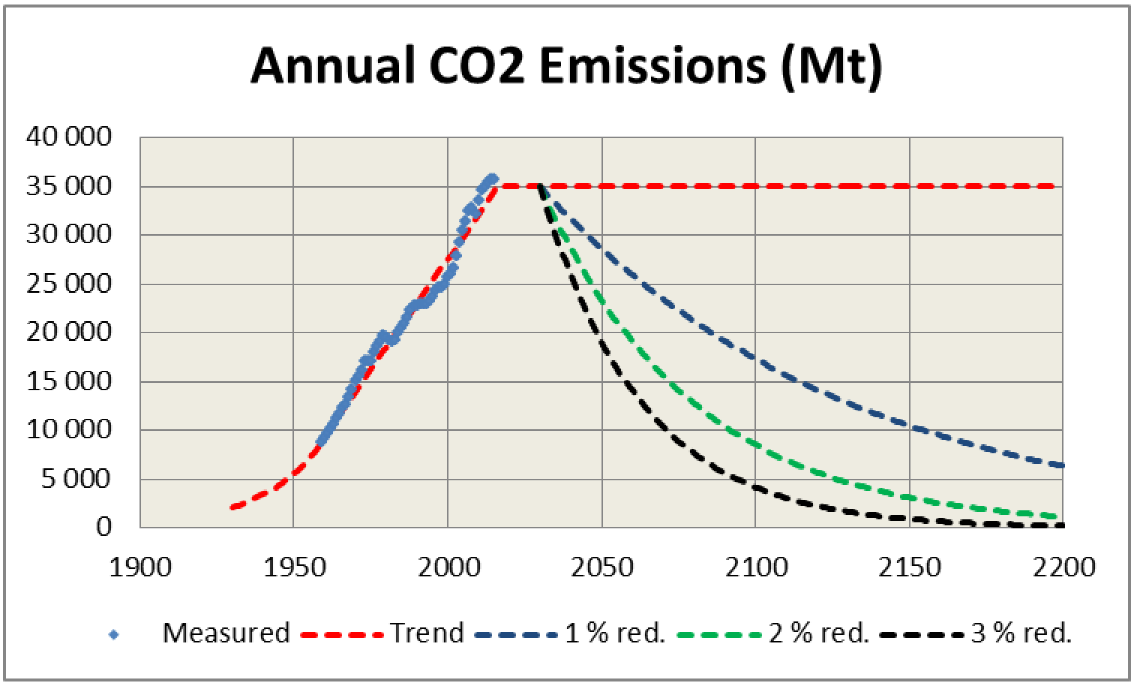


Figure 4.3.1 CO_2 emissions with constant 35 Gt plan (red) and if emissions will be reduced with 1 % (blue), 2 % (green) and 3 % (black) annually after 2040.

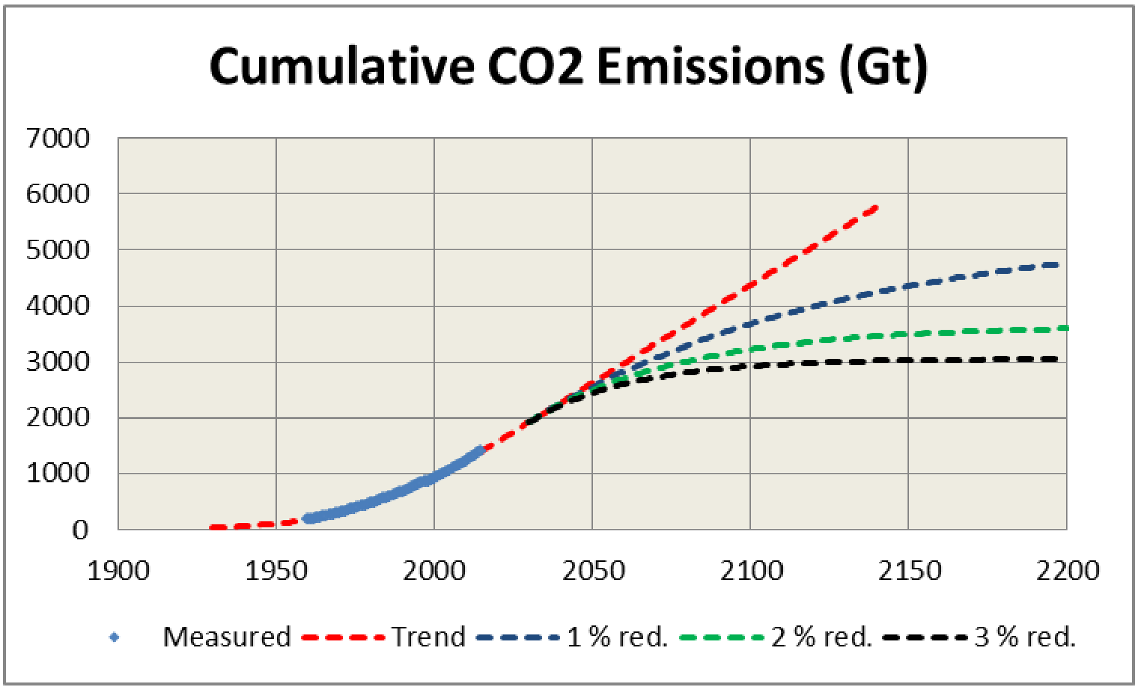


Figure 4.3.2 Cumulative CO_2 emissions with constant 35 Gt plan (red) and with an annual reduction of 1 % (blue), 2 % (green) and 3 % (black) annual emission reduction plans.

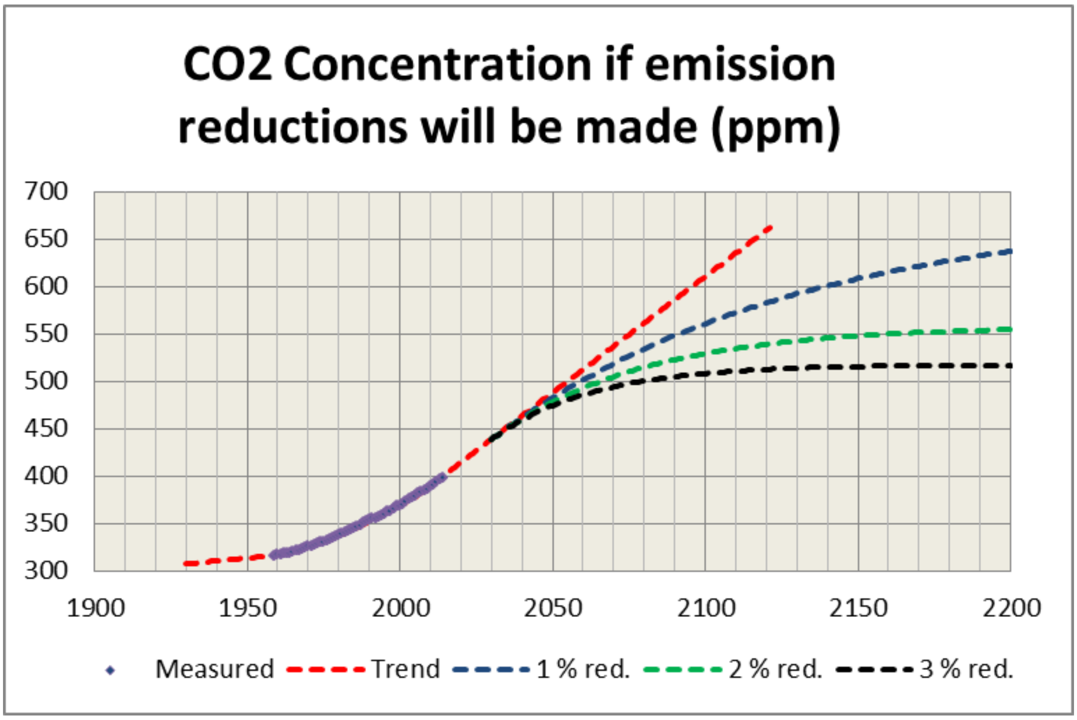


Figure 4.3.3 CO_2 concentration with 1 % (blue), 2 % (green) and 3 % (black) annual emission reduction plans.

4.4 CO2 balance

The mass of CO_2 in the atmosphere can be calculated by the formula

(4.1) $MCO_2 = CCO_2 \times mCO_2/mAIR \times MAIR$

Where CCO_2 = CO_2 content in the air (ppm)

mCO_2 = molar mass of CO_2 = 44.01

mAIR = molar mass of air = 28.97

MAIR = mass of air in the atmosphere= 5194 000 Gt

If CCO_2= 400 ppm, then mass of CO_2 in the atmosphere, MCO_2 = 400/1000000 x 44.01/28.97 x 5194 000 Gt =3156 Gt.

By using the formula (4.1) we can then calculate the mass of CO_2 in each year (Figure 4.4.1), increase of the mass in atmosphere (Figure 4.4.2) and absorption of CO_2 of the forest and seas (Figure 4.4.3).

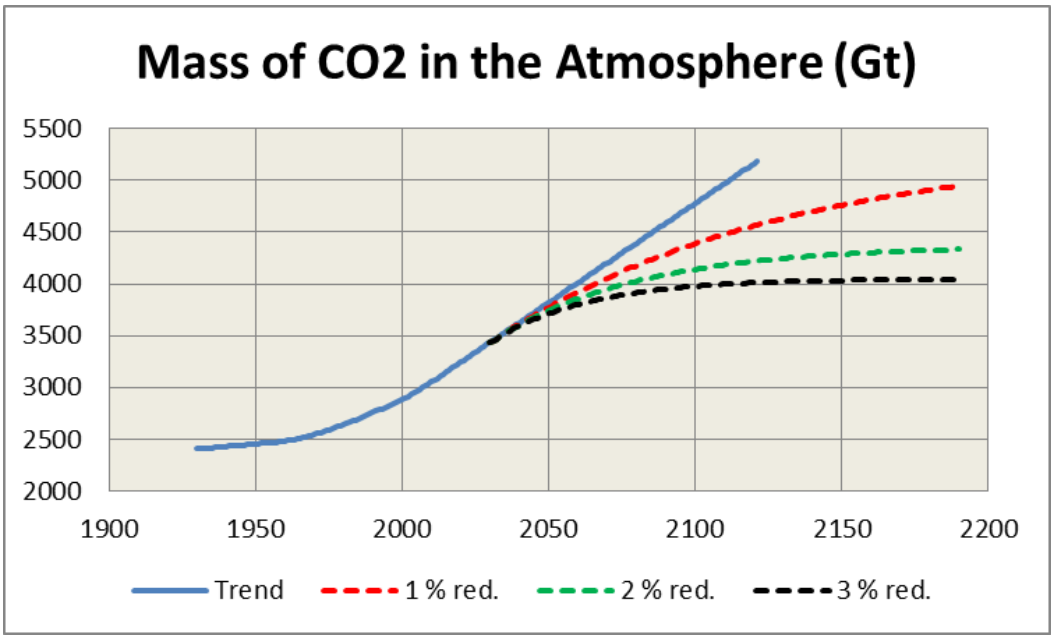


Figure 4.4.1 Mass of CO_2 in the atmosphere (Gt).

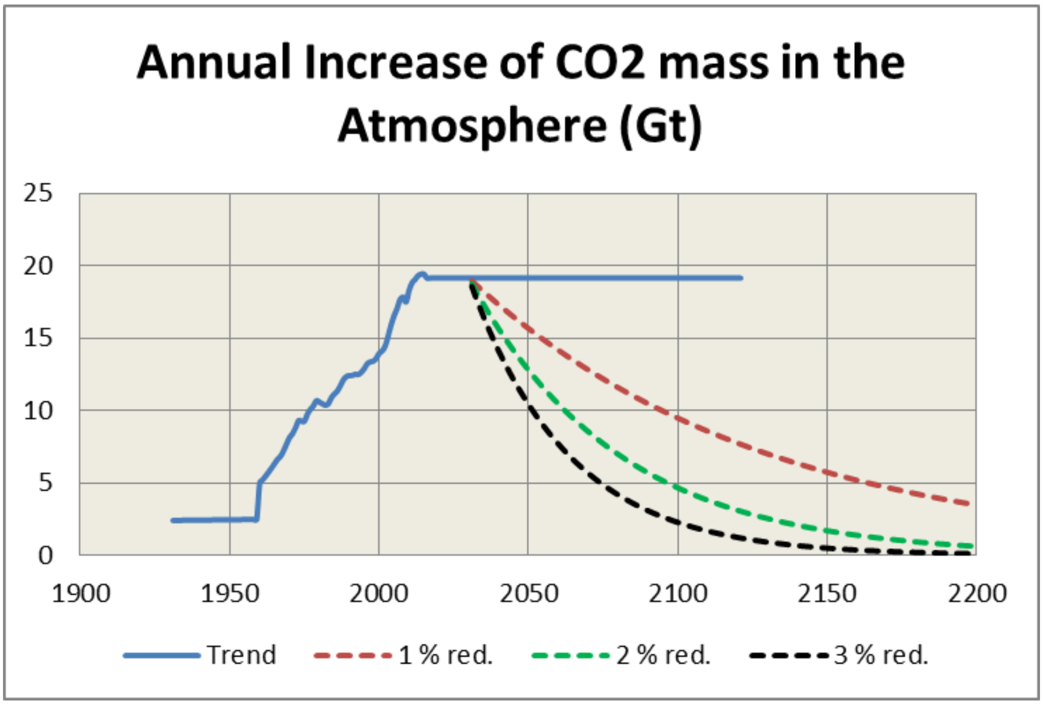


Figure 4.4.2 Annual increase of the CO_2 mass in the atmosphere (Gt).

Annual absorption of CO_2 mass can be calculated by subtraction the increase of CO_2 (Figure 4.4.2) from the annual emissions (Figure 4.4.1). The imbalance of CO_2 in the atmosphere (Figure 4.4.3) is absorbed by the seas and forests.

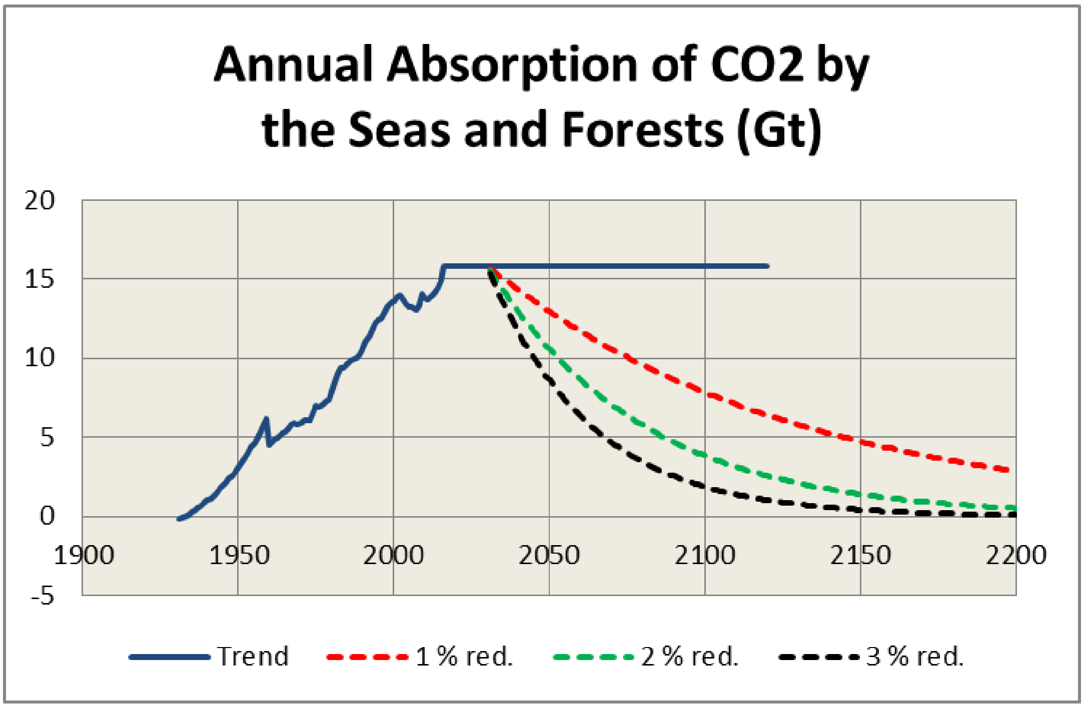


Figure 4.4.3 Annual absorption of the CO_2 by the seas and forests (Gt).

Cumulative absorption of CO_2 can be then calculated by summing the annual figures. The cumulative absorption would stabilize at 1750 Gt if emissions will be reduced 2 % annually and at 1400 Gt if reductions will be 3 % annually (Figure 4.4.4).

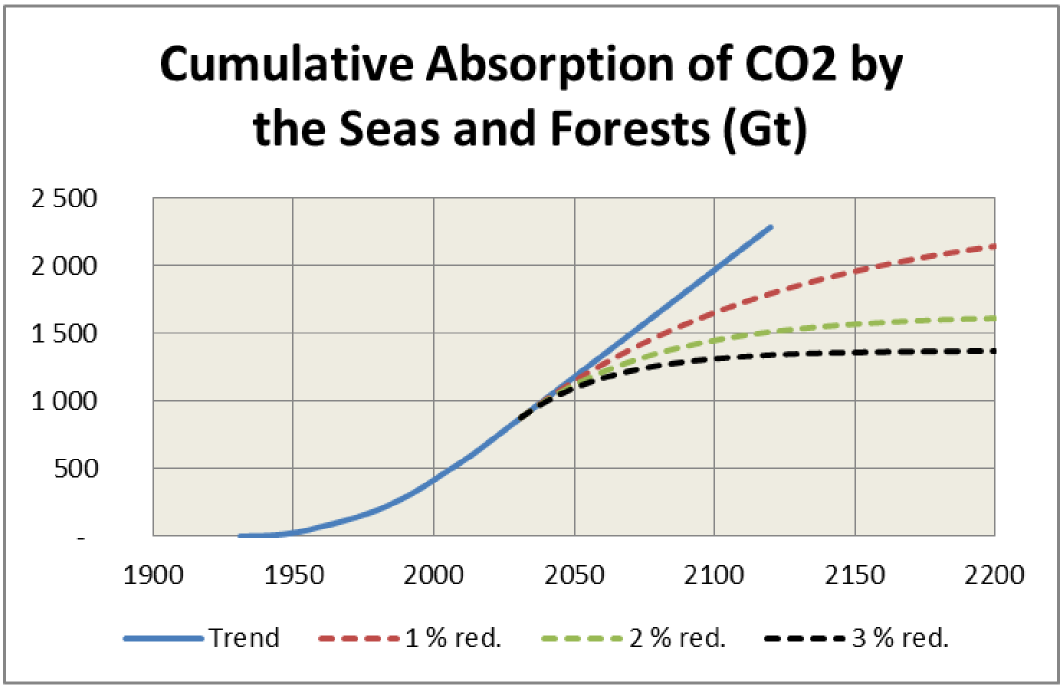


Figure 4.4.4 Cumulative net absorption of CO_2 by the seas and forests (Gt).

The mass of carbon in the seas is about 38 000 Gt, this corresponds 141 000 Gt of CO_2. Thus if all the carbon dioxide (1750 Gt) will be absorbed by the sea, the CO_2 concentration will be increased only by 1.2 %. This has thus only minor influence on the sea life if any. However, the carbon dioxide in the seas will make the sea acid and thus might harm the life in the seas.

5 METHANE

5.1 Concentration of methane in the atmosphere

Concentration data of methane (CH_4) in the atmosphere can be obtained only after 1984. But before this methane content has been obtained from ice core data for million years. However, this data is not very accurate. After 1900 the concentration has been growing from about 0.86 ppm in 1900 to 1.83 in the year 2014 (Figure 5.1.1).

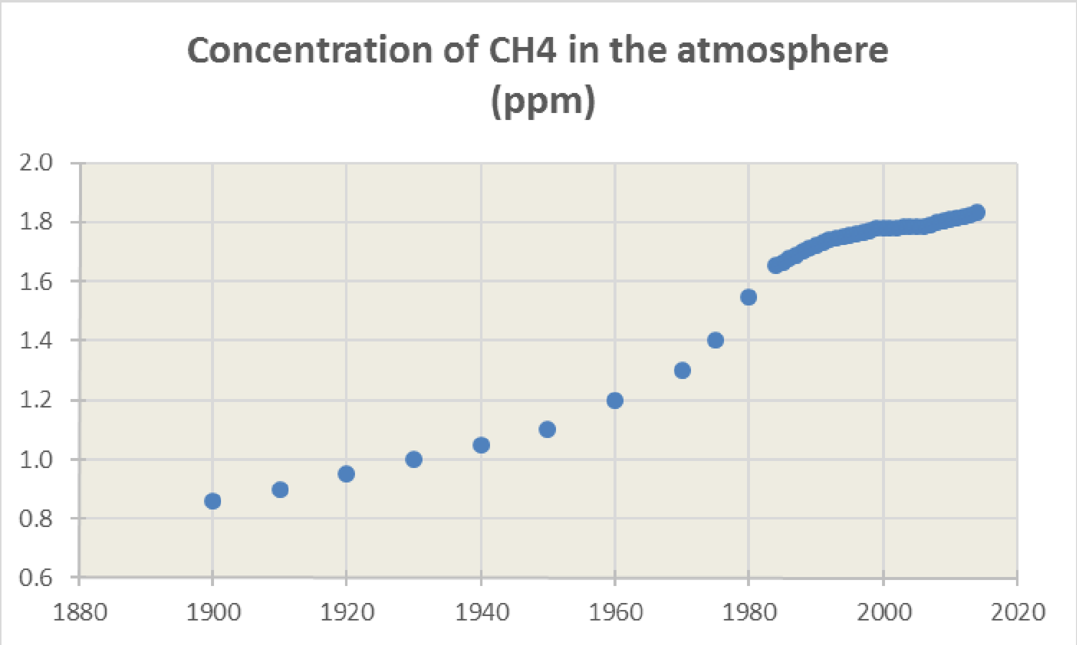


Figure 5.1.1 Concentration of methane in the atmosphere (ppm) (Source World Meteorological Organization WMO).

The concentration was increasing smoothly until the year 1960 from 0.85 to 1.2 ppm in 25 years. The increase was 0.35 ppm in 60 years or 0.6 ppm in hundred years. During years 1960 to 2000 the increase was to 1.8 ppm or 0.6 ppm in 40 years. After the year 2000 the trend is again quite modest 0.36 ppm in 100 years.

During the last 30 years there were stabilization phase until the year 2005 (Figure 5.1.2) and there after clear increase from 1.785 ppm to 1.833 ppm in 10 years. This trend corresponds to 0.53 ppm in hundred years.

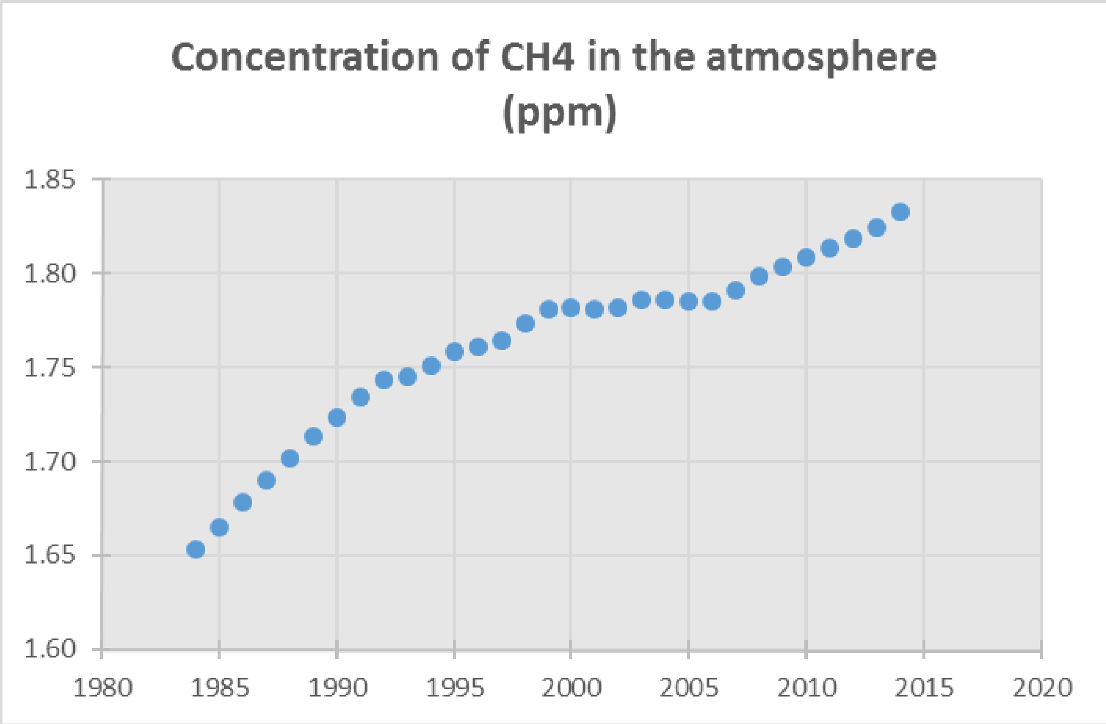


Figure 5.1.2 Concentration of CH_4 in the atmosphere.

5.2 Methane emissions

Anthropogenic methane emissions have been growing quite slowly during years 1860 to 1950 from about 80 Gt/a to 160 Gt/a. After 1950 emissions have grown to 370 Mt by 1992 (Figure 5.2.1). It can be seen that more than 50 % of the emissions have been caused by rice and other livestock.

The emissions after 1992 have not been documented by the same accuracy. However, we know that the emissions caused by coal mining have increased. If we assume that they will increase with constant relation to coal production, the estimate of methane emissions continuing smoothly with about 400 Mt/a (Figure 5.2.2).

However, the coal mining should decrease considerably, if the CO_2 emissions will be decreased. Thus this estimate seems to be a pessimistic one. If the coal mining emissions will drop from 77 Mt/a to 7 Mt/a, the total emissions will be 330 Mt/a in the year 2100.

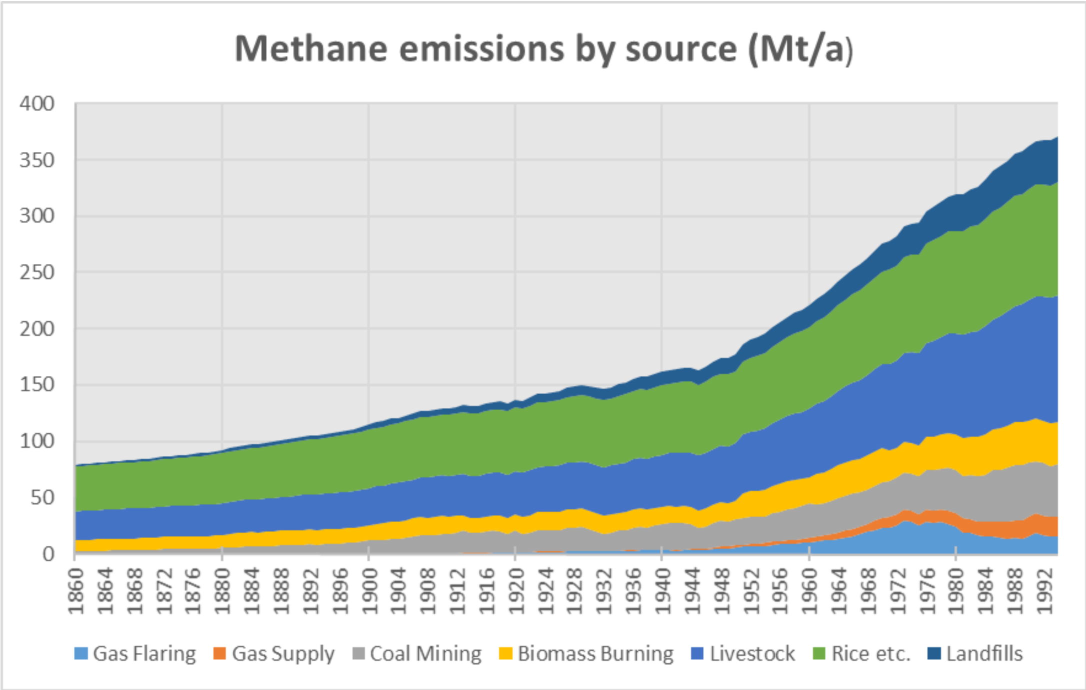


Figure 5.2.1 Methane emissions by sources 1960 – 1994 (Source: Stern Annual Estimates of Global Anthropogenic Methane Emissions: 1860-1994).

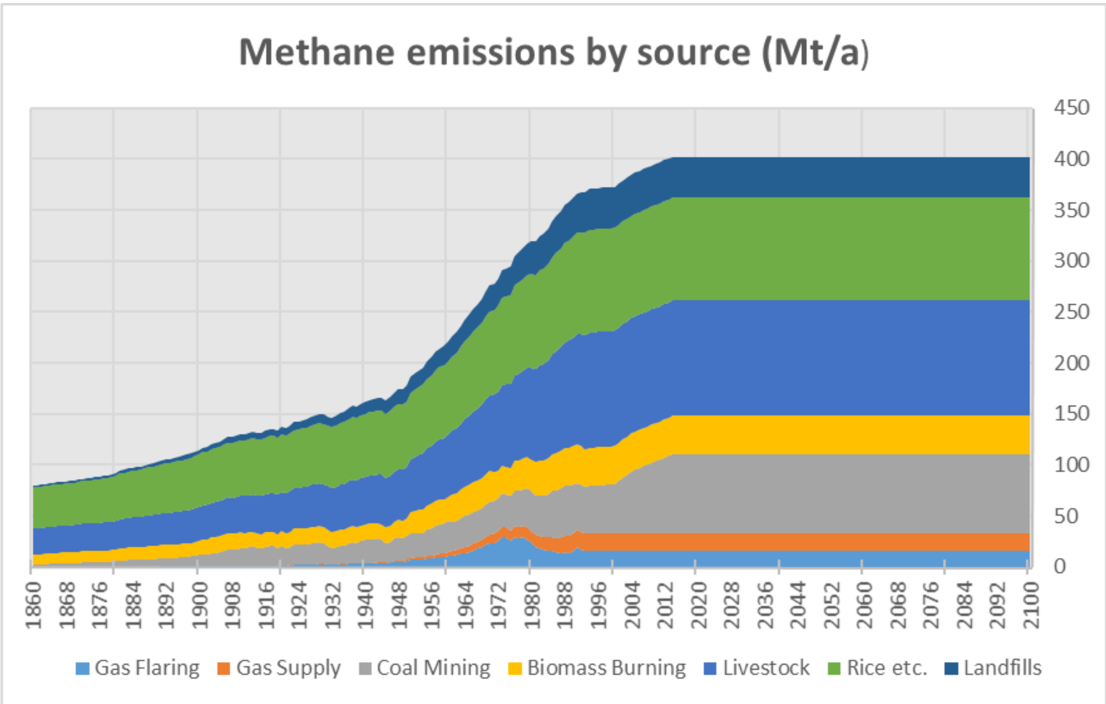


Figure 5.2.2 Methane emissions by sources until 2100 assuming that coal production stays constant.

5.3 Forecasting future concentration

After the year 2000 the methane emissions have been risen with a trend of 0.36 ppm in 100 years. If this trend continues the concentration will reach 2.1 ppm in the year 2100 and 2.5 ppm in the year 2200 (Figure 4.3.1).

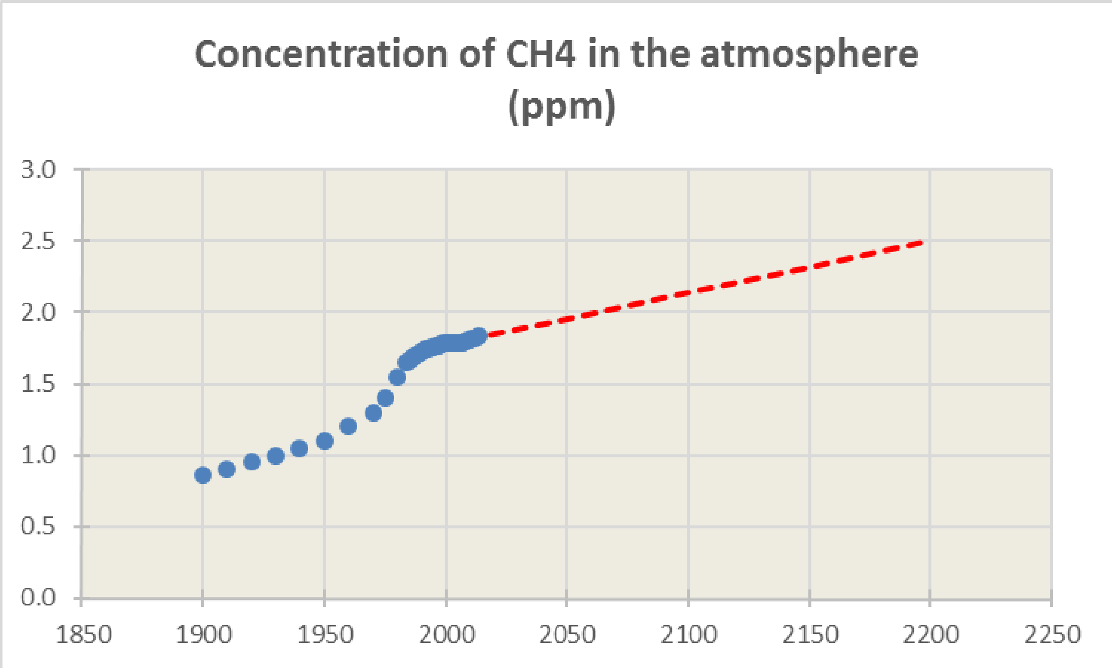


Figure 5.3.1 Trend in CH_4 concentration to the year 2200.

Another forecast can be made using the correlation between the emissions and concentration (Figure 5.3.2). The concentration of methane in the atmosphere has a life time of about eight years. Thus the concentration will stabilize in fixed level at each emission rate.

If the methane emissions remain at 400 Mt/a, then the concentration will stabilize at about 1.8 – 1.9 ppm level. The trend line of methane concentration is increasing by 0.8 ppm (from 1 to 1.8 ppm), if the emissions are increasing with 250 Mt (from 150 to 400 Mt). Thus 100 Mt additional emissions will rise concentration with 0.32 ppm.

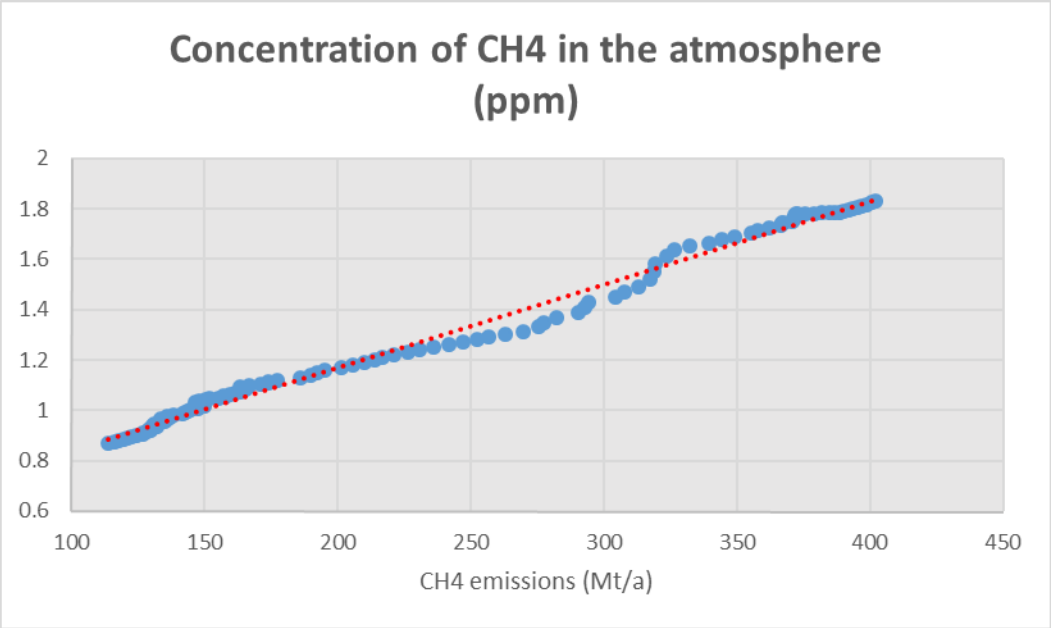


Figure 5.3.2 Trend in CH_4 concentration as a function of methane emissions.

6 NITROUS OXIDE N_2O

6.1 Concentration of N_2O

There has been a continuous increase in concentration of N_2O since the year 1900 (Figure 6.1.1). The speed of the growth was quite modest until the year 1950, but after the year 1970 the concentration has been increasing in average 0.8 ppb annually.

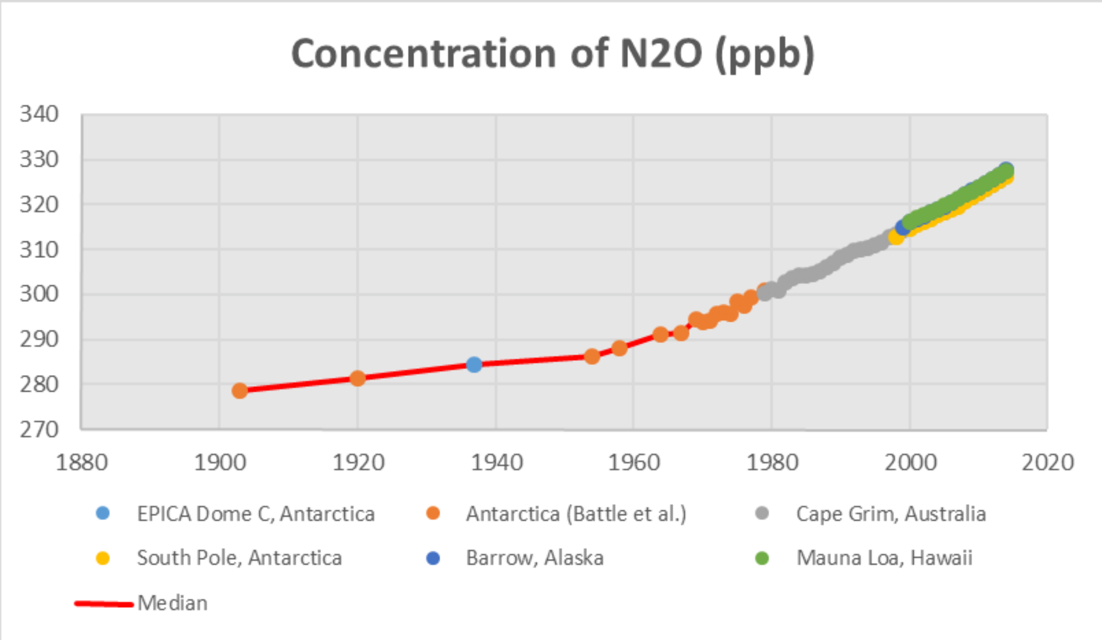


Figure 6.1.1 Concentration of N_2O since the year 1900 (Source: EPA's Climate Change Indicators in the United States: www.epa.gov/climatechange/indicators).

6.2 N_2O emissions

Global nitrogen oxide emissions are not known very well. One source says the total N_2O emissions are about 17.7 Gt annually. About 6.7 Gt/a are based on anthropogenic emissions. Anthropogenic nitrogen oxide emissions are mainly caused by agriculture (2.8 Mt/a) and fossil fuel combustion (0.7 Mt/a). Another source tells that anthropogenic emissions are today about 9.5 Mt/a (Figure 6.2.1).

Nitrogen based fertilizers is used in agriculture typically 50 – 200 kg/ha to increase crop sizes. The second source of N_2O is animal waste (urine), which are also used as fertilizers in agriculture. FAO has estimated that in 1995 nitrogen based fertilizers were used globally 73.5 Gt/a and animal manure 20.7 for crops. They caused globally 3.2 Gt/a emissions. Additionally, 0.8 Gt/a emissions were caused by fertilizers in grasslands.

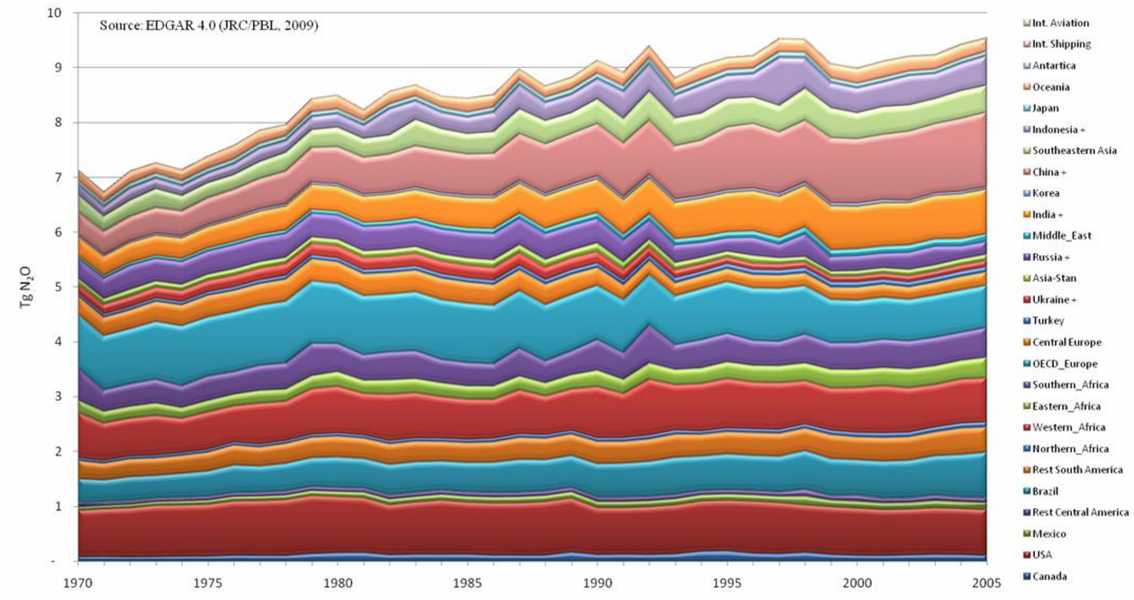


Figure 6.2.1 Sources of N_2O emissions by countries indicate that largest emitters from the bottom are USA (red), Brazil (blue), OECD Europe (blue), India (orange) and China (red).

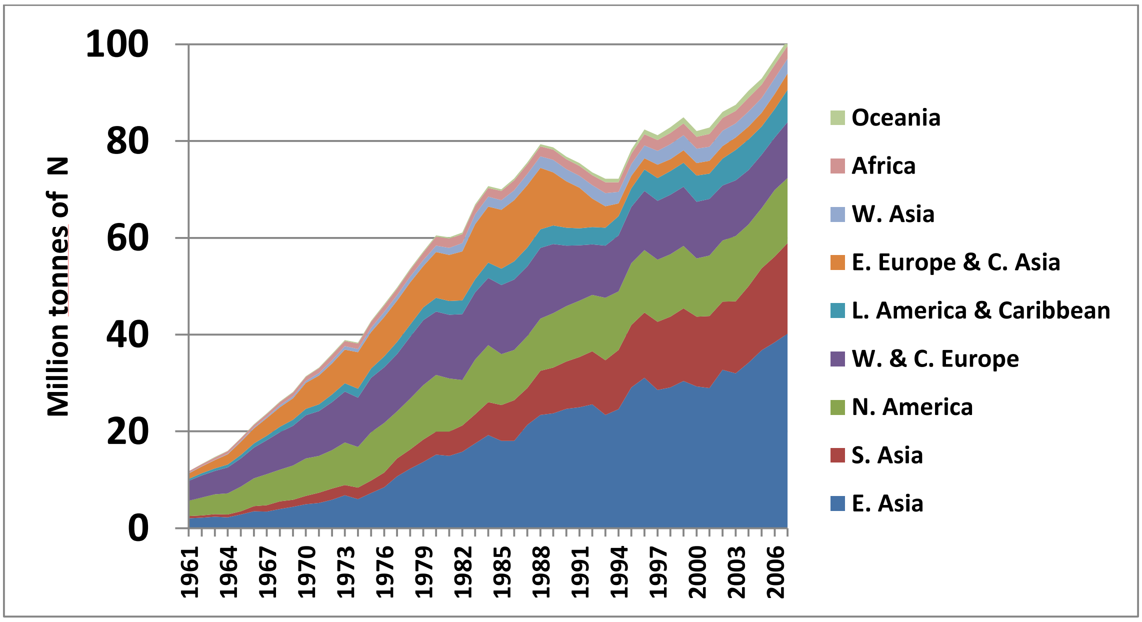


Figure 6.2.2 Use of nitrogen as fertilizer (IPNI August 3, 2010, C.S. Snyder, PhD, CCA Nitrogen Program Director).

One of the main sources of N2O emissions is the use of fertilizers which have nitrogen. Use of nitrogen fertilizers has grown from 10 million tons N in 1961 to 100 million tons in 2006 (Figure 6.2.2). Biggest growth has happened in East- and South Asia.

The N2O emissions are increasing, if the fertilization rate increases. At 120 kg N/ha rate emissions will be about 1 kg/ha (Figure 6.2.3).

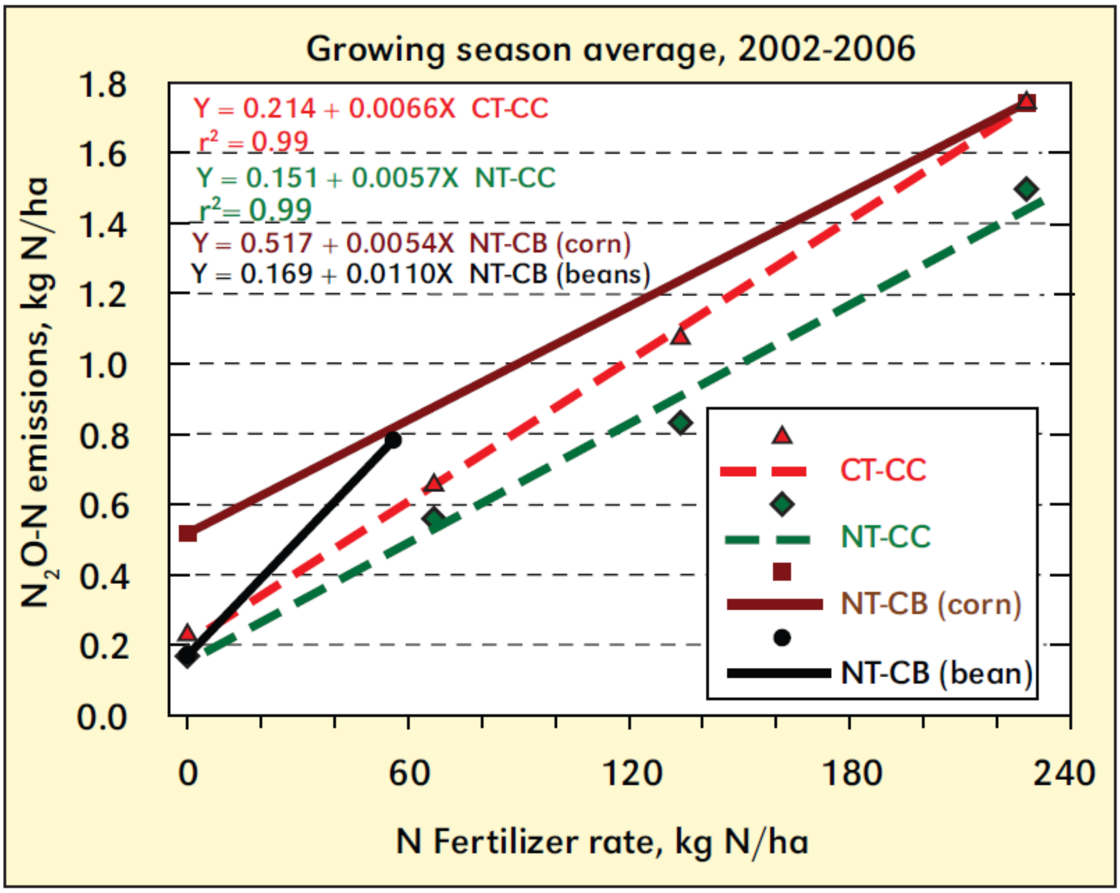


Figure 6.2.3 N2O emissions in function of nitrogen rate (IPNI August 3, 2010, C.S. Snyder, PhD, CCA Nitrogen Program Director).

6.3 Future concentration of N_2O

The average lifetime of N_2O in the atmosphere is 114 years. Thus the concentration could be estimated using cumulative N_2O emissions. However, the emissions are not known for sure. Thus future concentration has been estimated by using the trend line of atmospheric concentration from the years 2000 – 2014. This indicates that the concentration will increase from 316 ppb in the year 2000 to 397 ppb in 2100 (Figure 6.3.1).

Because the food production is directly linked to population growth, it is possible that need of food will also grow with population growth (Figure 6.3.2). In 2012 there were about 7 billion people and in the year 2100 the population might be 10 billion. The growth of population will be about 40 %. Thus the concentration will also be about 40 % higher than in 2012 (325 ppb) and reach 455 ppb.

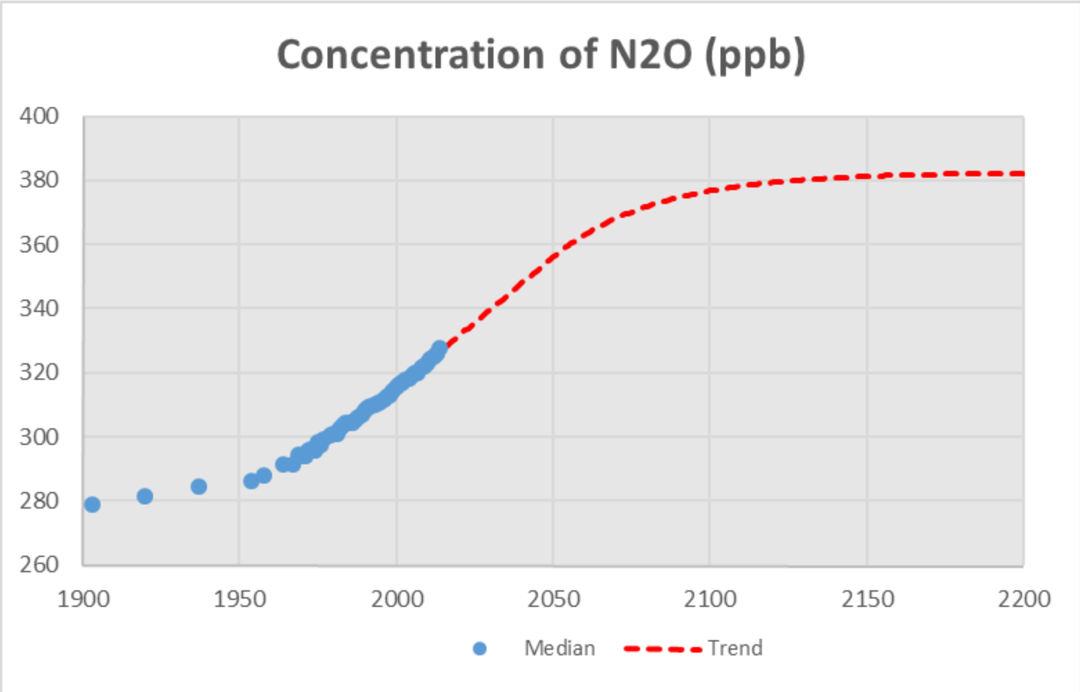


Figure 6.3.1 The trend in N_2O emissions after the year 2000.

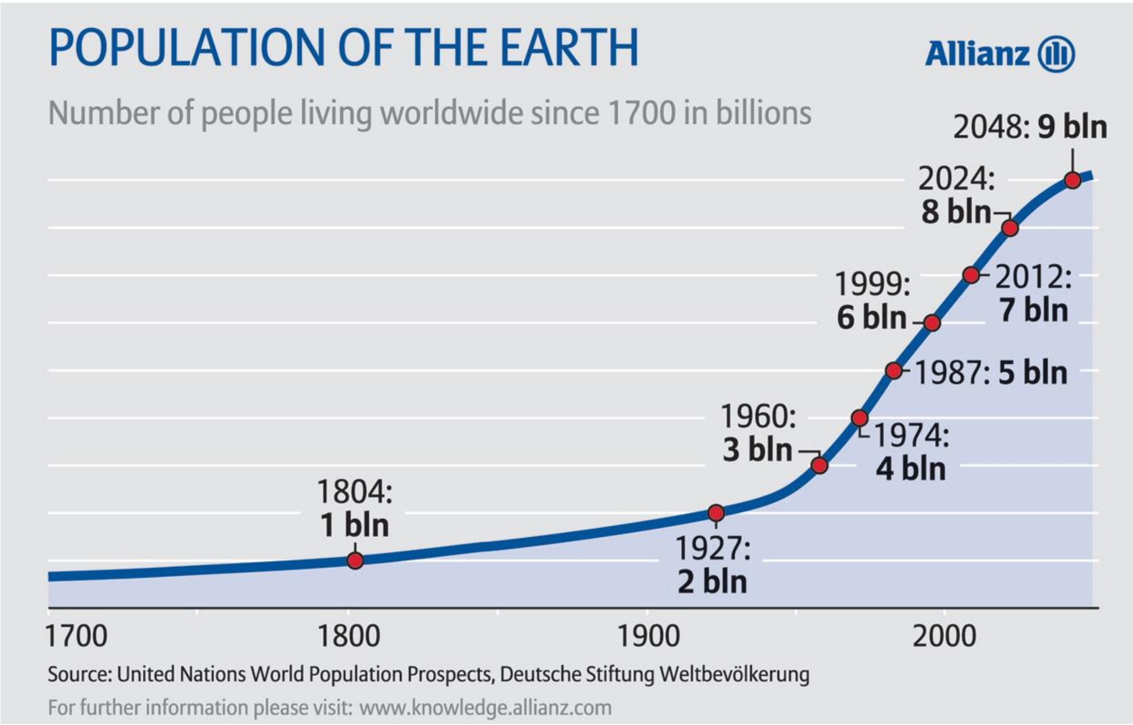


Figure 6.3.2 Forecast of world population (www.knowledge.allianz.com).

7 INFLUENCE OF GREENOUSE GASES

7.1 Radiative forces

Solar radiation

It was found with the latest satellite measurement that the solar radiation at the distance of the earth or solar constant (S_E) varies near 1366 W/m^2 (watts per square meter). The solar spots are the main reason for the variation.

If the energy remains constant in the space, so at distance d_E of the earth, the radiation received by the earth $E_E = A_{DE}$ x S_E (where $A_{DE} = 4\ \pi d_E^2$) should be the same as radiation emitted by the sun. Area of the surface of the sun is $A_S = 4\pi r_s^2$ and total energy radiated by the sun is then $E_S = A_S$ x S_S. Thus we can find that

$$\mathbf{S_E = E_S / A_{DE} = A_S / A_{DE} \text{ x } R_S = (r_S / d_{DE})^2 \text{ x } S_S}$$

Where S_E is radiation at the distance of the earth is depended on the second power of the ratio of sun radius (r_S) and distance of earth from the sun (d_{DE}). Thus radiation force at the surface of the sun $S_S = 63$ x 10^6 W/m^2.

But the radiation of the sun is affected only at area, which is the same as shadow of the earth constantly. The area of the earth is $A_E = 4\ \pi r_E^2$ and the area the shadow of the earth is $A_{ave} = \pi r_E^2$. Thus the average radiation received by the surface of the earth is $S_{ave} = S_E$ x $A_{ave}/A_E = S_E/4 = 1366/4 = 341.5$ W/m^2.

Temperature of sun and planets

The radiation of a black body is following Stefan-Bolzmann law

$$\mathbf{S = \sigma\ T^4}$$

where σ is the Stefan-Bolzmann constant (5.67 x 10-8 W/m^2/K^4) and T is the temperature of the object. We know the radiation (S) then T = (S/ σ) ¼. = 5800 K. The temperature of the sun is then 5800 $^{\mathbf{o}}$K.

The temperature of the earth (T_E) can be calculated using Stefan-Bolzmans law, which takes into account albedo (α) of the earth, which is about 0.3. Thus 30 % of the incoming flux is reflected back by the clouds and 70 % is received by the atmosphere. Thus

$$\mathbf{S_{ave}(1 - \alpha) = \sigma\ T_E^4}$$

From which we find that temperature of the earth

$$T_E = (S_{ave}(1- \alpha)/ \sigma)^{1/4}= 255\ ^oK = -18\ ^oC$$

However, the average temperature of the earth is not -18 ^oC but +15 ^oC. Because of the absorption infrared radiation (IR) of the greenhouse gases in the atmosphere the earth is about 33 ^oC warmer than without them. Without the greenhouse gases, there would not be any life in the earth.

In the same way we can calculate the temperature of the Venus and Mars, which should be 232 ^oK (-41 ^oC) and 209 K (-64 ^oC) correspondingly. However, the temperature of the Venus is 735 ^oK (+462 ^oC) and the temperature of the Mars is 215 ^oK (-58 ^oC) because of the greenhouse gases. The difference of measured and the theoretical temperature of Venus is very large (503 ^oC) because the atmosphere of Venus filled with carbon dioxide (CO_2).

The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water (H_2O). The radiative forcing factors until the year 2014 have been evaluated in Table 7.1.1.

Table 7.1.1 Radiative forcing (W/m^2) of greenhouse gas components (Source: THE NOAA ANNUAL GREENHOUSE GAS INDEX (AGGI) NOAA Earth System Research Laboratory, R/GMD, 325 Broadway, Boulder, CO 80305-3328 *James.H.Butle*r and *Stephen .A.Montzka*).

Year	1980	2014	Change	2014	Change
CO2	1.058	1.909	0.851	65%	72%
CH4	0.413	0.500	0.087	17%	7%
N2O	0.104	0.187	0.083	6%	7%
CFC12	0.097	0.166	0.069	6%	6%
CFC11	0.042	0.058	0.016	2%	1%
15-minor	0.034	0.116	0.082	4%	7%
Total	1.747	2.936	1.189	100%	100%
CO2 eq	385	481	96		
1990 = 1	0.807	1.356	0.549		

We can find that the total radiative forcing of greenhouse gases is 2,94 W/m^2 in the year 2014. CO_2 has 65 % (0.85 W/m^2), CH_4 17 % (0.50 W/m^2) and N_2O 6 % (0.19 W/m^2) of radiative forcing. Together these three have caused 88 % of the radiative forcing.

The change from 1980 has been 1.19 W/m^2 and CO_2 has influenced 72 % of the change. Other two CH_4 and N_2O have influenced 7 % of the change each. Thus these three have caused 86 % of the change in the radiative forcing.

It seems that the radiative forcing has been increasing at constant speed from the year 1990 from 2.17 to 2.94 W/m^2 in 2014 or increase of 3.2 W/m^2 in hundred years (Figure 7.1.2). With the same trend radiative forcing would reach 5.7 W/m^2 in the year 2100.

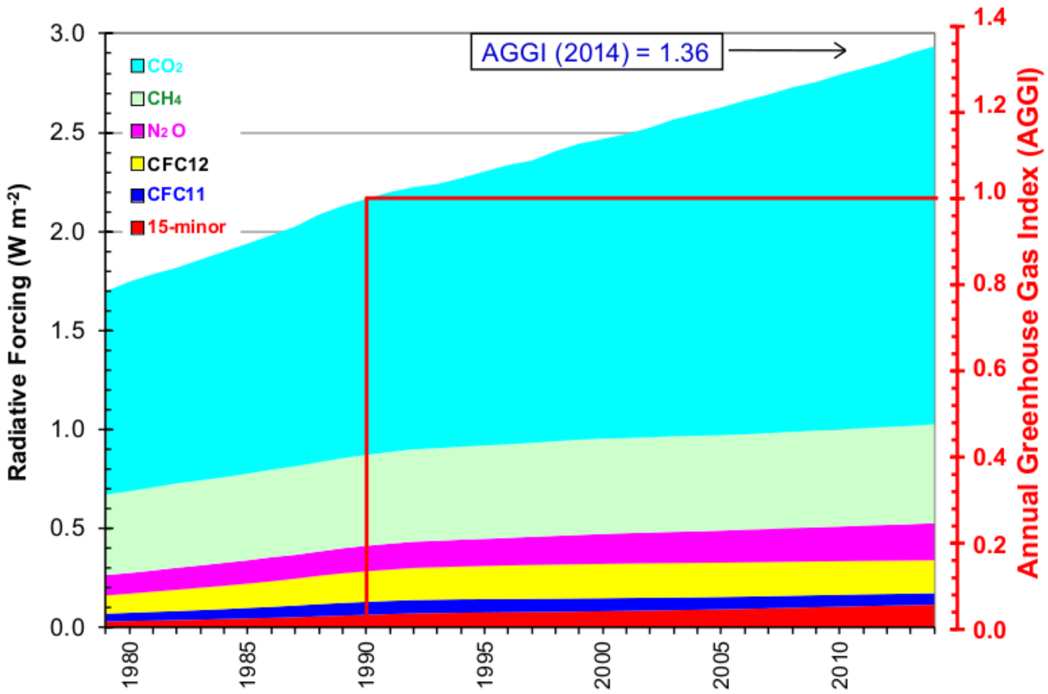


Figure 7.1.2 Radiative forcing of greenhouse gases (Source NOAA).

7.2 Influence of CO_2 on the global temperature.

It has been proven that concentration of CO_2 in the air, will influence on the global temperature. **Svante Arrhenius** (1859 – 1927) published his study "On the Influence of Carbonic Acid in the Air upon the Temperature in the Ground" in Philosphical Magazine in April 1896. In his article he had a table, in which he had calculated temperature increases, if CO2-content will increase 1.5, 2.0 and 3.0 times from the present (1896) concentration (Figure 7.2.1). The increase is between 5 – 6 deg. C or in average 5.5 deg. C, if concentration will double.

The CO_2 measurements have started in the year 1958, thus it is very speculative to estimate how much warming was caused by CO_2 before this date. To be on the safe side I have evaluated the influence of the greenhouse gases only after 1960. The measurements of methane, N_2O and other greenhouse gases have started even later than 1960, thus it is pure speculation to say how, much warming was caused by man and nature. My estimate is that the greenhouse gases (GWG) have caused 0.1 deg. C warming until the year 1960 (Figure 3.2.3) and 0.97 deg. C warming from the year 1960 to 2014.

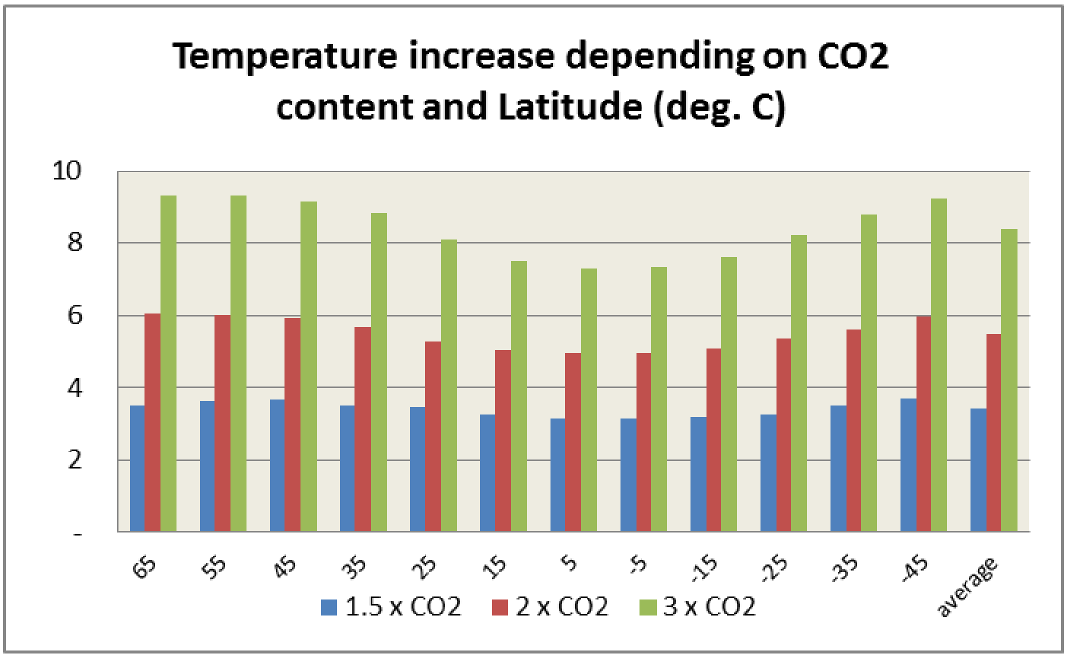


Figure 7.2.1 Increase of global temperature depending on Latitude and multiples of CO_2-concentration (Source Arrhenius).

Arrhenius law of radiative force ΔF is proportional to natural logarithm of CO_2 concentration:

$$\Delta F = \alpha \ln (C/C_0)$$

Additionally, the temperature increase ΔT is directly proportional to radiative force ΔF. If we assume that the concentration was about 316.9 ppm in the year 1960 and 398.6 ppm in the year 2014, the ratio of concentrations is 1.258.

If the sunspot and sulfur corrected temperature has increased by 0.97 deg. C from the year 1960 (Figure 3.2.3), then 72 % or 0.714 deg. C of the increase has been caused by CO_2 (Table 6.1.1). Then we could find the coefficient **α** (alpha) = 3.11. Then the law of global warming by CO_2 is following:

$$(7.2) \quad \Delta T = 3.11 \ln (C/316.9)$$

The concentration can increase to 600 ppm temperature will increase with 2 deg. C (Figure 7.2.2). 820 ppm concentration will mean the temperature rise of 3 deg. C. Because the warming by GHG has caused already small change before 1960, the total warming is somewhat larger.

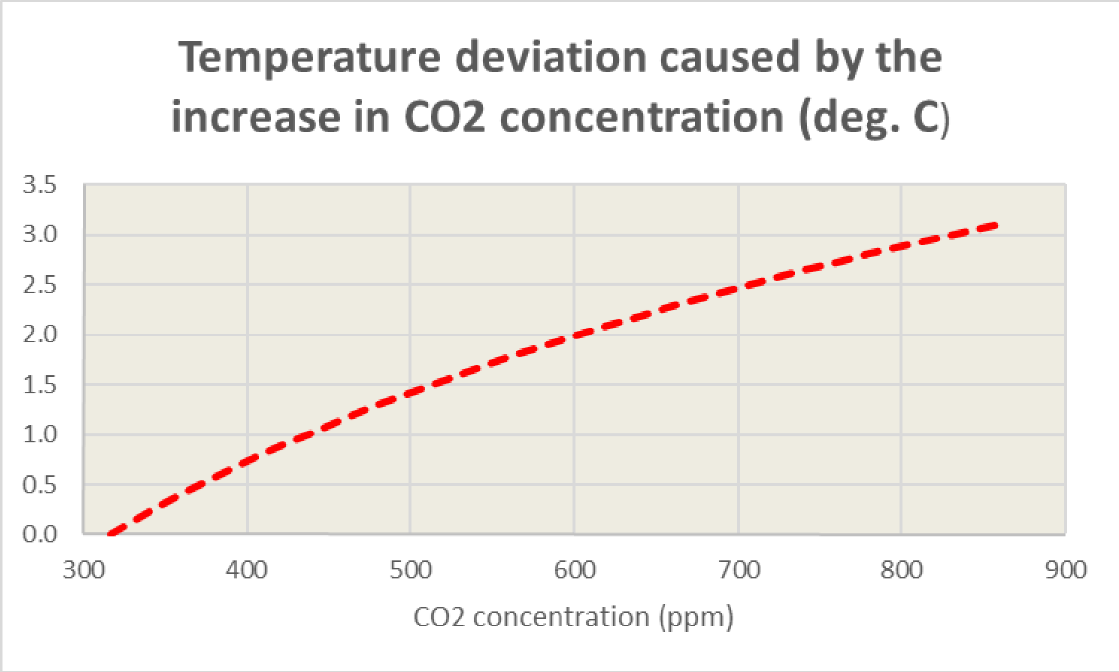


Figure 7.2.2 Formula of global warming (3.11 x ln(C/316.9)) depending on the CO_2-concentration.

By using the formula for CO_2 concentration temperatures rise will reach 2.0 deg. C by 2100 at constant emission rate of 35 Gt per year (Figure 7.2.3). If reductions will be 1 % annually, the 2 deg. C limit will be reached by 2150. With 3 % annual reductions the temperature increase will remain below 1.5 deg. C. until the year 2200.

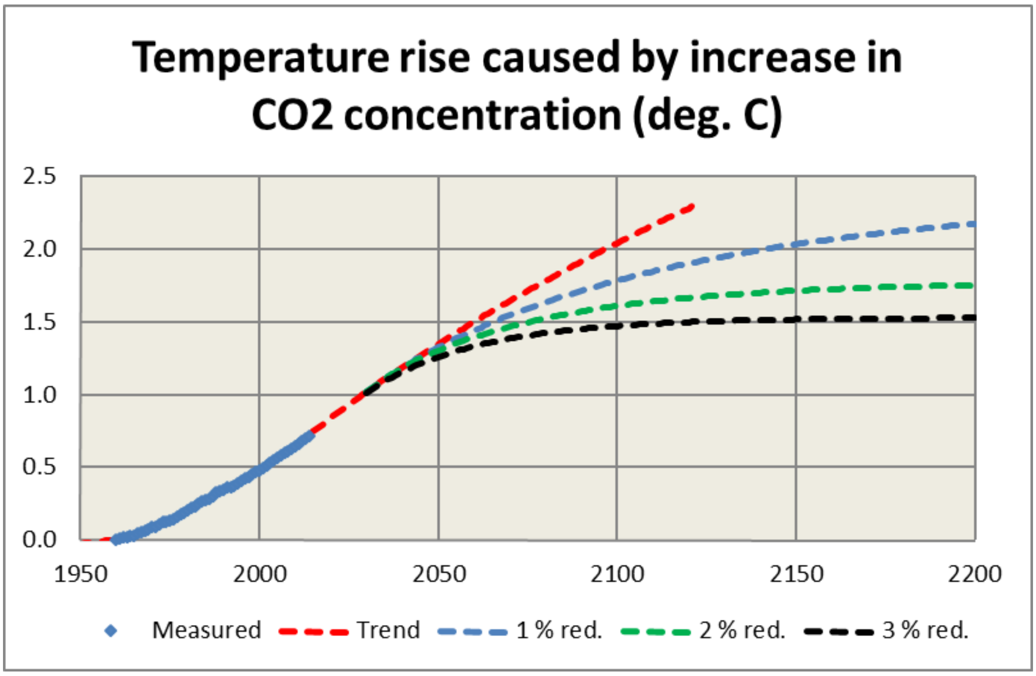


Figure 7.2.3 Global temperature rise caused by CO_2 emissions.

Conclusion:

The global temperature rise after the year 1960 caused by CO_2 can be limited to less than 1.5 – 1.8 deg. C, if CO_2 emissions will be limited by 2 – 3 % annually starting from the year 2030.

7.3 Influence of methane on global temperature

Methane concentration has been growing from 1.2 ppm in the year 1960 to 1.8 ppm in the year 2014. If the sunspot and sulfur dioxide corrected global temperature has risen by 0.97 deg. C since 1960 and 7 % of the increase has been caused by methane, then methane has caused 0.041 deg. C ((1.8-1.2) x .07 x 0.97) warming since 1960.

The future warming caused by methane will probably continue with the present trend since the year 2200 and the warming will be 0.064 deg. C until the year 2100 and 0.088 deg. C until the year 2200.

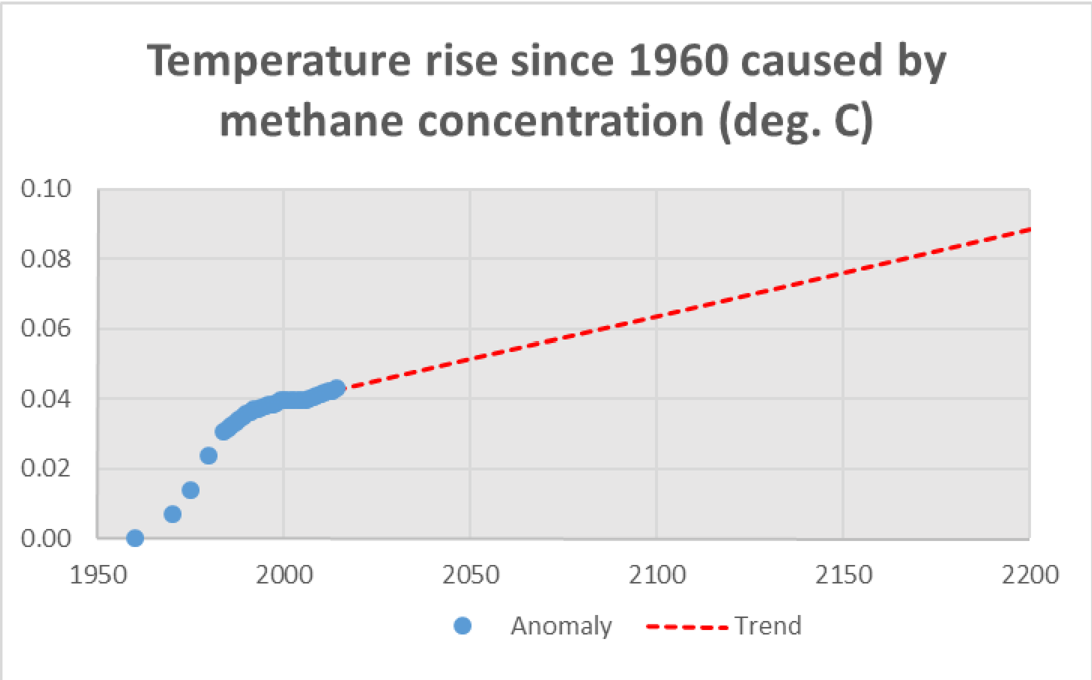


Figure 7.3.1 Warming caused by methane in the atmosphere.

7.4 Influence of N_2O on global temperature

Influence of nitrogen oxide (N_2O) has been about 7 % on the temperature increase of 0.97 deg. C since the year 1960. Then the influence of N_2O has been 0.042 deg. C on the global temperature, which is the same as the influence of methane (7.3).

N_2O concentration in the atmosphere has been rising with linear trend since 1960 and thus the anomaly caused by N_2O is also rising with linear trend. However, after the year 2050 the concentration is following the population growth and will slow down. Warming caused by N_2O will be 0.15 degrees until the year 2100 and 0.16 deg. C until 2200 (Figure 7.4.1).

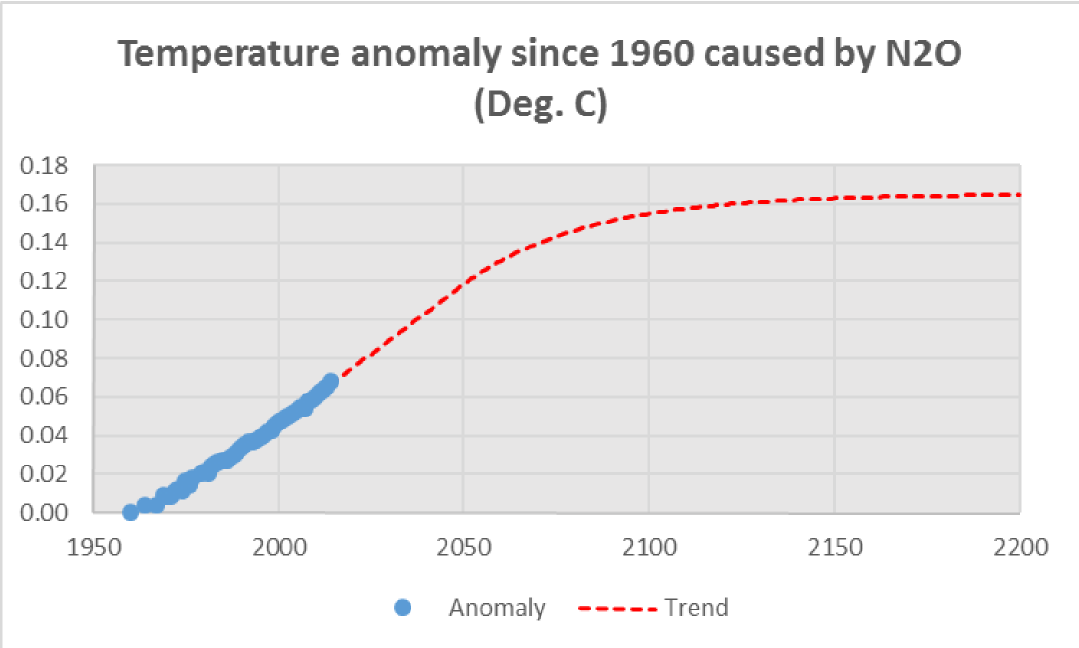


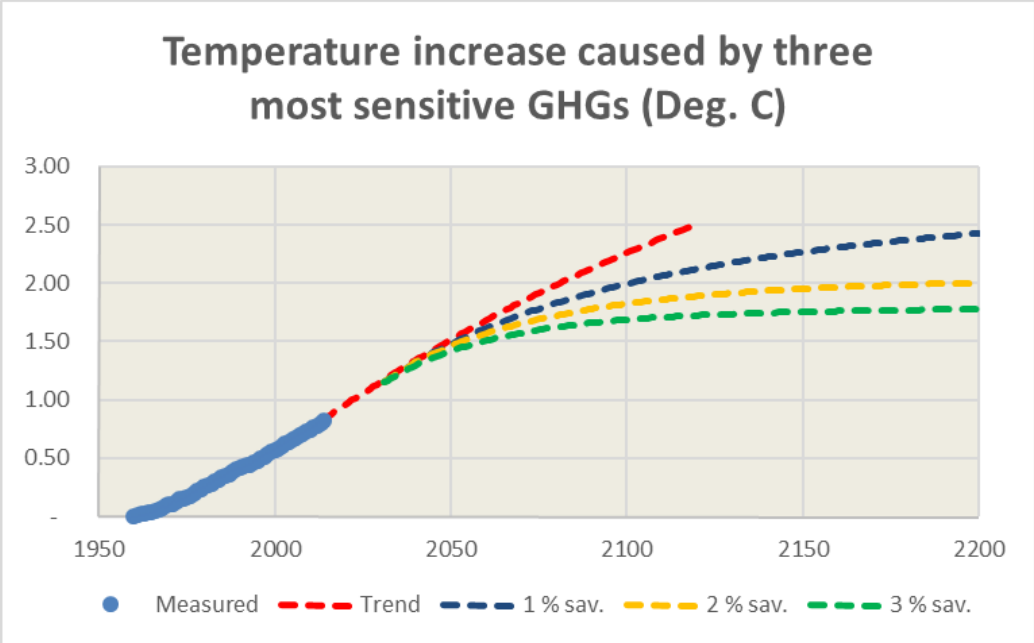
Figure 7.4.1 Warming caused by N_2O since 1960.

7.5 Influence of the other GHG

There are about 17 other greenhouse gases which have totally about 14 % influence of all greenhouse gases (Table 7.1.1). Thus they have influenced 14 % or 0.136 deg. C from the total increase of 0.97 deg. C of the global temperature since 1960.

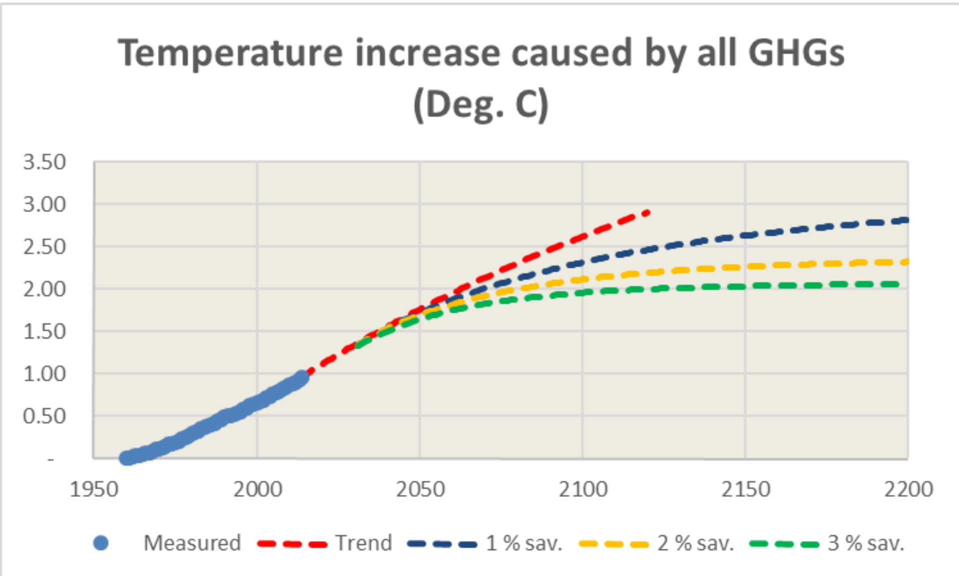
There are gases as CFCs which will decrease and other gases which will increase in concentration in the future. Their contribution on global warming can be evaluated assuming that they will continue to have this 14 % influence on global warming in the future.

By summing up the warming caused by CO_2, methane and N_2O we can make a prediction until the year 2200 has been evaluated in Figure 7.5.1 without the other greenhouse gases.



7.5.1 Temperature increase from the year 1960 caused by three most sensitive greenhouse gases (CO_2, methane and N_2O).

If we add the 14 % influence of other 17 greenhouse gases assuming that they will increase temperature rise by factor 1.16 (1/0.86), the influence of all 20 greenhouse gases is given in Figure 7.5 2. We can then find that in the year 2200 the temperature will be 2 deg. C warmer than in the year 1960, if CO_2 reductions will be 3 % in the year starting from 2030.



7.5.2 Temperature increase from the year 1960 caused by all greenhouse gases.

7.6 Influence of SO_2 on temperature

Finally, we have evaluated the influence of sulfur oxide on global temperature using four scenarios. If the emissions stay at present level, they will cause temperature decrease by 0.1 deg. C compared to year 1960. If SO_2 emissions will be saved by 1 % annually, temperature will rise with 0.1 deg. C until the year 2100 and 0.22 until the year 2200. With 3 % saving the rise would be 2.5 deg. C until 2100 and 0.3 deg. C until 2200.

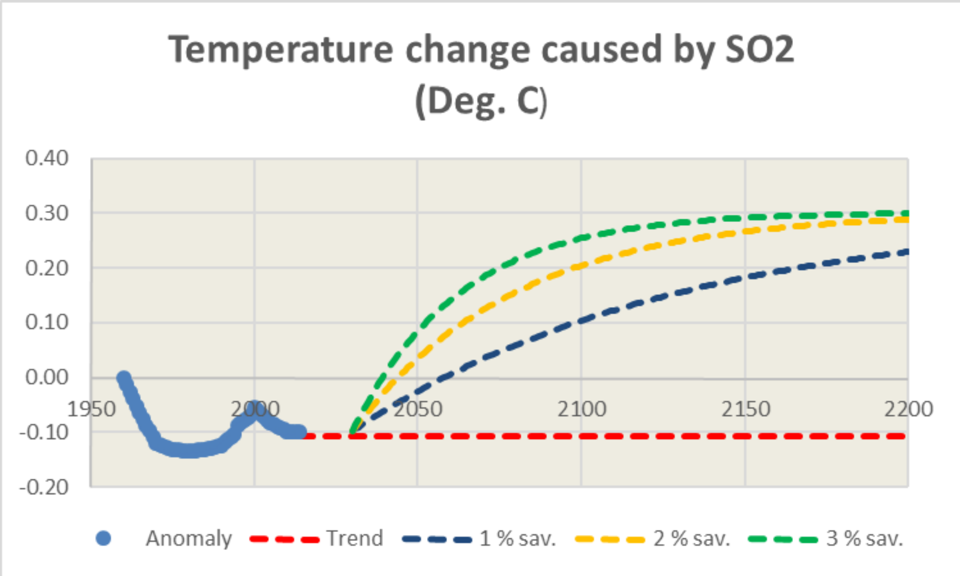


Figure 7.6.1 Influence of SO_2 on global temperature.

7.7 Anthropogenic warming until the year 2200

If we add the influence of greenhouse gases (Figure 7.5.1) and SO_2 (Figure 7.6.1) together, we will get the estimate for the global warming until the year 2200 (Figure 7.7.1). The warming until years 2070, 2100 and 2200 are given in Table 7.7.1.

Table 7.7.1 Warming caused by man's actions.

Year	Trend	1% Saving	2% Saving	3% Saving
2070	2.03	2.04	2.04	2.01
2100	2.52	2.42	2.32	2.21
2200		3.04	2.61	2.36

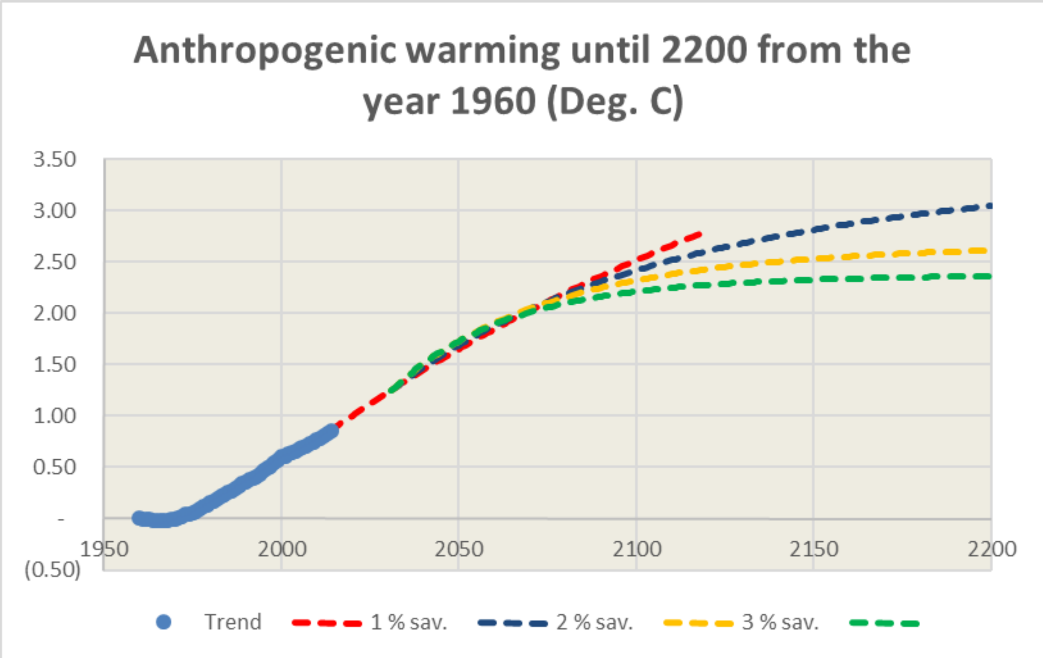


Figure 7.7.1 Anthropogenic warming (warming caused by man) until the year 2200.

We can find that 2 deg. C warming will happen by the year 2070 from the year 1960. The saving in SO_2 emissions will add warming at the same time when CO_2 emissions are reduced. These action will compensate each other. Thus there is no big difference in these four scenarios until then.

In the year 2100 warming will be 2.2 – 2.4 deg. C as compared with level in the year 1960 depending on the saving scenarios. Then we should add about 0.1 – 0.2 deg. C, which is the anthropogenic warming until the year 1960. By the year 2200 warming will be 2.4 – 3.0 deg. C or 2.5 – 3.2 deg. C, if the reference point is the year 1900.

Conclusions:

We should be prepared for 2.3 – 2.6 deg. C global warming until the year 2100 from the year 1900. The global warming will be 1.3 – 1.6 degrees after the year 2014, when the warming of 1.0 deg. C is the reality.

8 ELECTRICITY GENERATION

8.1 Electricity consumption

Population will be growing from 7.1 billion in 2015 to 10.5 billion by the year 2100 Figure 8.1.1). The fastest growth will happen in Africa and India, where the population will reach 2000 million. At the same time electricity consumption will grow from 24000 TWh in 2015 to 66 000 TWh in 2100 (Figure 8.1.2).

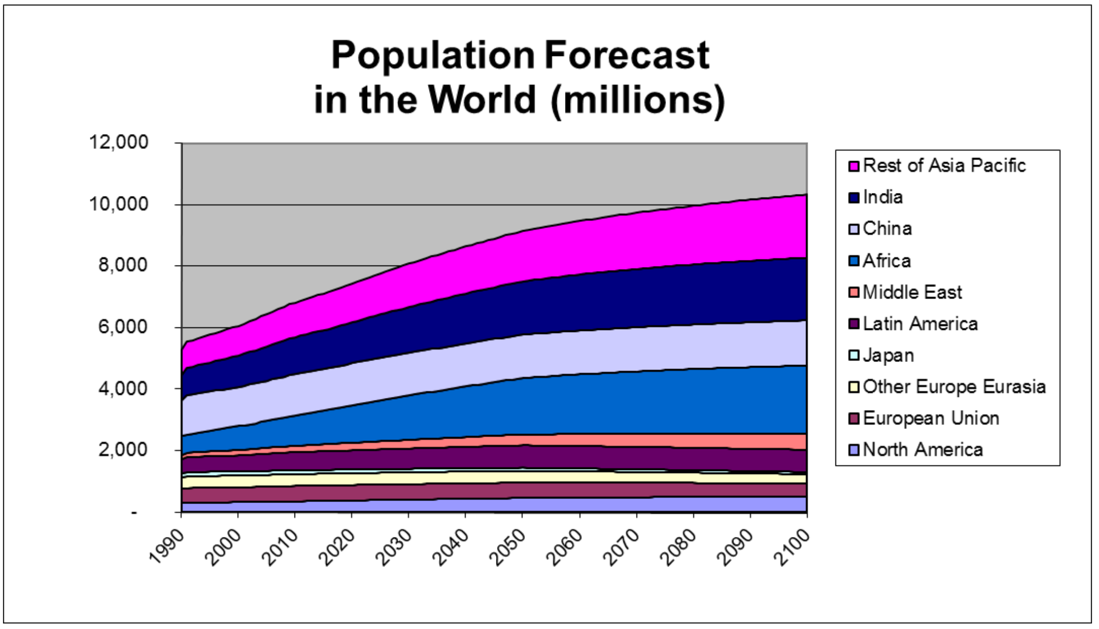


Figure 8.1.1 Population growth in the world.

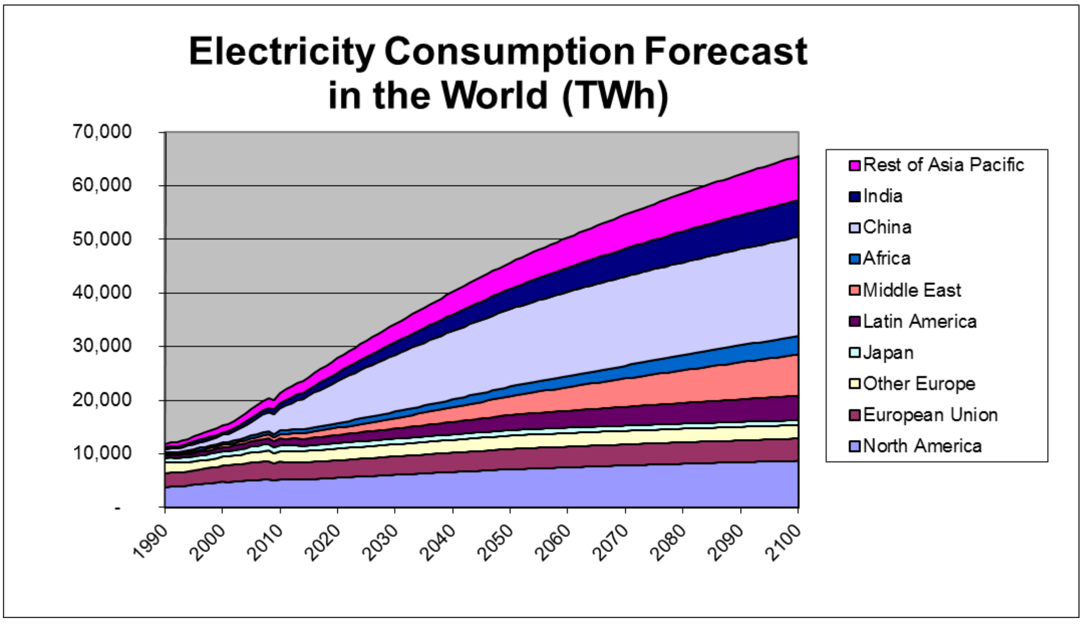


Figure 8.1.2 Electricity consumption will grow in the world.

The specific electricity consumption will grow from 3400 kWh/capita to about 6200 kWh/capita by the year 2100 (Figure 8.1.3). The highest specific consumption will be in 2100 in North America, the Middle East, China and Japan, which will achieve 12000 kWh per capita. Africa, India and the rest of Asia Pacific will remain below 4000 kWh/capita.

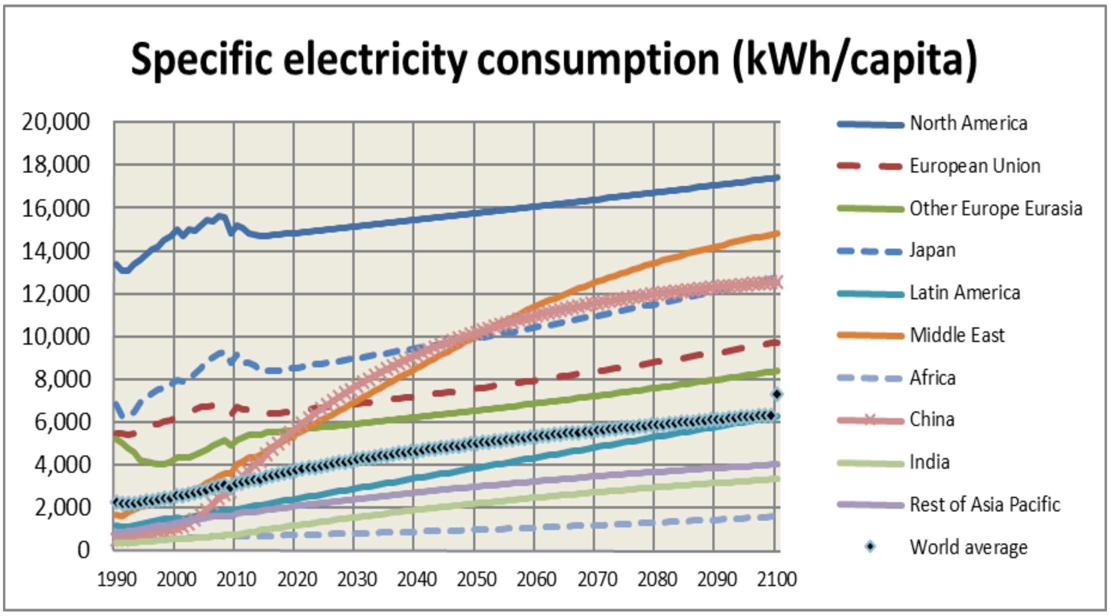


Figure 8.1.3 Specific electricity consumption.

8.2 Generation sources

The planning of the electricity generation for the year 2100 has been made so that normal electricity generation by fossil fuels should end by the year 2100. Coal fired generation should end by the year 2080. Oil and gas fired generation will decrease to 3 % by the year 2100 (Figure 8.2.1). It will be needed for balance control of power systems.

Renewable electricity sources will increase from 22 % in 2015 to 50 % by the year 2050 and to 82 % by the year 2100. The nuclear share of electricity generation will increase from 11 % in 2015 to 15 % in 2100. Thus the share of CO_2 free electricity will increase from 33 % in 2015 to 97 % by 2100.

Electricity generation by using fossil fuels will peak at 2035, when they will generate about 19 000 TWh of electricity or 53 % of all. Coal fired generation will increase until 2025, when China will generate about 50 % of the coal electricity of all (Figure 8.2.2). Oil and gas generation will increase until the year 2050 and North America and Rest of Asia Pacific will be the largest uses of oil and gas in the power generation (Figure 8.2.3).

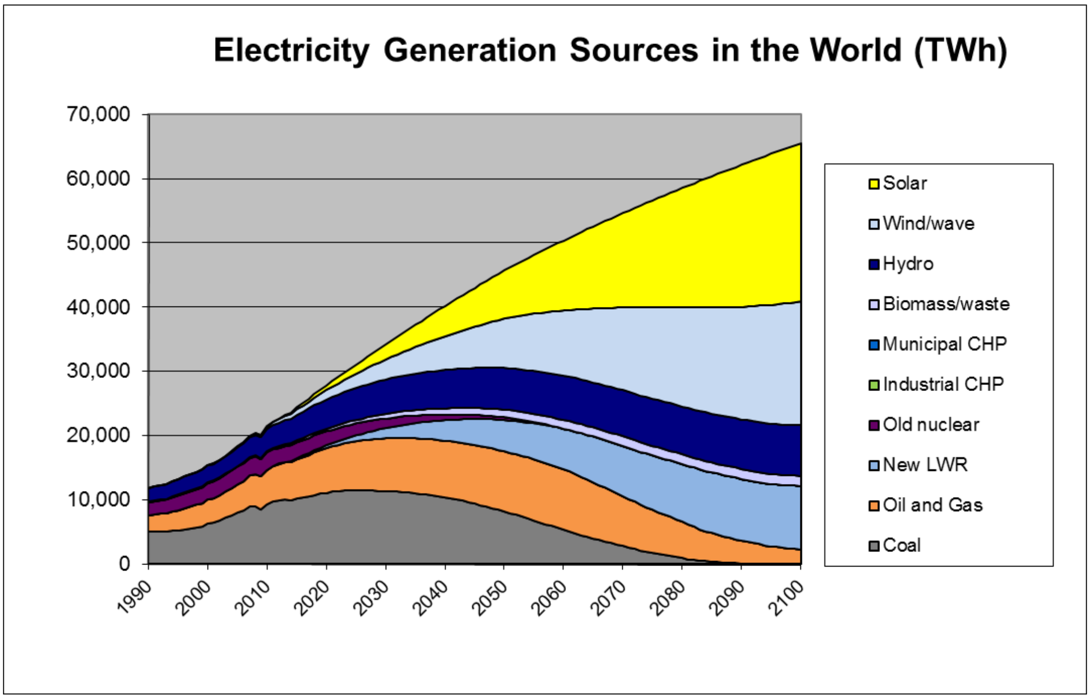


Figure 8.2.1 Electricity generation sources by 2100.

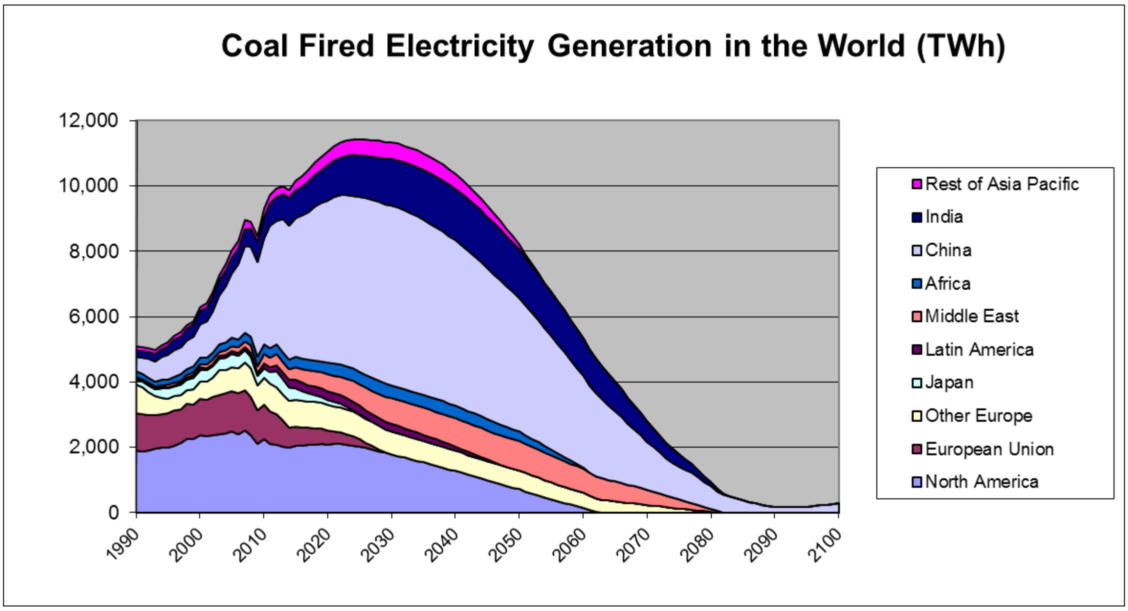


Figure 8.2.2 Coal fired generation will peak at 2025.

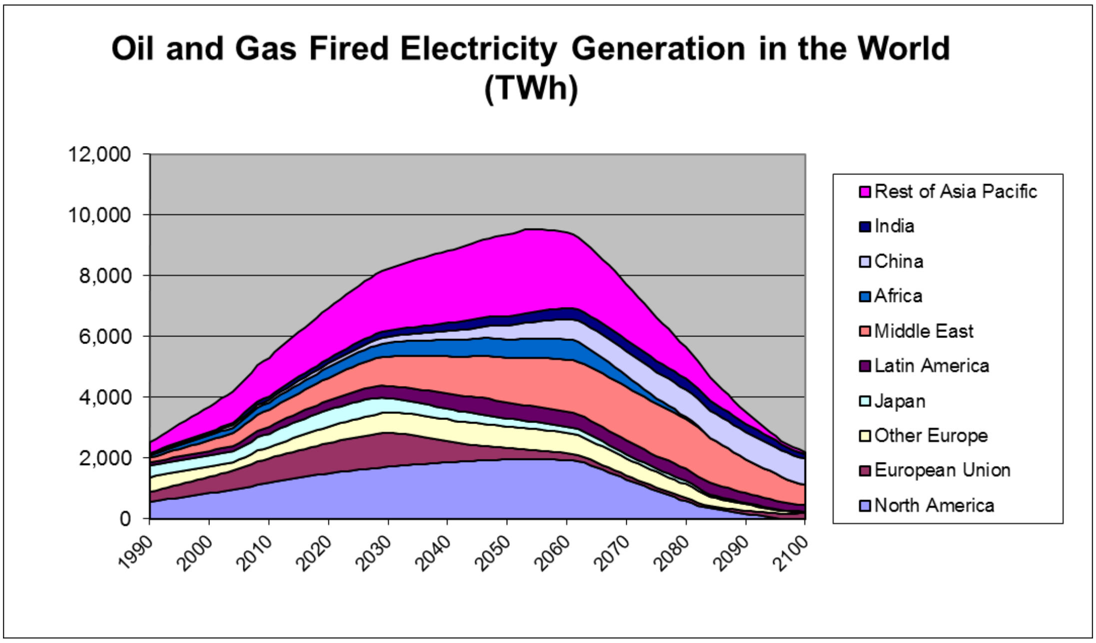


Figure 8.2.3 Electricity generation with oil and gas (TWh).

Nuclear power will remain as one of the main sources of electricity generation because USA and China will remain in the nuclear power market. While the electricity generation by nuclear plants will be stable until the year 2025, after this the new nuclear plants will increase the output, which will peak in the year 2100 at 10000 TWh (Figure 8.2.4).

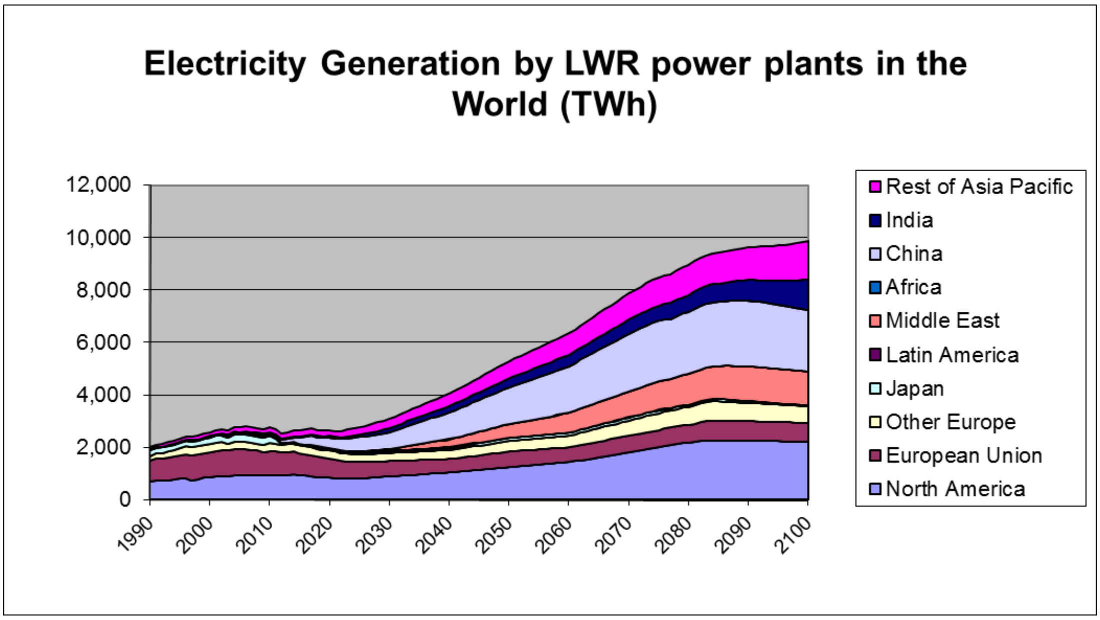


Figure 8.2.4 Electricity generation by nuclear Light Water Reactor (LWR) plants.

The largest increases will happen in solar and wind power generation. Wind and wave powered electricity will lead renewable generation until 2050 (Figure 8.2.5). But after the year 2050 solar will overtake wind and wave generation. Solar power will be the largest source of the generation by 2050 (Figure 8.2.6). Solar electricity generation will increase to 25 000 TWh by 21000 or the same as total electricity generation in 2015. This will be 38 % of the total 65 000 TWh electricity consumption.

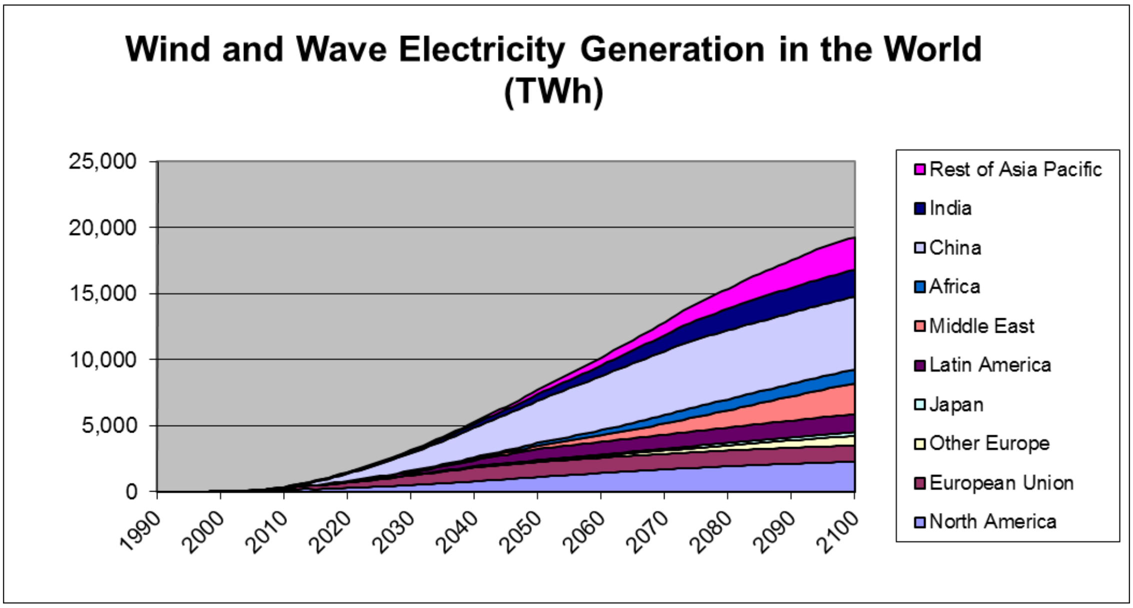


Figure 8.2.5 Wind and wave power generation in the world.

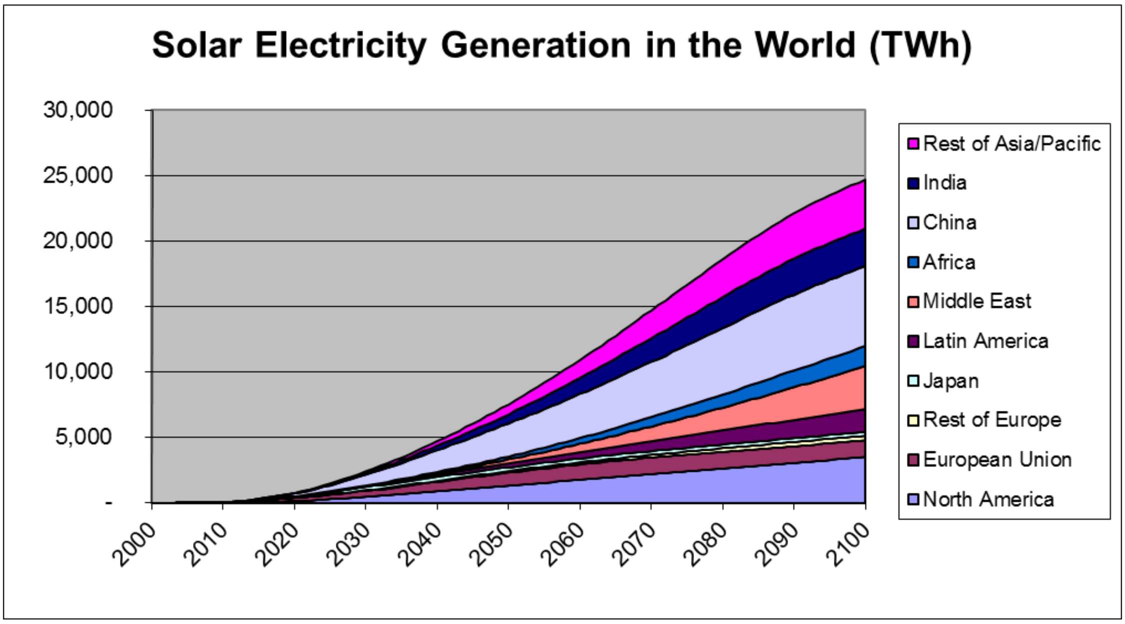


Figure 8.2.6 Solar power generation in the world.

Also hydro and biomass power plants will increase electricity generation considerably. Hydro generation will double, because of large increases in China and Africa (Figure 8.2.7). Electricity generation using biomass will increase to 1600 TWh by 2100 (Figure 8.2.8).

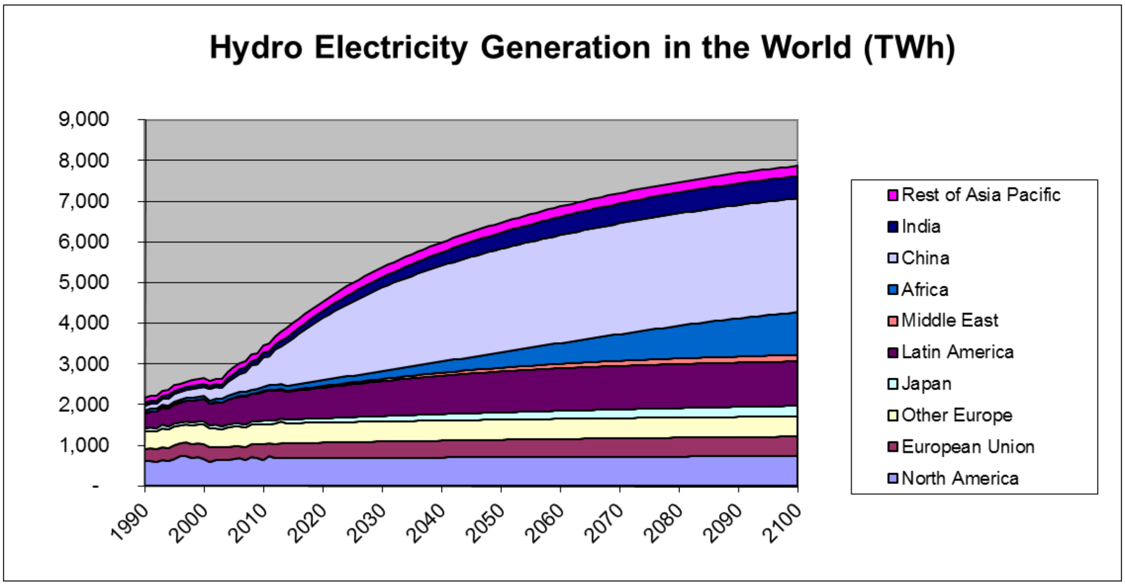


Figure 8.2.7 Hydro electricity generation.

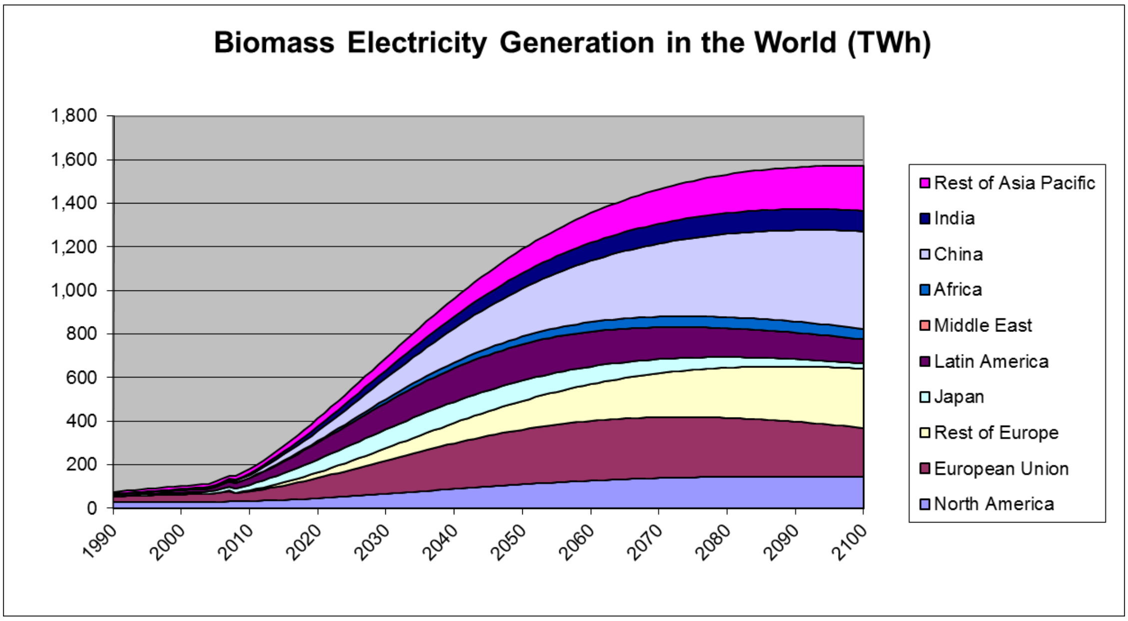


Figure 8.2.8 Biomass electricity generation.

8.3 Electricity generation by countries

Same kind of changes will happen in each part of the world. European Union will be leading the change, where renewable sources in electricity generation will increase from 27 % in 2015 to 74 % in 2050 (Figure 8.3.1). North America will follow EU with about 30 year lagging and the renewable share will rise there from 17 % in 2015 to 45 % in 2050 (Figure 8.3.2).

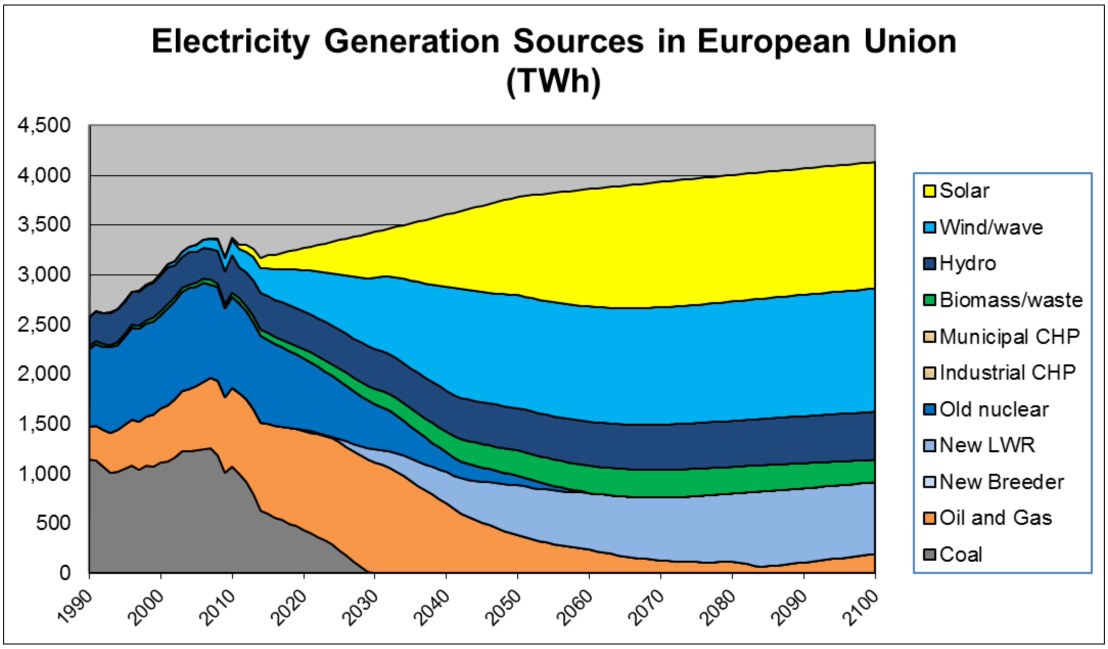


Figure 8.3.1 Electricity generation sources in European Union.

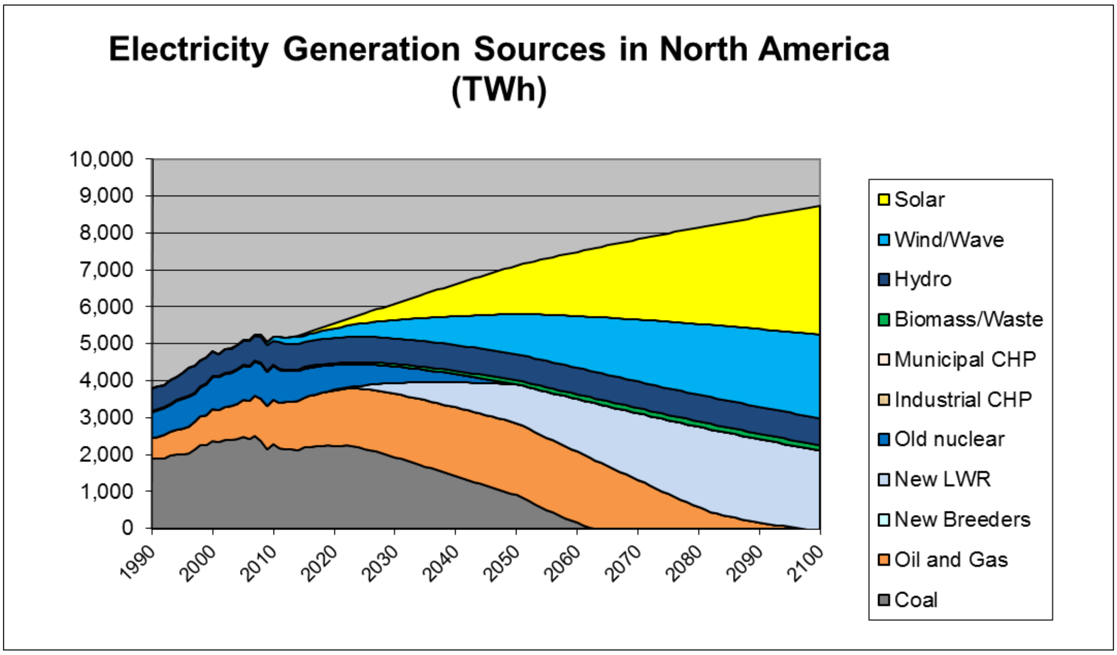


Figure 8.3.2 Electricity generation sources in North America.

The biggest growth will happen in China where the electricity consumption will grow from 6100 TWh in 2015 to 18 000 TWh in 2100 (Figure 8.3.3). Renewable sources will take 59 % of electricity generation in 2050. However, fossil fired plants will generate still 18 % of electricity in the year 2050.

India will be following China but its electricity consumption will grow from 1200 TWh in 2015 to 6800 TWh in 2100 of relatively faster than in China (Figure 8.3.4). However, the renewable share will increase from 17 % in 2015 to 45 % in 2050.

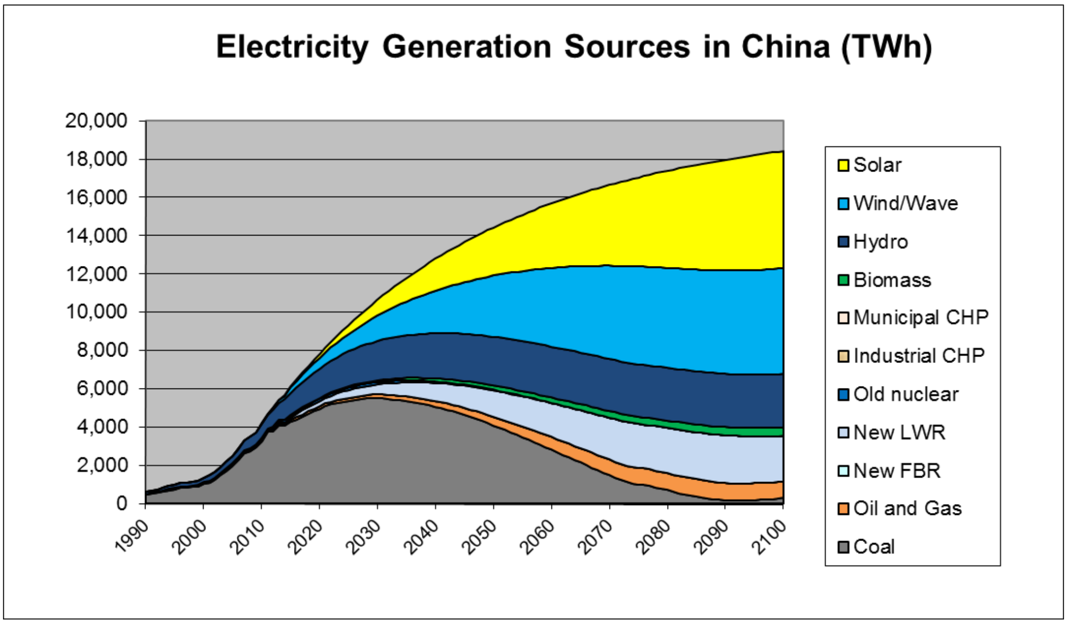


Figure 8.3.3 Electricity generation sources in China.

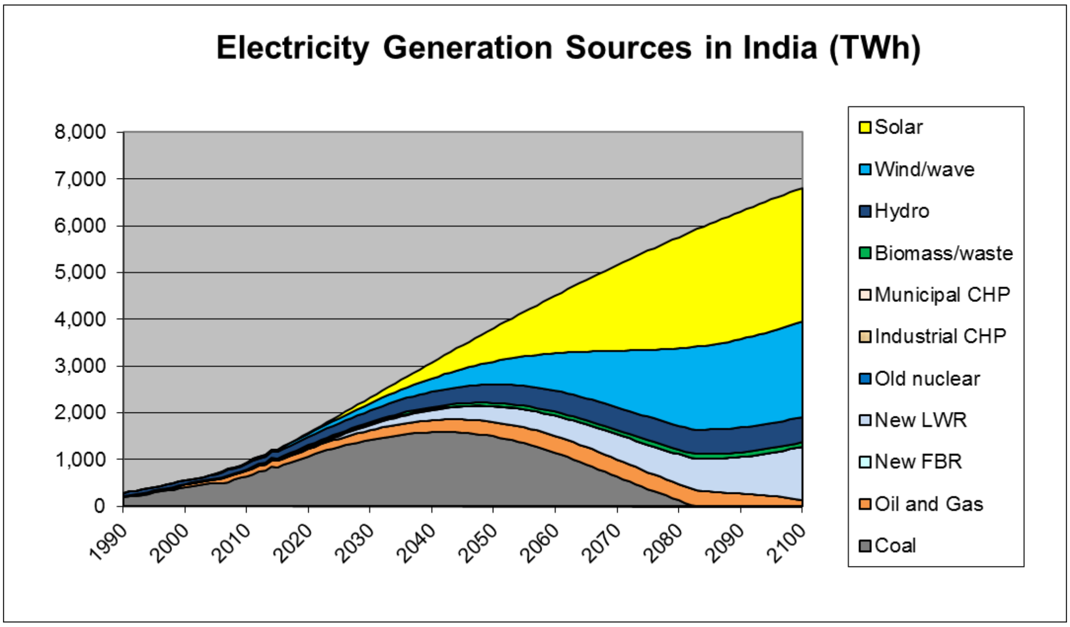


Figure 8.3.4 Electricity generation sources in India.

Large changes can also happen in Africa, which can change to 100 % renewable electricity sources by the year 2080 (Figure 8.3.5). There is a lot of sunshine and only small part of Sahara could generate enough electricity to power the whole world.

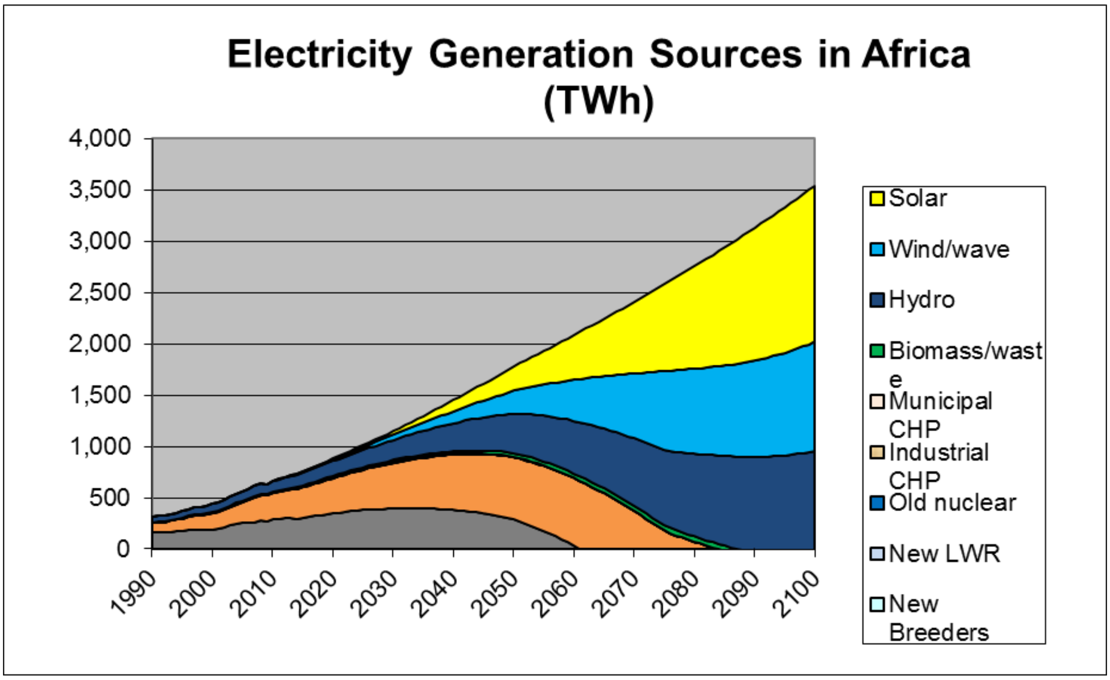


Figure 8.3.5 Electricity generation sources in Africa.

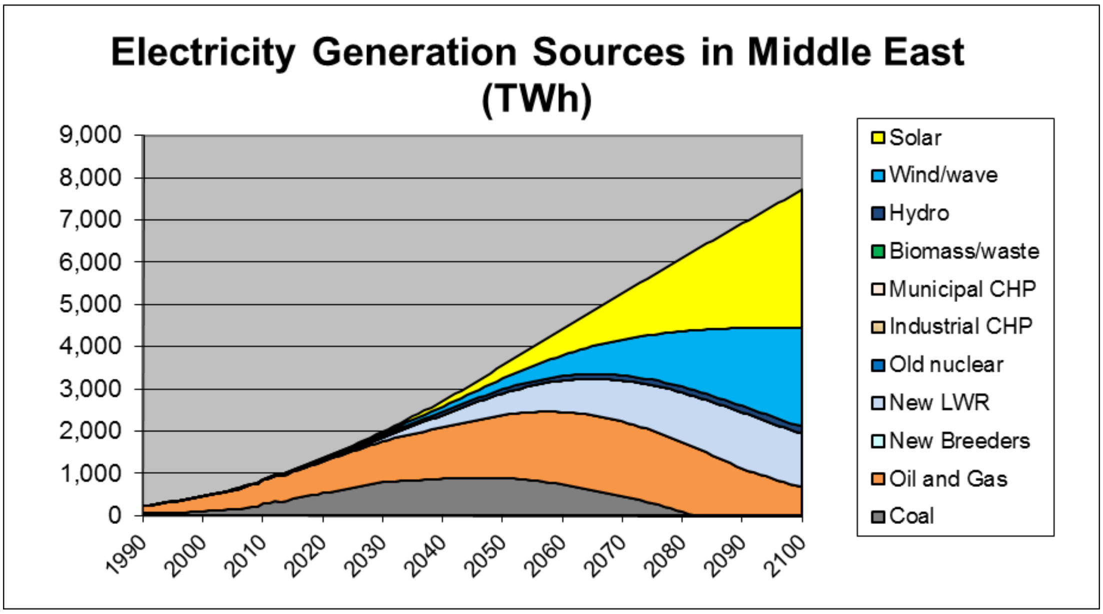


Figure 8.3.6 Electricity generation sources in the Middle East.

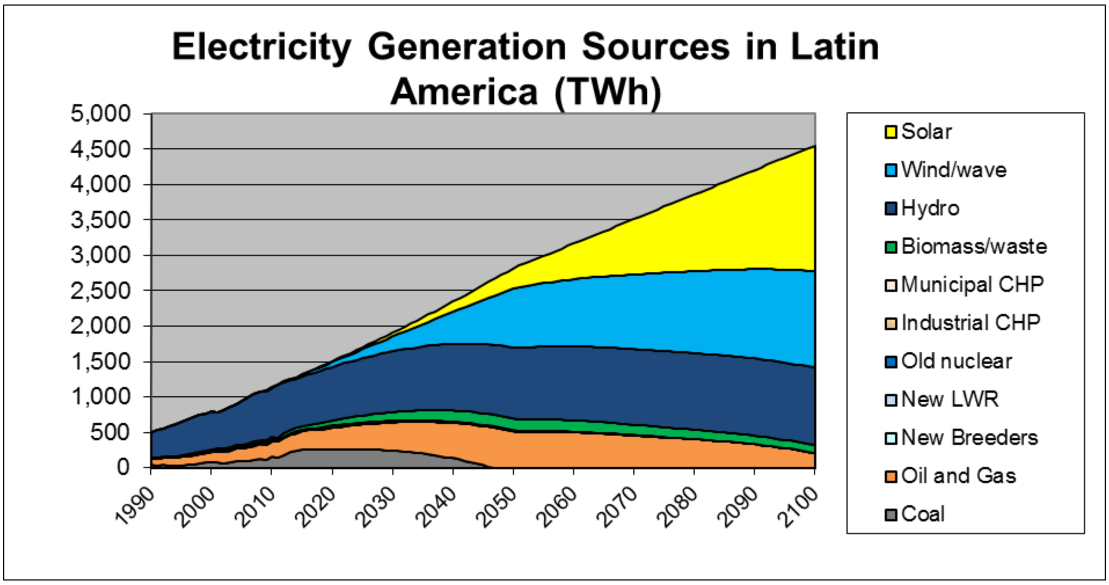


Figure 8.3.7 Electricity generation sources in Latin America.

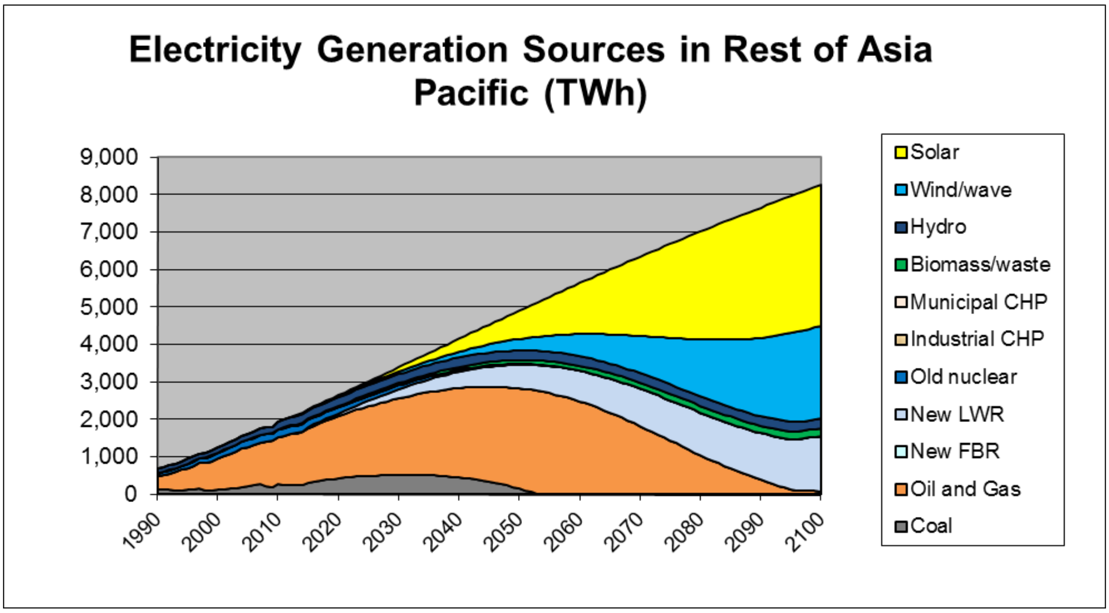


Figure 8.3.8 Electricity generation sources in the Rest of Asia Pacific.

8.4 CO_2 emissions caused by electricity

The CO_2 emissions of power plants can be evaluated using specific CO_2 coefficients for each fuel (Figure 8.4.1). Coal plants start from 950 g/kWh and end with 800 g/kWh in 2100. Oil and gas plants start from 550 g/kWh in 1990 and end with 420 g/kWh in 2100.

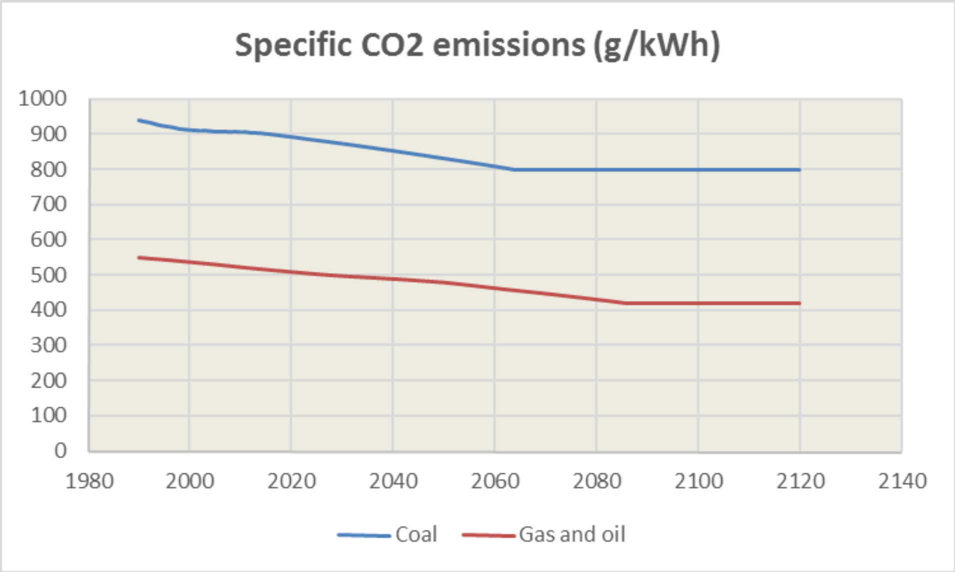


Figure 8.4.1 Specific CO_2 emissions of power plants.

CO_2 emissions of electricity generation will peak at 14 Gt in the year 2030 (Figure 8.4.2). The largest emissions have been in China and North America. The emissions will decrease to about 1 Gt per year by 2100. This will be about 80 % less than the emissions in the year 1990.

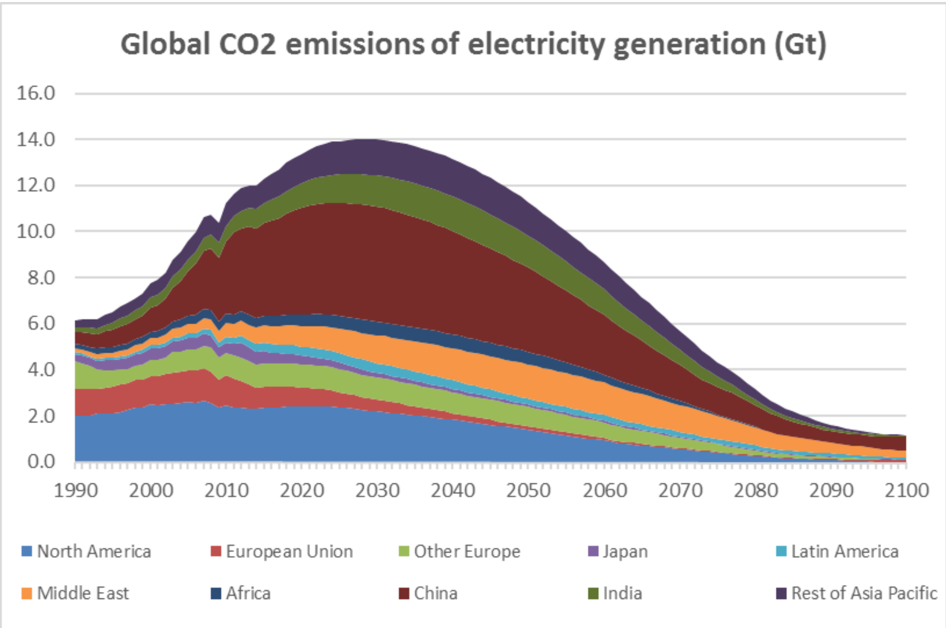


Figure 8.3.2 Global CO_2 emissions of electricity generation by countries.

The specific CO_2 emissions of electricity generation will drop continuously from 500 g/kWh in 2015 to about 20 g/kWh in 2100 (Figure 8.3.3). EU will lead the development and it will reduce emissions from 310 g/kWh in 2015 to 50 g/kWh in 2050 (Figure 8.3.4).

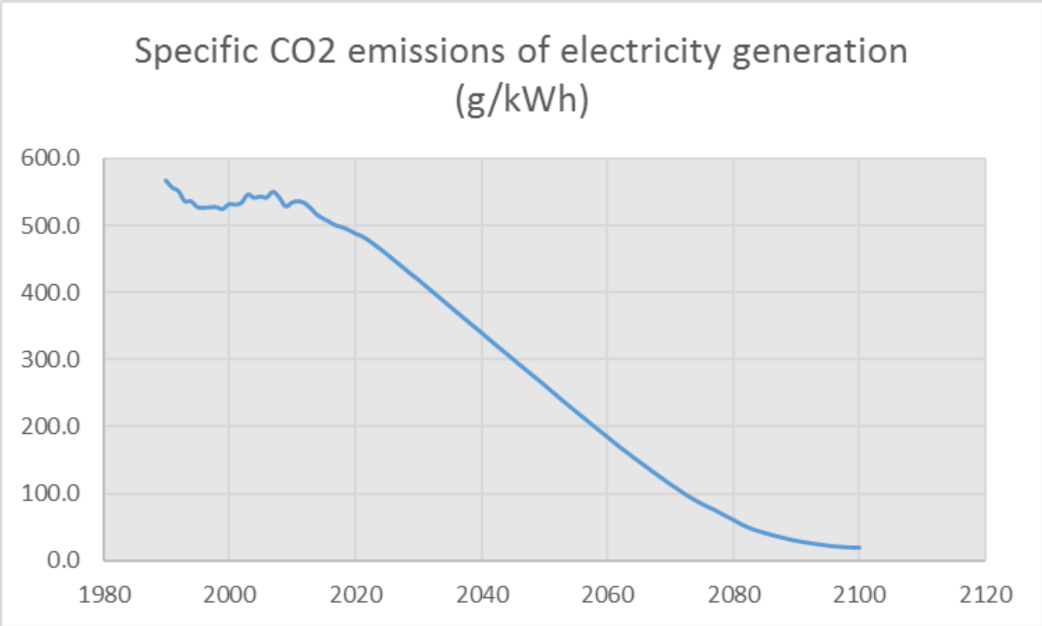


Figure 8.3.3 Specific CO2 emissions of electricity generation.

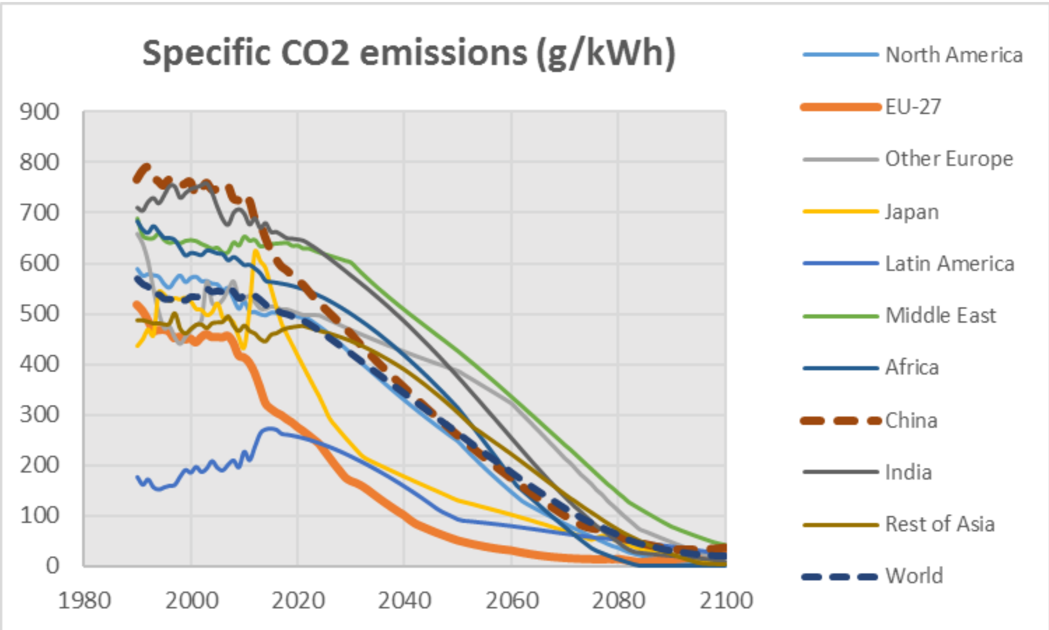


Figure 8.3.4 Specific CO2 emissions of electricity in countries.

The coal plants will cause major part of the CO_2 emissions (Figure 8.3.5). However, the coal plants can be decommissioned totally. The oil and gas plants will be needed to balance the power systems because of changes in generation of solar and wind power plants.

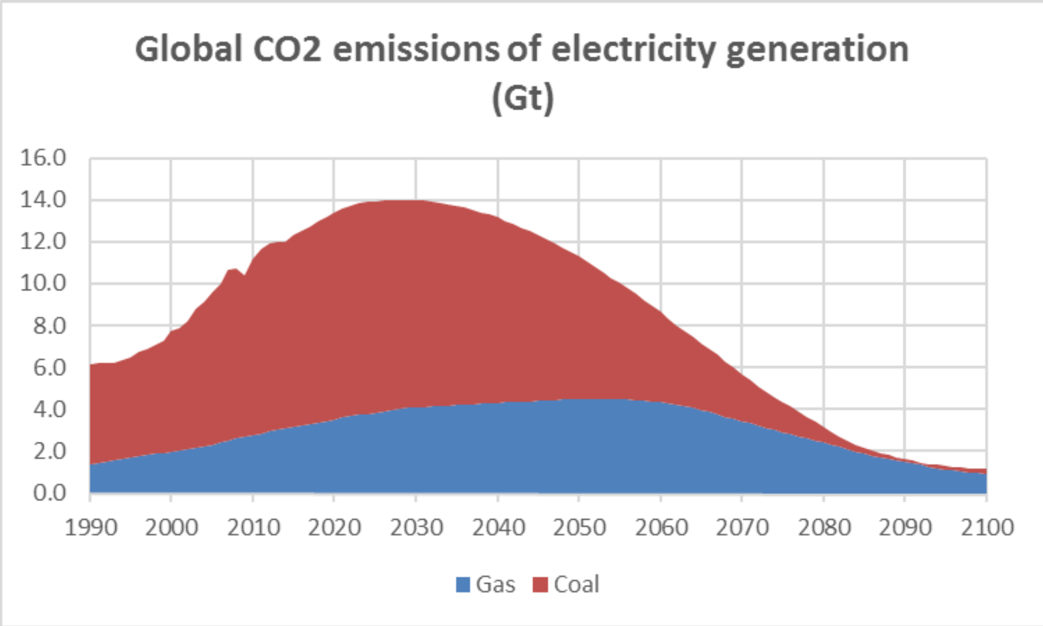


Figure 8.3.5 Global CO_2 emissions of electricity generation by fuels.

With these emissions the cumulative emissions from electricity generation sector will be 900 Gt in the year 2100 (Figure 8.3.6) and 200 Gt of these have already emitted. The maximum emissions will be 3000 Gt (Figure 4.3.2) and about 1500 Gt have already emitted. Thus 800 Gt has been left to other sectors after the year 2015.

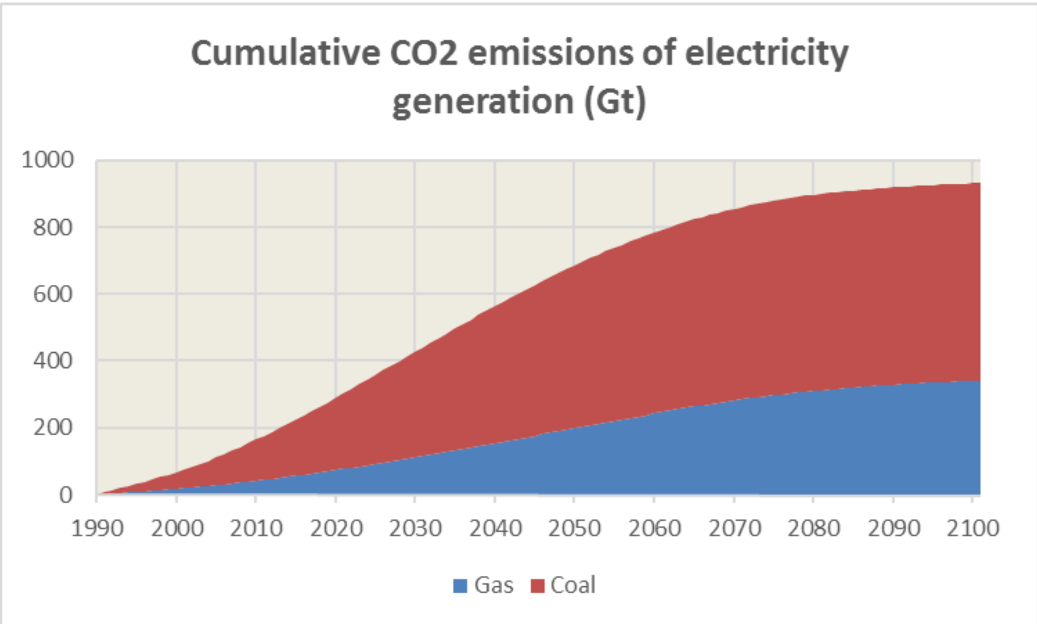


Figure 8.3.6 Cumulative CO_2 emissions of electricity generation by fuels.

The 3 % annual saving plan after 2030 was selected as a basic plan to limit warming to less than 2.5 deg. C (Figure 4.3.3). Then the cumulative CO_2 emissions should not exceed 3000 Gt by the year 2200. The emissions have been 690 Gt before 1990, thus 2310 Gt of emissions can be emitted after the year 1990.

The cumulative emissions of electricity generation will be 930 Gt after 1990 according to the above plan. The CO_2 emissions of the other sectors should be then less than 2310 Gt minus 930 Gt or 1480 Gt (Figure 8.3.7).

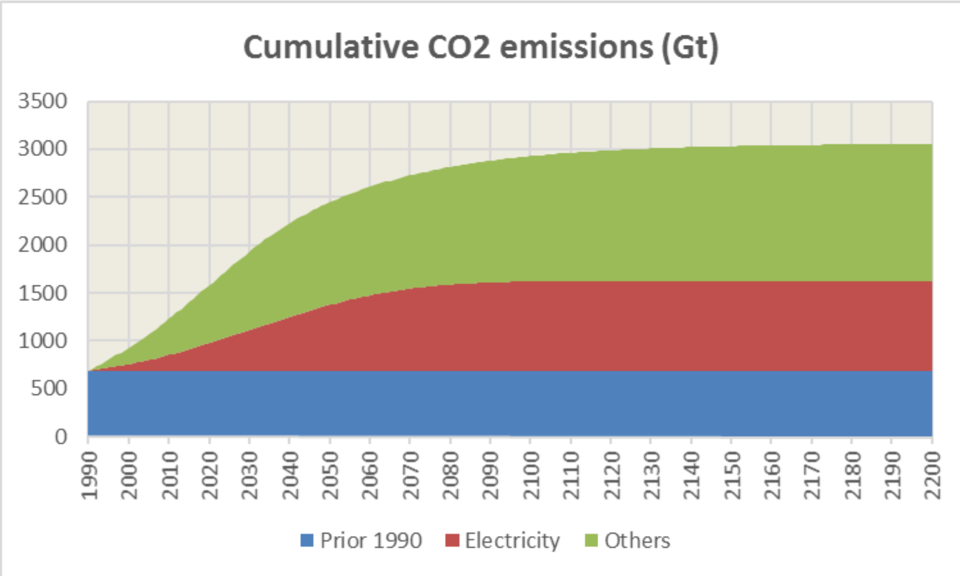


Figure 8.3.7 Maximum cumulative CO_2 emissions allowed to limit global warming to less than 2.5 deg. C.

9 OIL CONSUMPTION AND EMISSIONS

9.1 Oil consumption

After electricity another major form of energy is used as direct oil consumption. It is used for transportation with almost 100 % market share in cars, airplanes and ships. It is used also for heating of houses, industries and also small amount in fueling power plants.

The oil consumption can be grouped by products: light distillates, middle distillates and others. Light distillates are mainly used by cars, middle distillates by trucks and heavier distillates by ships and industries. The consumption of oil has been growing in light and middle distillate products (Figure 9.1.1).

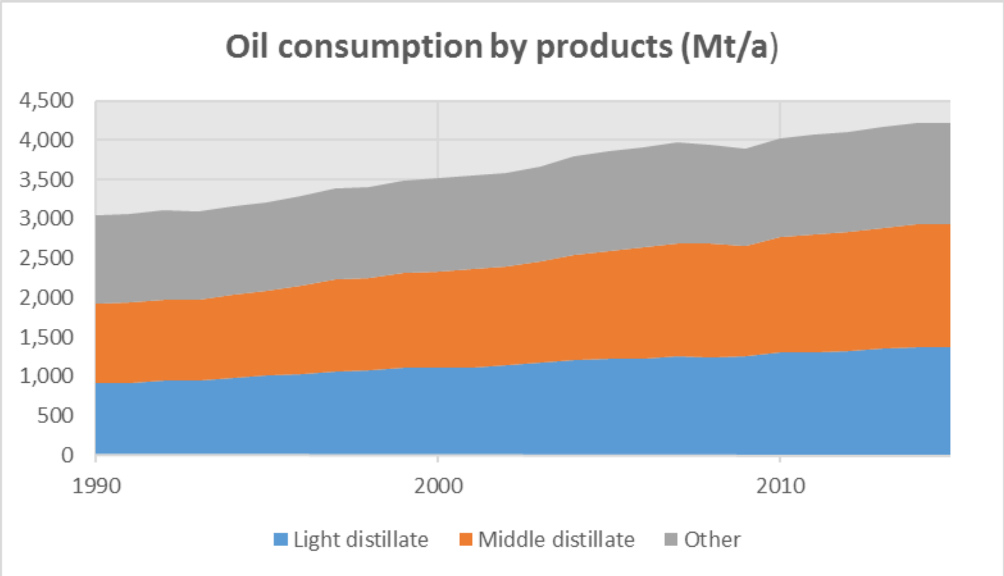


Figure 9.1.1 Oil consumption by products (Source BP)

The growth has happened mainly in light and middle distillates, which market shares have increased from 30 % and 33 % to 33 % and 37 % respectively (Table 9.1.1). However, other products as heavy fuel oil has diminished.

Table 9.1.1 Market shares of oil products.

Product	1990	2014
Light distillate	30%	33%
Middle distillate	33%	37%
Other	37%	30%

Oil consumption has been the largest in North America, which has consumed about 25 % of all oil in 2014 (Figure 9.1.2). However, the growth in oil consumption has been decreased in North America after 2008, but increased in China.

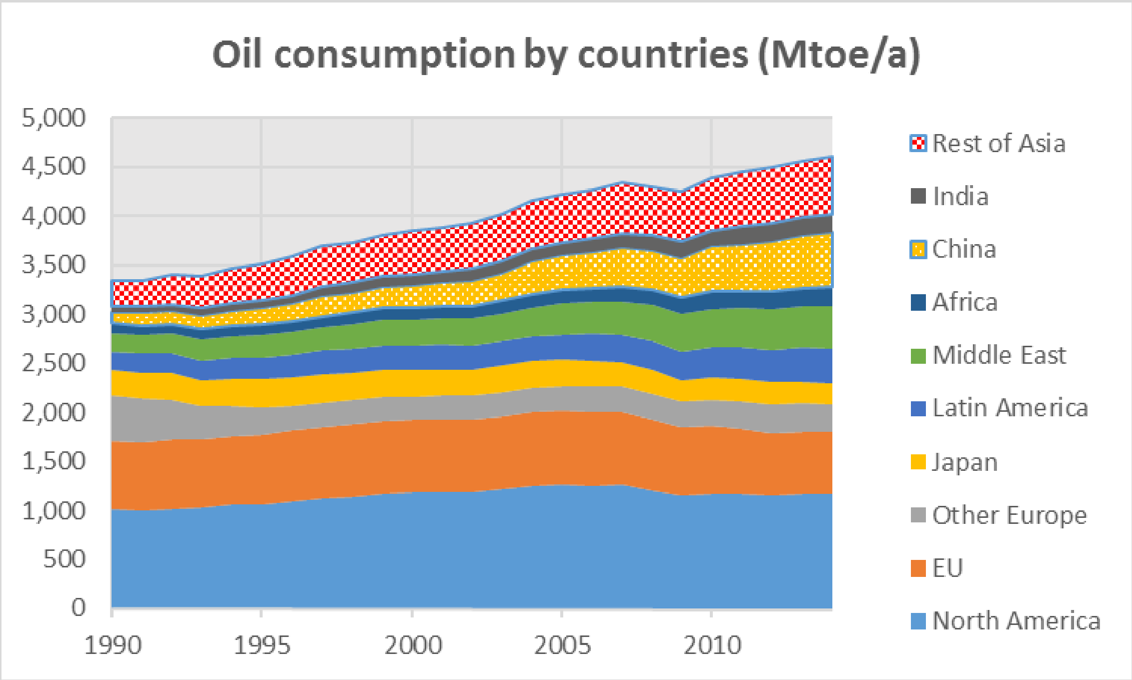


Figure 9.1.2 Oil consumption by countries (BP).

Oil consumption per capita figures have very big differences with North America leading at 3.3 toe/capita (Figure 9.1.3) and following by Middle East and Japan at 1.8 toe/capita levels. European Union is at level of 1.2 toe/capita.

Average consumption of oil in the world has been constant at 0.65 toe/capita (Figure 9.1.4). East Europe and Latin America are quite near the world average figures. China has 0.4 toe/capita oil consumption, but it has been increasing constantly from 0.1 toe/capita in the year 1990. The main reason is cars, which are now filling the roads in the biggest cities in China.

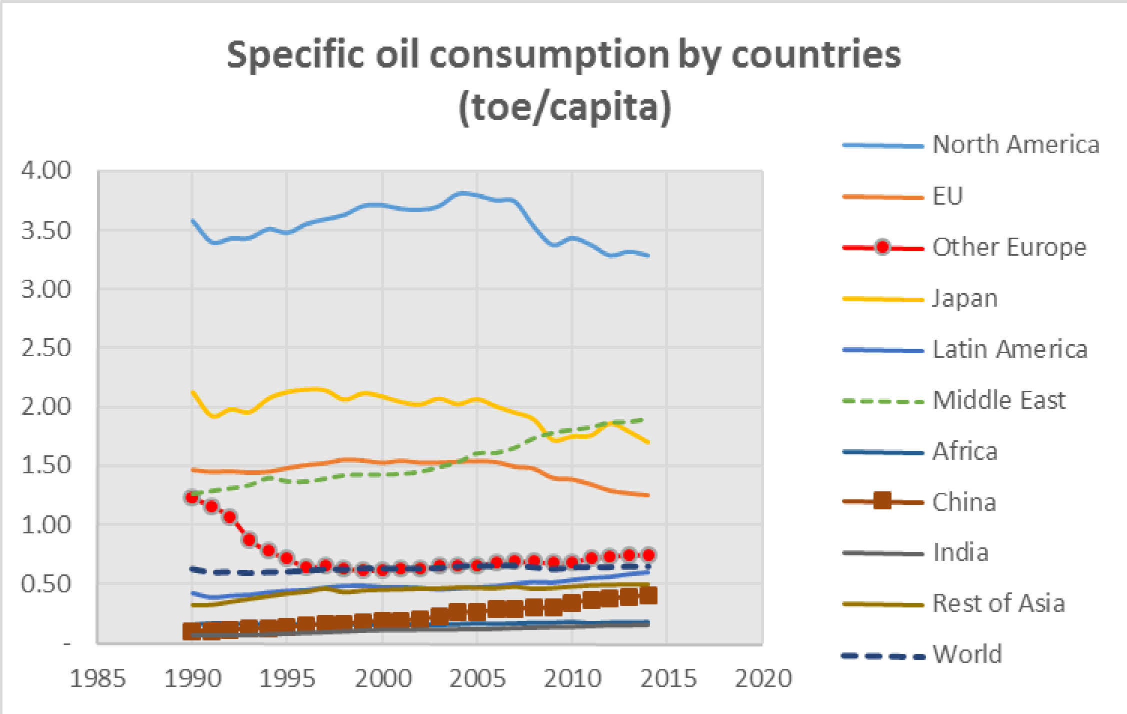


Figure 9.1.3 Specific consumption of oil (BP).

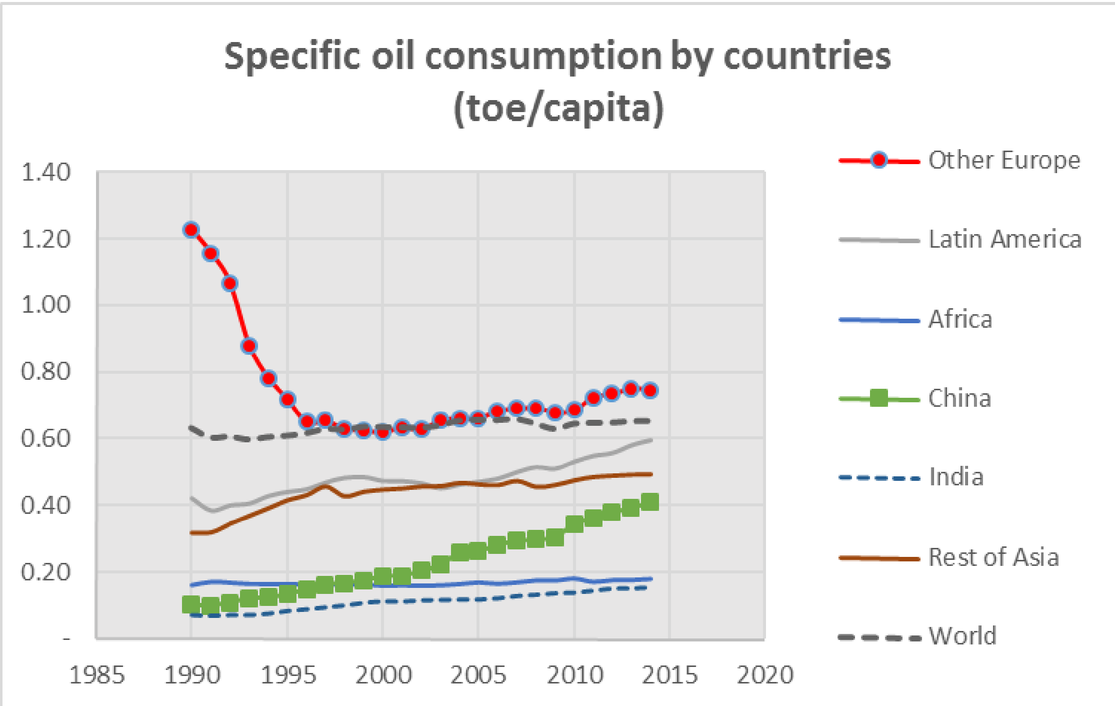


Figure 9.1.4 Specific consumption of oil (BP).

9.2 Motor vehicles

It is possible now to make a change from oil to electricity very rapidly with electric cars. They have been coming into markets. Today about 90 million motor vehicles sold annually. More than one million of the cars are plug in electric vehicles. Leading model is Nissan Leaf which has 20 % of the market of electric cars.

We can assume that the change can happen very rapidly so that by 2040 more than 50 % of the sold cars are electric (Figure 9.2.1). Then by 2050 all new vehicles will be electric.

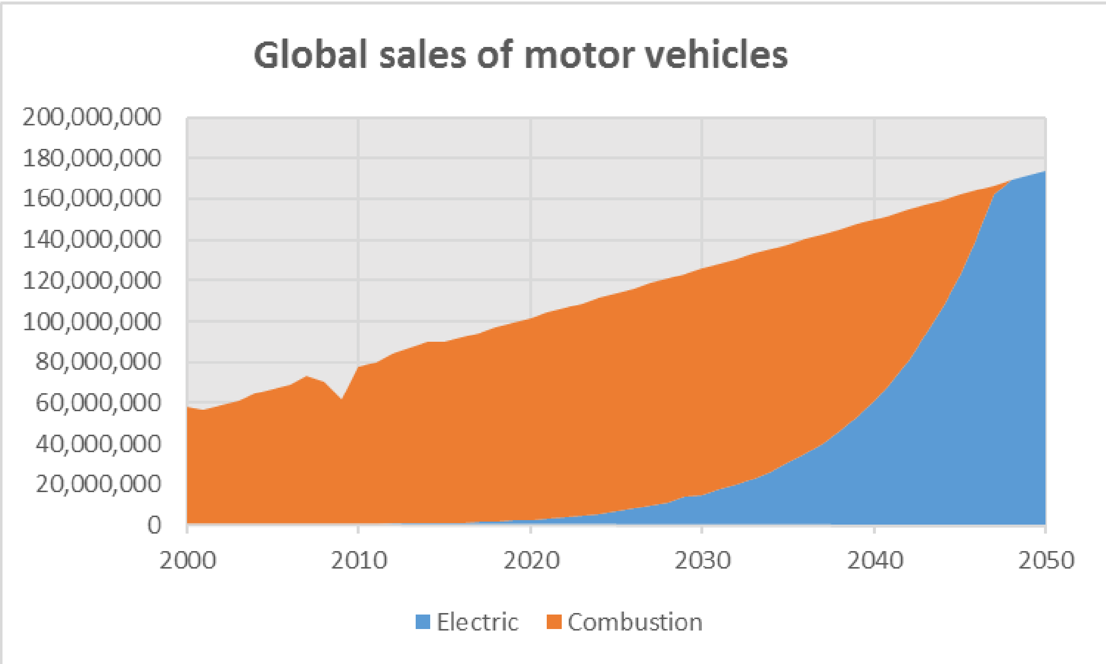


Figure 9.2.1 Sales of motor vehicles.

Change in vehicles on the roads happened more slowly. By 2050 about 50 % of the all vehicles will be electric (Figure 9.2.2). It will take until 2065 until almost all vehicles will be electric.

The fuel consumption will change so that oil peak will happen in the year 2030 (Figure 9.2.3). Then after 2070 all vehicles are electric and no oil is needed. However, ships and airplanes need oil also ling after this.

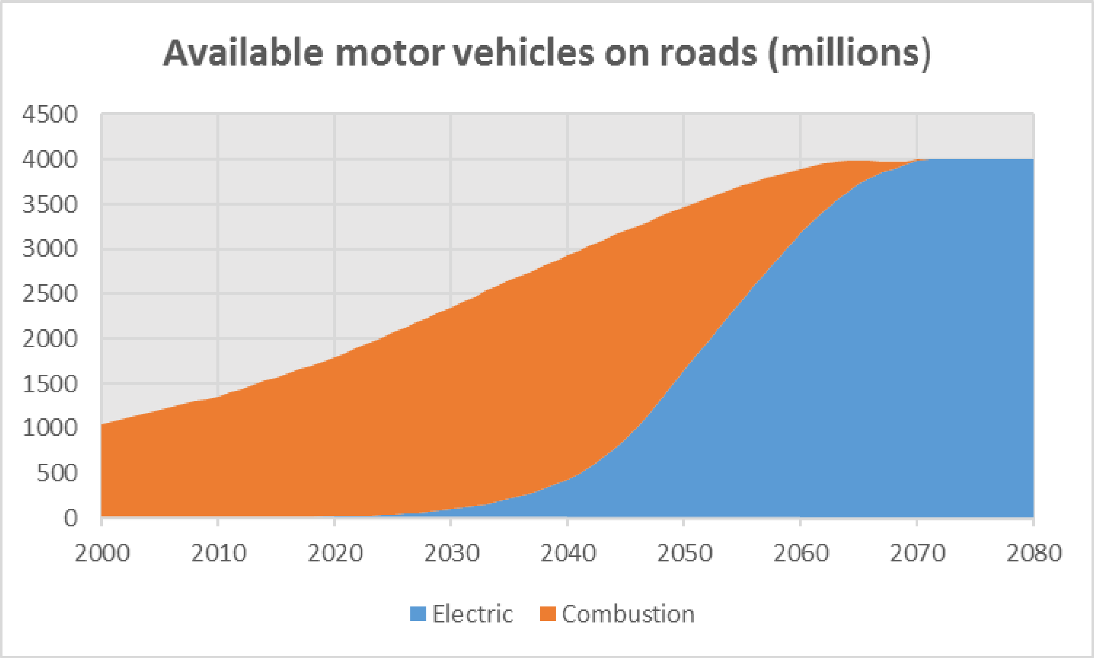


Figure 9.2.2 Available motor vehicles on the roads.

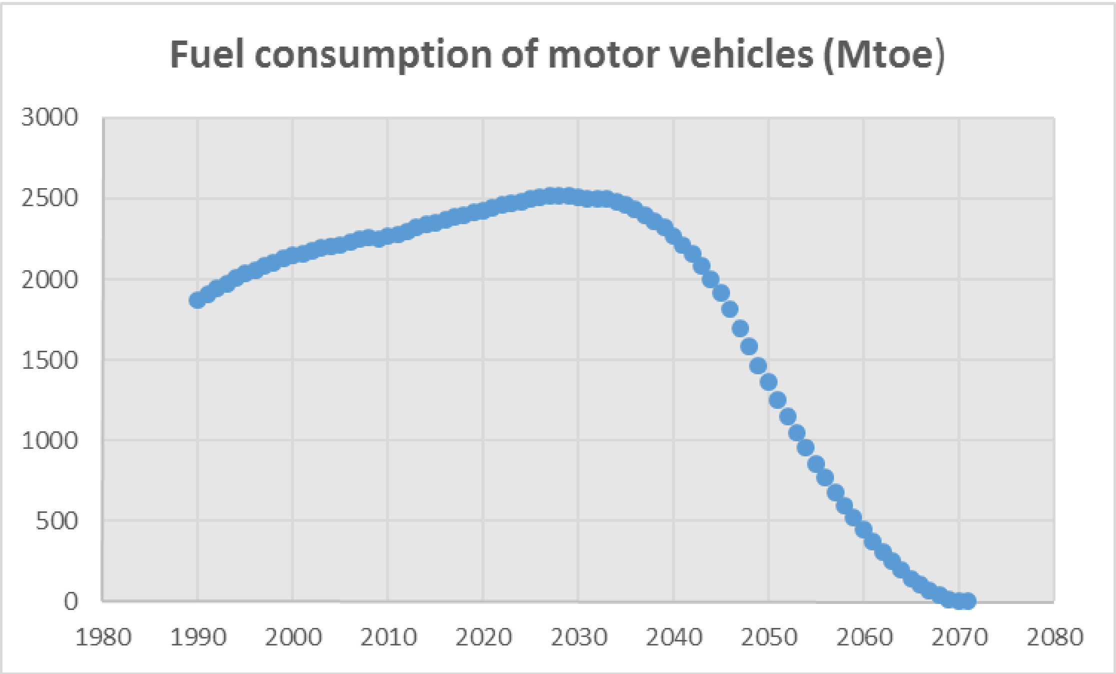


Figure 9.2.3 Fuel consumption of motor vehicles.

9.3 Future oil consumption

If the consumption of light and middle distillates will follow the forecast of fuel use in motor vehicles (Figure 9.2.3), then use of them will practically end by 2070. However, the use of other products will continue in ships and industries. It is assumed that use of oil in the other products will decrease with 3 % annually starting from the year 2030. Then use of oil will peak at 2030 at 5000 Mt per year (Figure 9.3.1).

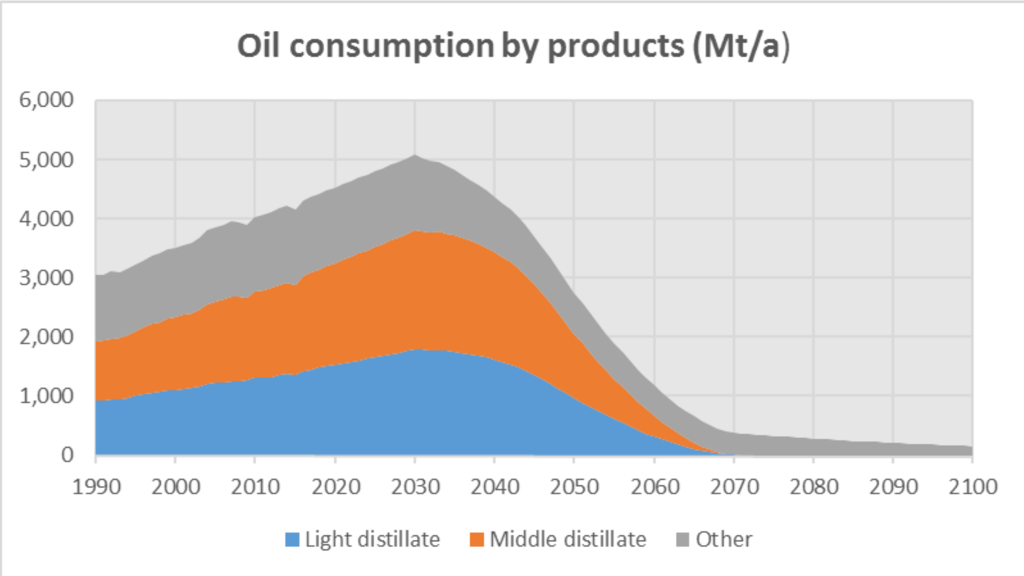


Figure 9.3.1 Oil consumption forecast by products.

Assuming that the consumption of oil will follow the same pattern given in Figure 9.3.1 in all countries, then the consumption of oil is forecasted in Figure 9.3.2 by countries. Oil peak will happen in the year 2030 and by 2070 only other products will remain.

The CO_2 emissions caused by oil will peak in the year 2030 at 14.5 Gt (Figure 9.3.3). The cumulative CO_2 emissions of oil will be 800 Gt after the year 1990 (Figure 9.3.4).

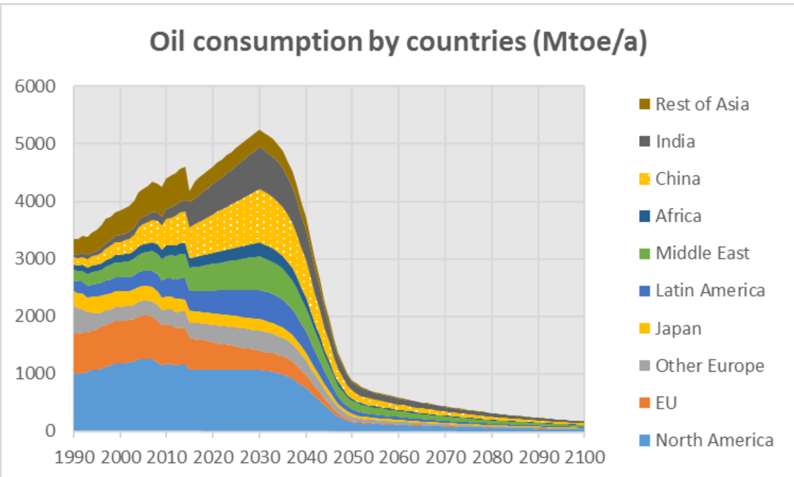


Figure 9.3.2 Oil consumption forecast by countries.

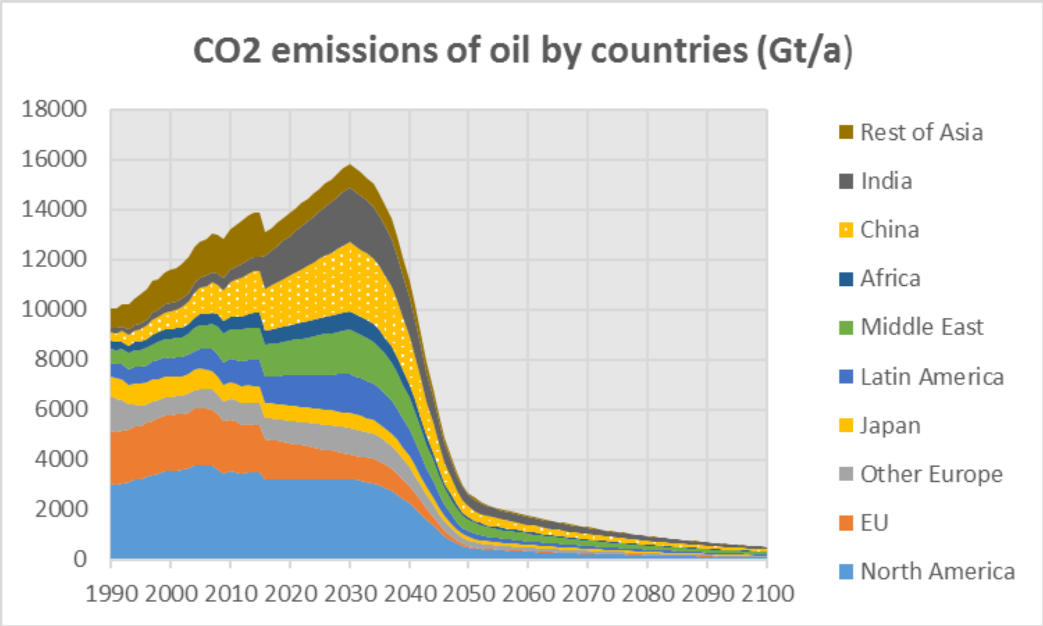


Figure 9.3.3 CO_2 emission forecast of oil products by countries.

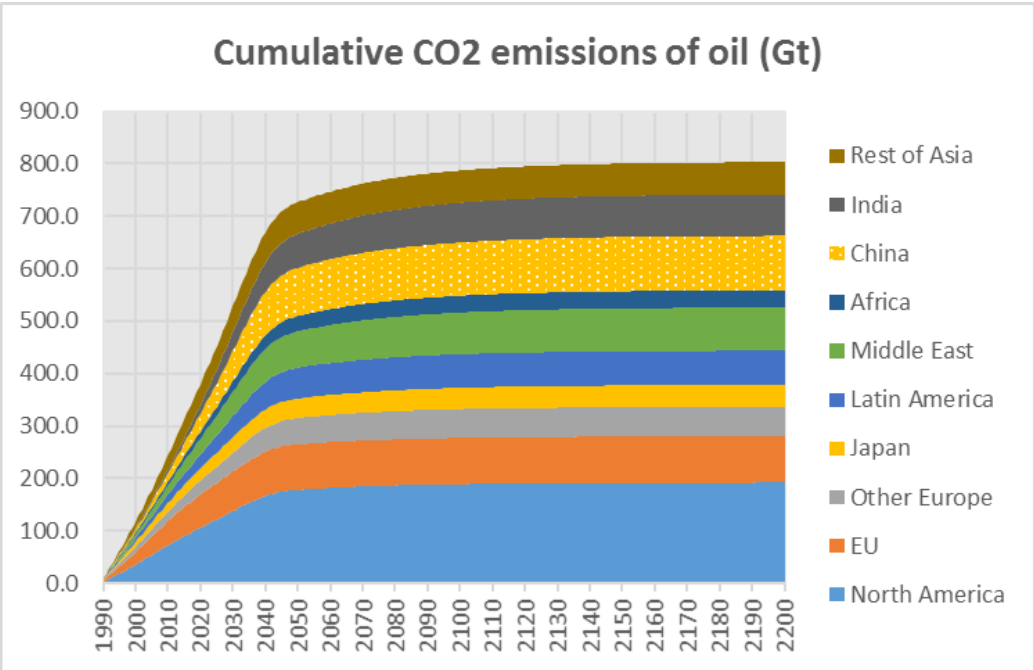


Figure 9.3.4 Cumulative *CO_2 emission forecast of oil by countries.*

10 TOTAL CO_2 EMISSIONS

10.1 CO2 emissions of other sectors

There are also other sectors then electricity and oil which cause CO_2 emissions. Coal is used for steel production and natural gas for heating of houses. It is assumed that these sectors will follow electricity and oil sectors in CO_2 emissions and the peak emissions will be in 2030. It can be found that China is the biggest emitter because its huge steel industry (Figure 10.1.1). The cumulative emissions of other sectors will be 700 Gt (Figure 10.1.2).

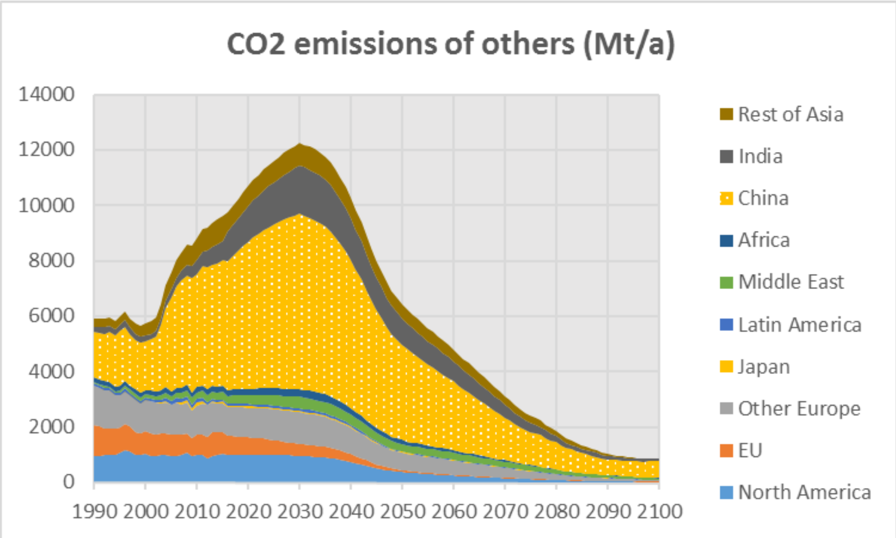


Figure 10.1.1 CO_2 emissions of other sectors.

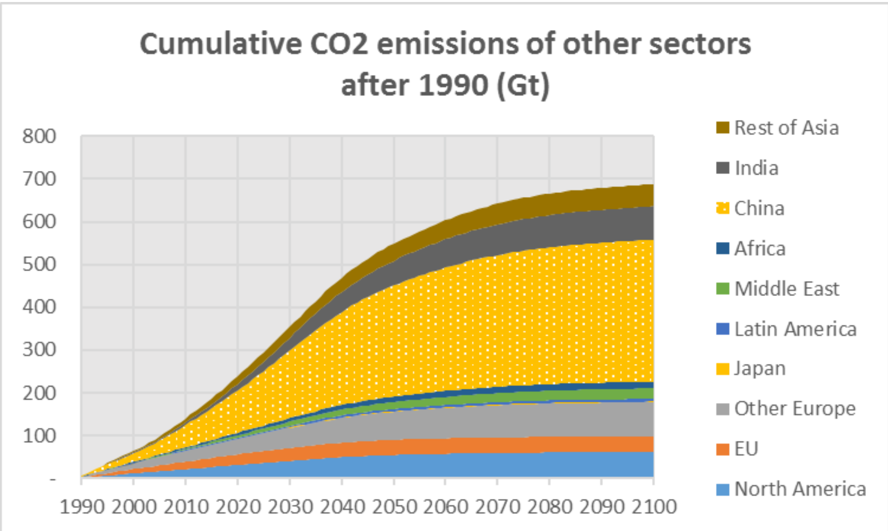


Figure 10.1.2 Cumulative CO_2 emissions of other sectors.

10.2 Global CO_2 emissions

Global CO_2 emissions will peak at 42 Gt in the year 2030 (Figure 10.2.1). Largest emissions are coming from China. Specific emissions are largest in North America. By 2030 the world average emissions will 5 t/capita and then start to decrease to 2.5 t/capita Figures 10.2.2 and 10.2.3).

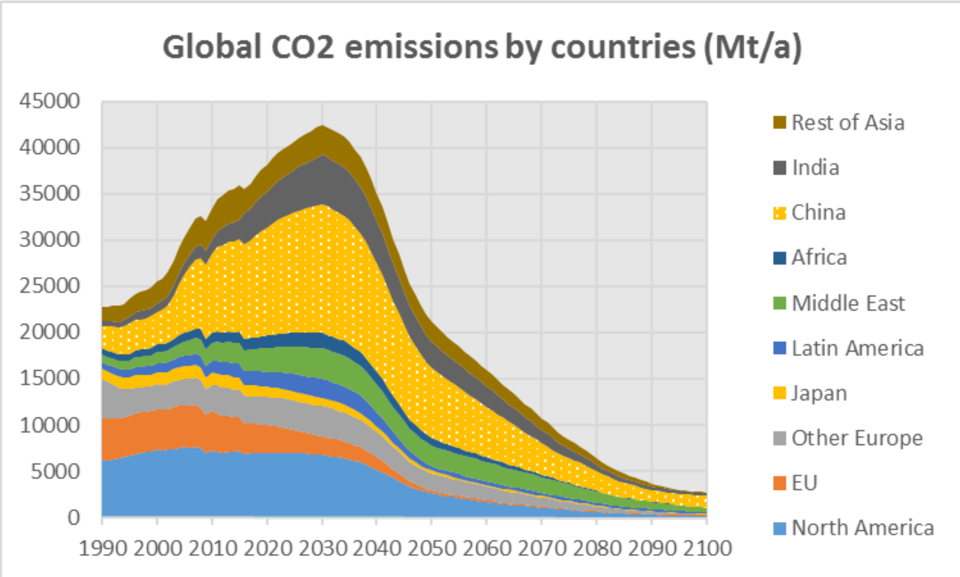


Figure 10.2.1 CO_2 emissions by countries.

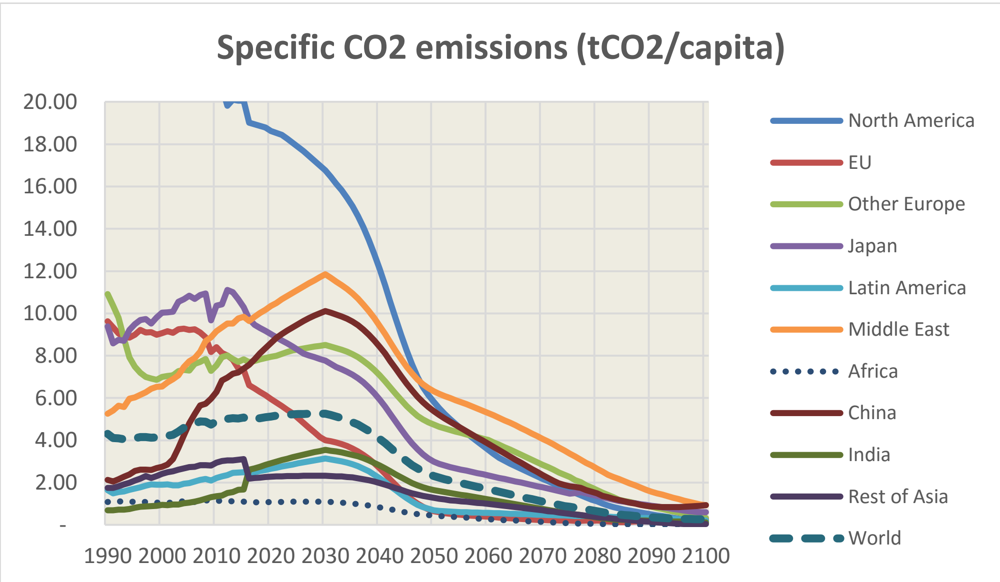


Figure 10.2.2 CO_2 emissions per capita.

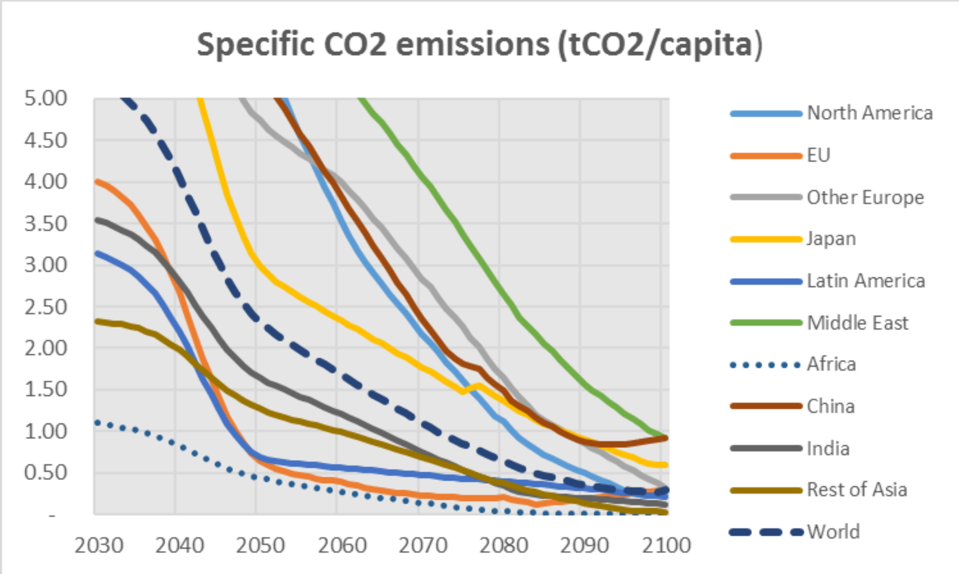


Figure 10.2.3 CO_2-emissions per capita.

They are mainly coming from the other sectors, which are more than 50 % of all emissions (Figure 10.2.4). Cumulative CO_2 emissions after 1990 will reach 2500 Gt (Figure 10.2.5). This is about 250 tons/ capita. Main source of emissions is China. The cumulative emissions will reach 3200 Gt before the year 2100 (Figure 10.2.6).

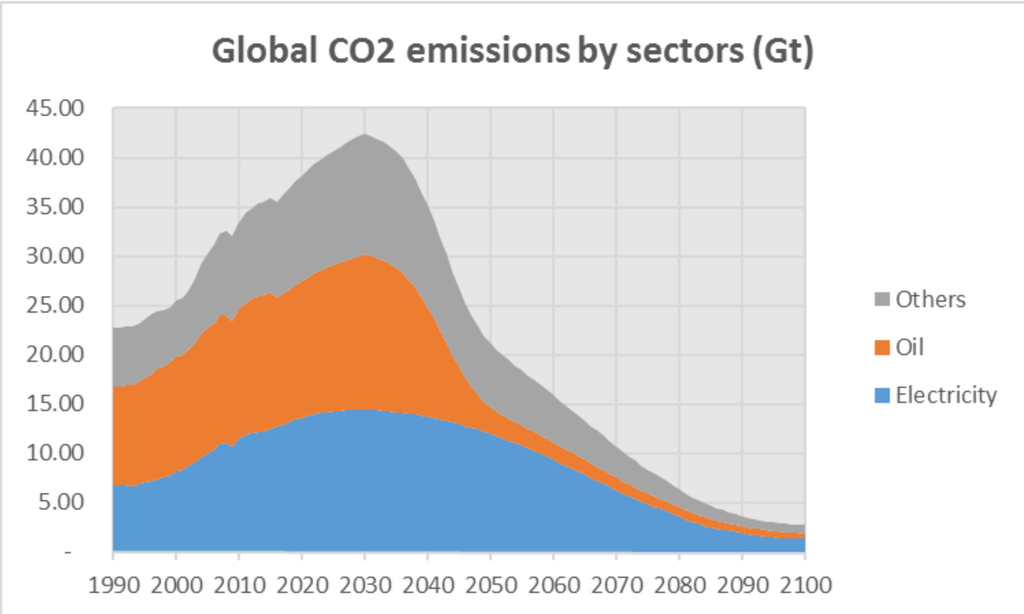


Figure 10.2.4 CO_2 emissions by sectors.

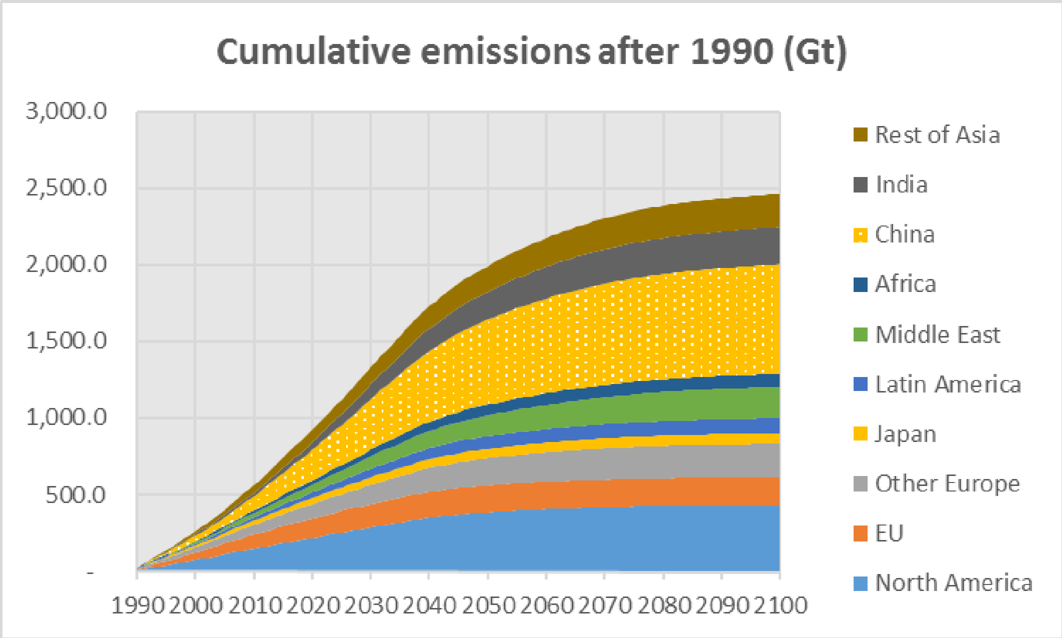


Figure 10.2.5 Cumulative emissions after 1990 by countries (Gt).

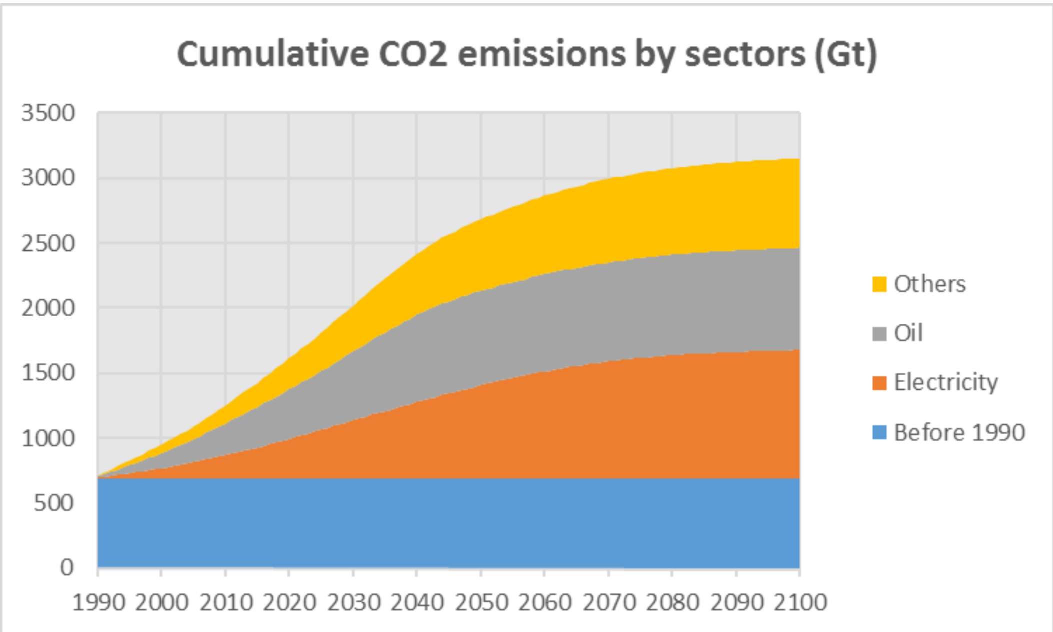


Figure 10.2.6 Cumulative emissions by sectors (Gt).

10.3 Summary

The cumulative CO_2 emissions of energy sectors will be 3200 Gt before the year 2100. This will mean that the anthropogenic global warming by the year 2100 will follow between the green and yellow curves in Figure 10.3.1, which correspond to 2 % and 3 % saving in CO_2 emissions after the year 2030. By the year 2200 the AWG caused temperature rise will be then 2.3 – 2.6 deg. C starting from the year 1960.

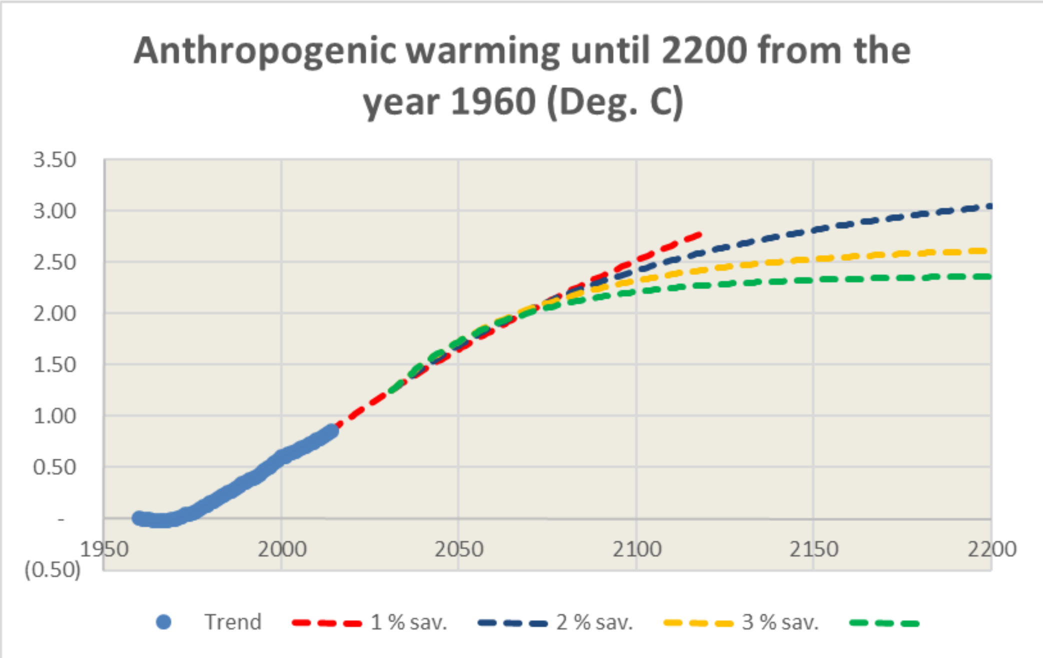


Figure 10.3.1 Anthropogenic global warming (AWG) since 1960.

The year 1958 is the first year when CO_2 was measured and the statistics of BP start from the year 1964. Thus we know greenhouse gases quite well since then. AWG before the year 1960 is speculation, because the contents of them has not been measured.

The warming will continue until 2050 independently, because decreasing the use of coal is decreasing the SO_2 emissions at the same time. If the SO_2 emissions decreasing, this will warm the earth as much as decreasing of CO_2 emissions will cooling it. However, after the year 2070 the when the coal emissions will end, the decreasing of CO_2 emissions will work at their total force.

11 ENERGY POLICIES

11.1 North America

North America has been the leading CO_2 emitter for long time, but the its emissions have been declining after the financial crisis in 2008. However, the emissions have been rising after 1990 and were 14 % higher in 2014 than in the year 1990. US has promised in Paris climate talks in December 2015 to cut its emissions by 2025 by 26 % from the emission figures in 2005. This means that the emissions in 2025 should be 10 % lower than in 1990. However, it seems that emissions in North America will be still 10 % higher in 2025 than in 1990 (Figure 11.1.1).

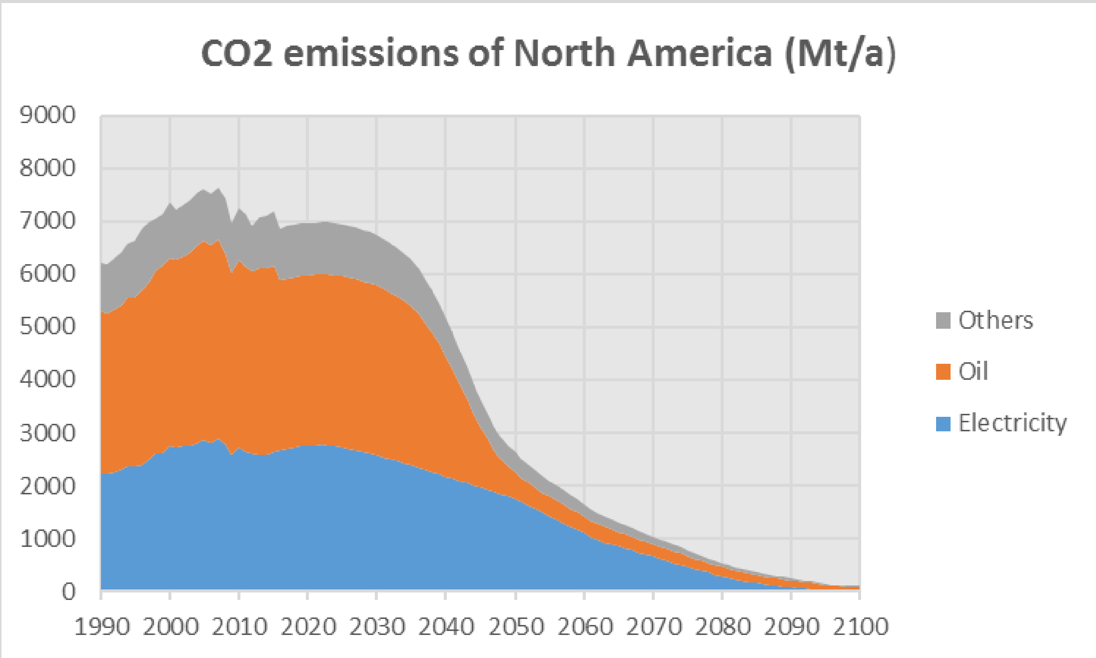


Figure 11.1.1 CO_2 emissions in North America.

However, it is possible that the emissions in North America will be 50 % lower in 2050 compared with emissions in 1990. USA will have the leading the electric vehicle industry and thus the use of oil in transportation will decrease dramatically by 2050. The electricity generation will be the main source of emissions by 2050.

The cumulative emissions of North America until 2100 will be 430 Gt or 800 tons per capita (Figure 11.1.2). This will be more than three times the global cumulative emissions of 250 tons per capita.

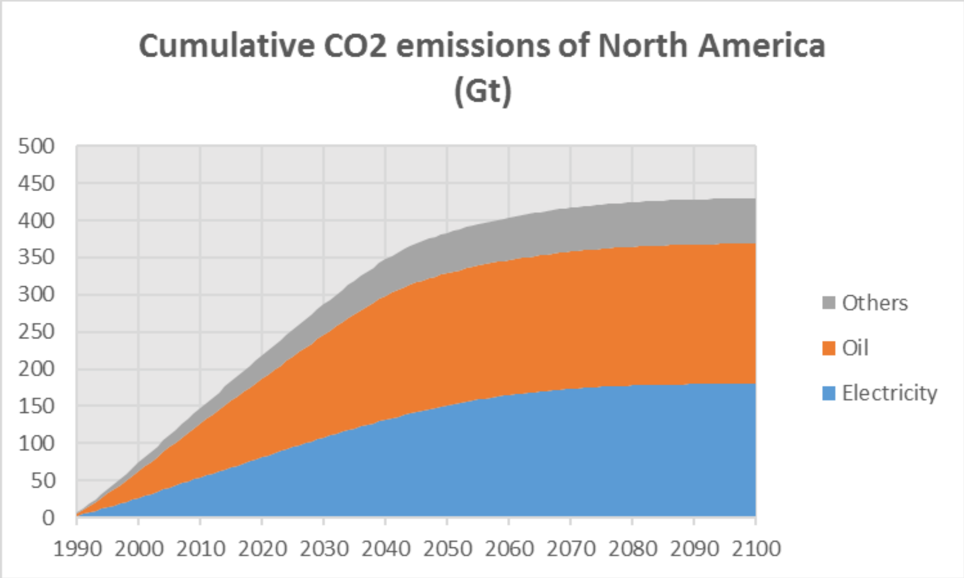


Figure 11.1.2 Cumulative emissions of North America after 1990.

11.2 European Union

European Union has been leading the emission reduction plans. It published the 2020 plan, according which the CO_2 emissions should be 20 % lower in 2020 as compared with the base year 1990. It seems that this target will be achieved already in the year 2015. The next target is set to the year 2030, when 40 % reduction should be reached. It seems that already 50 % reduction can be reached by 2030 (Figure 11.2.1). Thus EU is discussing to reduce emissions by 30 – 40 % before the year 2030.

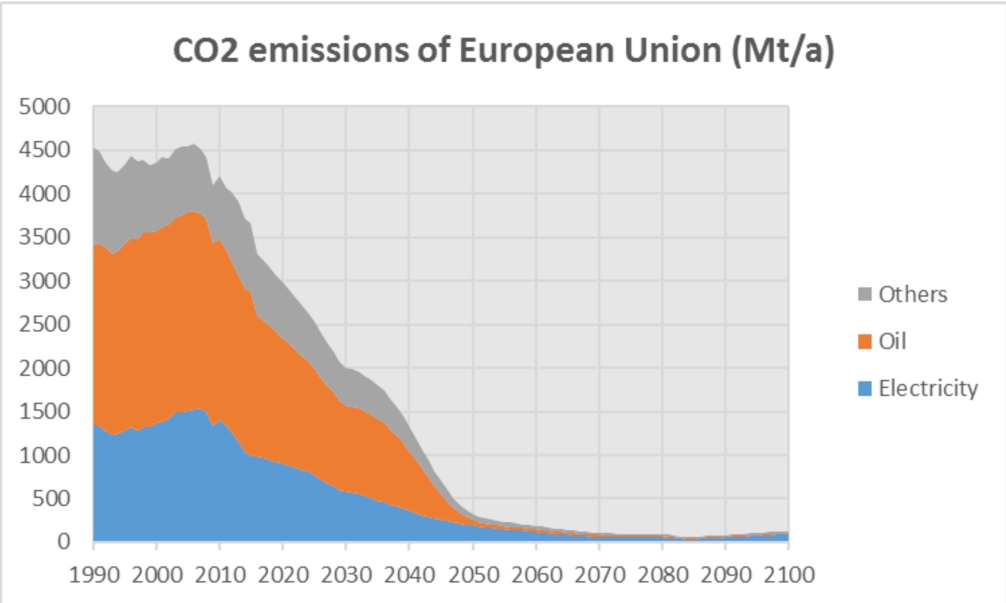


Figure 11.2.1 CO_2 emissions of European Union.

It is possible that before 2050 EU has reduced its 1990 emissions more than 90 %. This means that use of oil has been mainly stopped in the car industry and electricity will be free of CO_2 emissions.

The cumulative emissions of European Union will then increase to 180 Gt by 2100 (Figure 11.2.2). This is about 360 t CO_2 per capita. The average figure was 250 t/capita for the whole world. Thus EU is one of largest emitters of all countries, but it will emit less than 50 % of specific emissions of North America (800 t/capita).

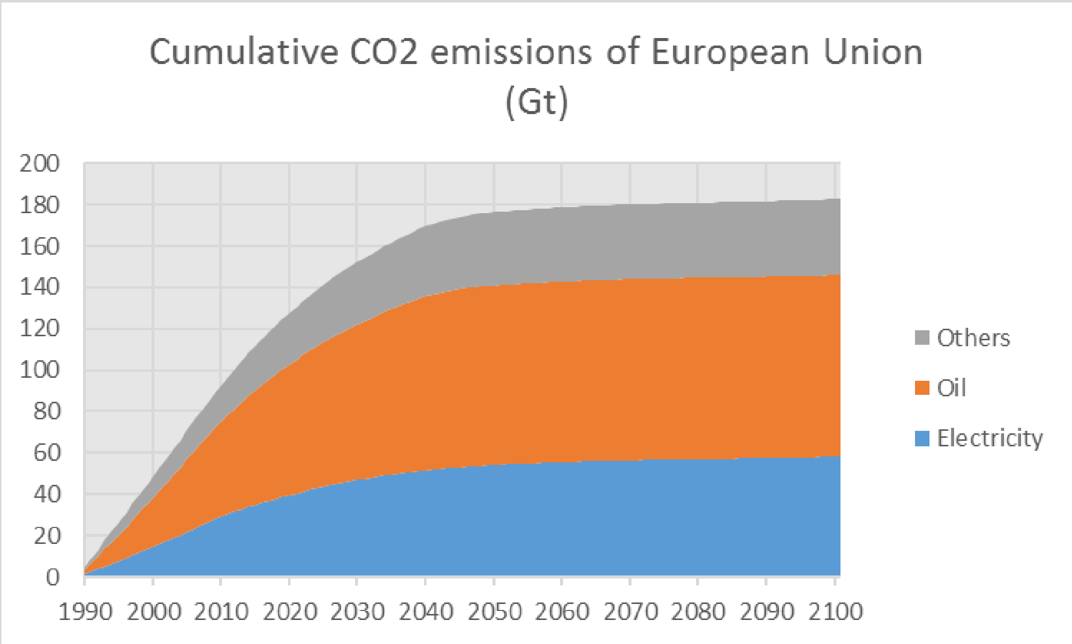


Figure 11.2.2 Cumulative CO_2 emissions of European Union after 1990.

11.3 China

China has been the biggest emitter of CO_2 with its quickly rising energy consumption and GDP figures. China has promised in Paris talks to start reducing its CO_2 emissions after the year 2025. It seems that the peak CO_2 emissions will happen in the year 2030 at 14000 Mt (Figure 11.3.1). This is, however, 470 % more that its emissions in the year 1990.

After 2030 China has promised to reduce its emissions 2 % per year until 2040 and 4 % per year after 2040. It will mean that the emissions will be 11400 Mt in 2040 and 1000 Mt in the year 2100. This is quite near the forecast given in the Figure 11.3.1.

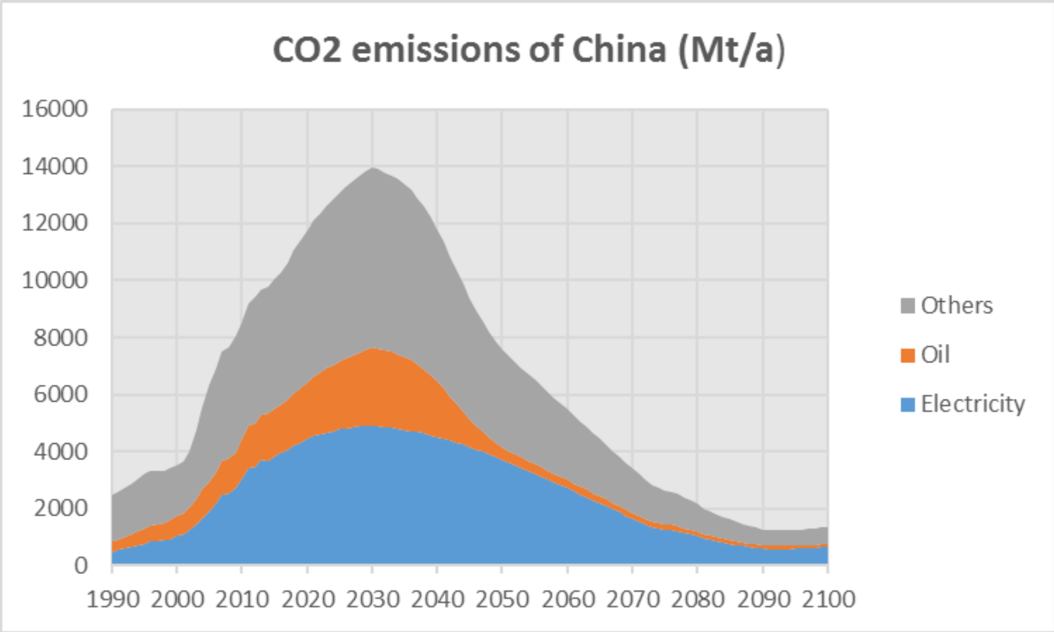


Figure 11.3.1 CO_2 emissions of China.

The cumulative CO_2 emissions of China will reach 720 Gt by the year 2100 from the year 1990. This is more than North America and EU combined. However, the cumulative emissions of China will be 500 tons per capita, which will be higher than in EU, but much lower than in North America.

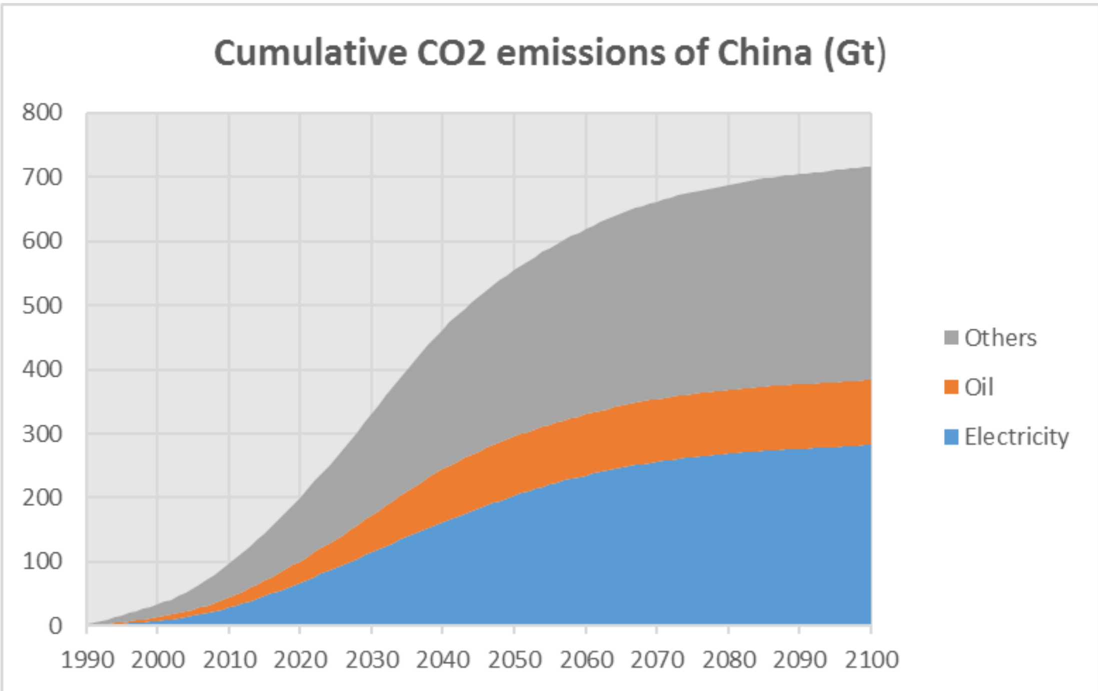


Figure 11.3.2 Cumulative emissions of China after 1990.

11.4 Rest of the world

The CO_2 emissions in the world outside North America, European Union and China will be increasing until the year 2030, when they will peak at 20000 Mt (Figure 11.4.1). Then they will start decreasing because of the electric vehicles are coming into the markets. The emissions of electricity will peak in the year 2040.

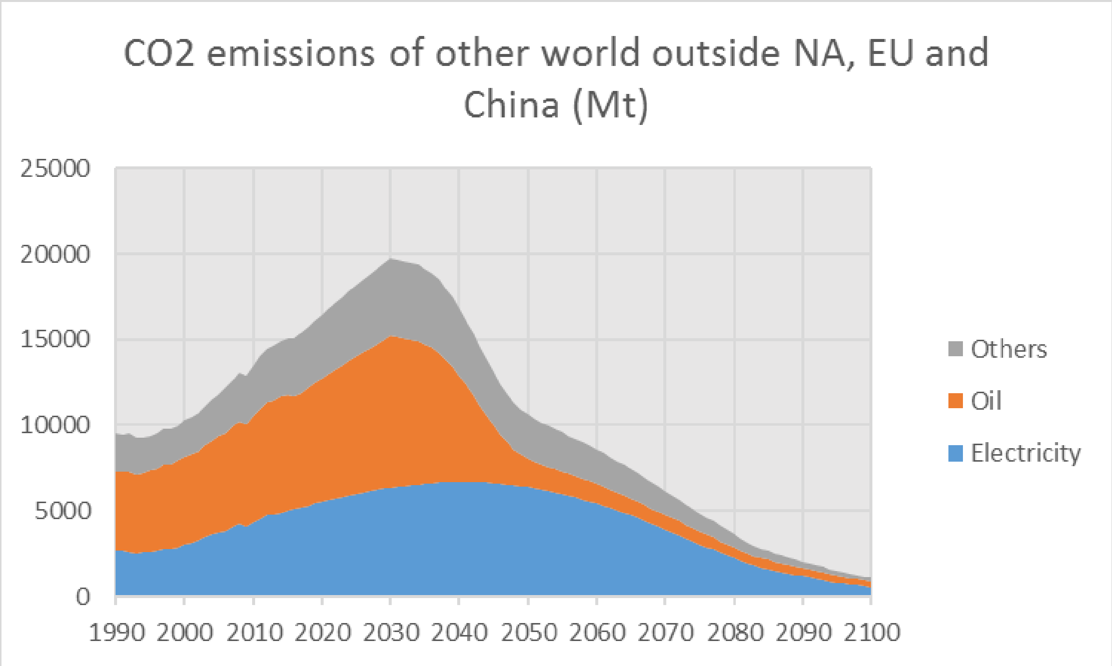


Figure 11.4.1 CO_2 emissions of countries outside North America, European Union and China.

The cumulative CO_2 emissions outside North America, European Union and China will be 1130 Gt by the year 2100 (Figure 11.4.2). The cumulative emissions were estimated to be 430 Gt in North America, 180 Gt in EU and 720 Gt in China or 1330 Gt combined. These three areas will emit 54 % of the total (2460 Gt) cumulative emissions until 2100.

Because of the majority of population is living in these countries outside NA, EU and China, the specific emissions will be there much lower. The specific emissions in the rest of the world are 180 tons per capita, which is 70 % of the average emissions of the whole world of 260 tons per capita (Figure 11.4.3).

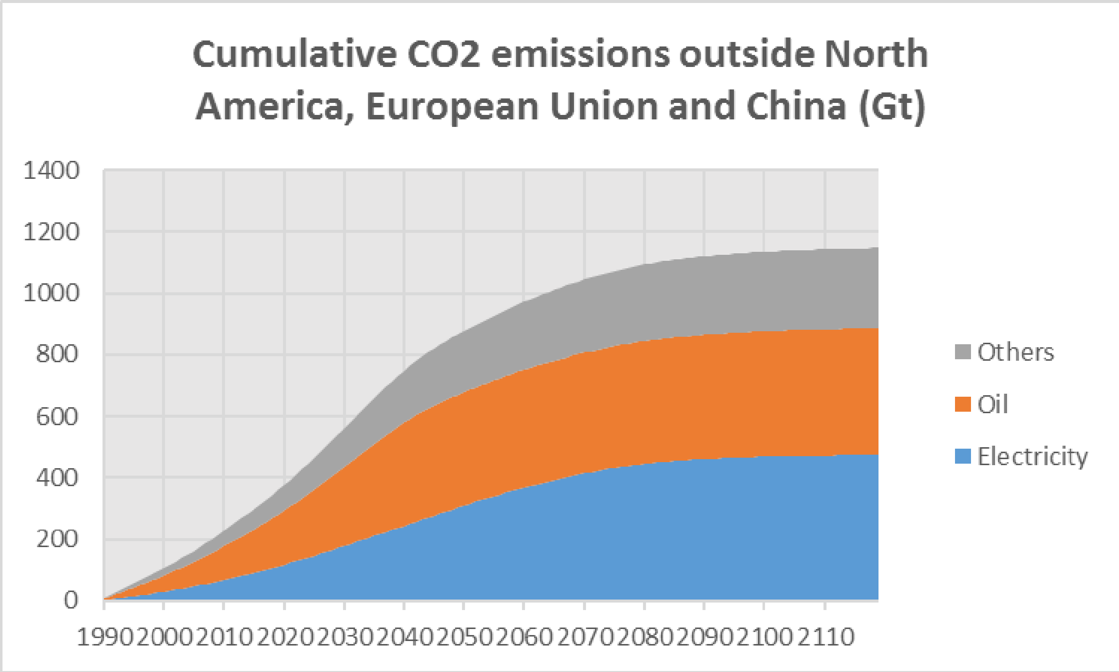


Figure 11.4.2 Cumulative CO_2 emissions outside North America, European Union and China after 1990.

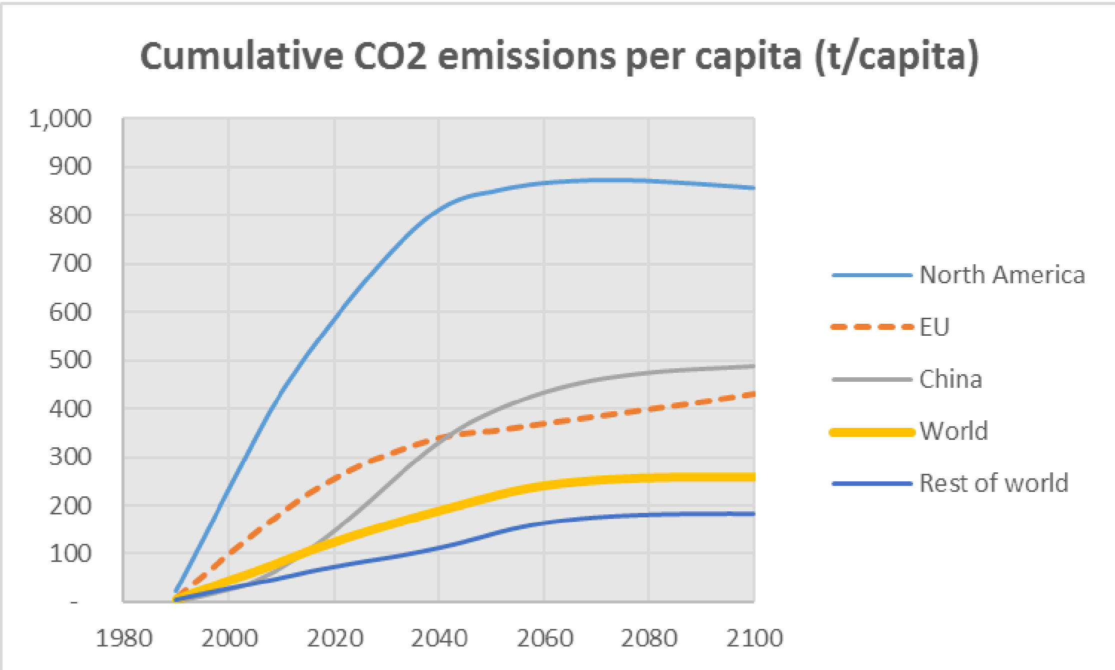


Figure 11.4.3 Cumulative CO_2 emissions per capita after 1990.

11.5 Summary

The COP 21 talks in December 2015 set a target to limit anthropogenic global warming to 1.5 deg. C. They wanted to stop the greenhouse gas emissions in the second half of the 21th century. The global emissions will be increasing until the year 2030 and will start reducing thereafter.

Only EU has been able to reduce its CO_2 emissions after 1990. The emissions in North America and China are today much higher than in 1990. The other countries outside North America, European Union and China will be increasing their emissions until the year 2030.

The realistic truth is that the cumulative CO_2 emissions after the year 1990 will reach 2500 Gt until 2100. With the CO_2 emissions of 690 Gt before 1990 the total anthropogenic emissions until 2100 will be about 3200 Gt. This will lead to anthropogenic global warming (AWG) with 2.5 deg. C by the year 2100.

12 WINDS

12.1 Sailing routes

Old sail ships could not sail against the wind. Thus the routes of them indicate prevailing wind directions in globe. A famous sailing boat was clipper **Cutty Sark**, which was used for transporting cargo from London to Australia and back. It was launched in 1869 and it can still be seen in Greenwich, London. The site has also smaller sailing boat, Gipsy Moth, which was the first sailing boat used for single handed round the world sailing by **Francis Chichester** (1901 – 1972). He arrived in London in 1967 after his voyage had lasted 226 days with only one stop in Australia.

Its route started from London and continued first to Rio de Janeiro in South America and from there round Cap Town to East using the "Roaring Forties" (between latitudes 40^o and 50^o S) to Australia (Figure 12.1.1). The voyage to London used again the Roaring Forties to South America through

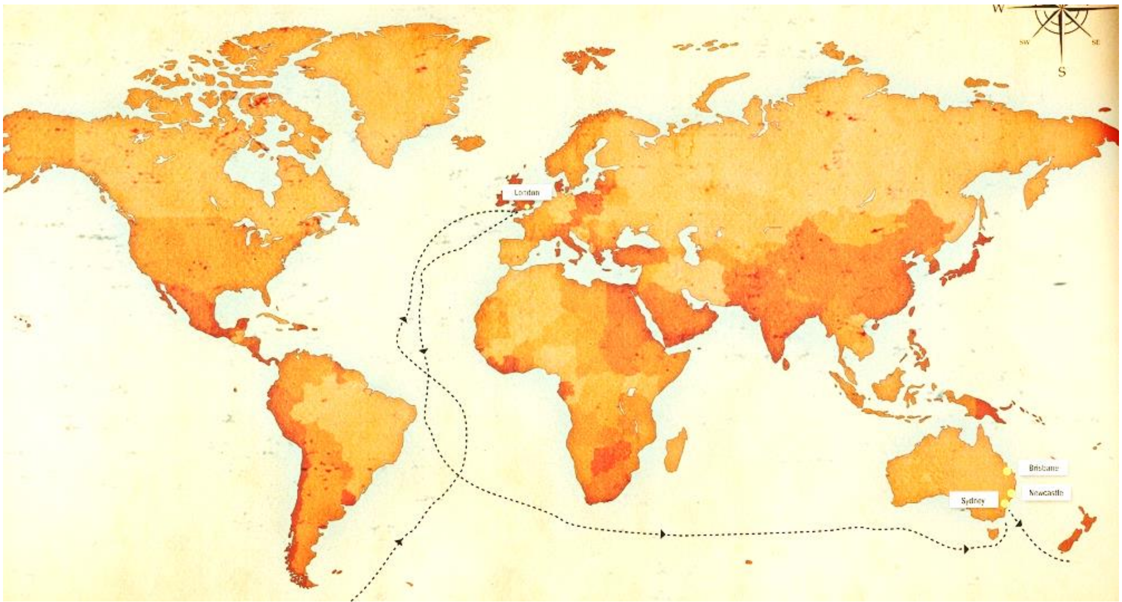


Figure 12.1.1 Route of Cutty Sark was used transport cargo from London to Australia and back.

The prevailing winds are blowing to west (Trade winds) near equator and to east at the Roaring Forties (Polar Easterlies) in southern hemisphere and also to east in northern hemisphere (Figure 12.1.2).

The origin of the trade winds near the equator is the low pressure zone which drives the wind towards the equator and coriolis forces. Without rotation of the sun the trade winds would be blowing from north to south in the northern hemisphere and south to north in the southern hemisphere (Figure 12.1.3).

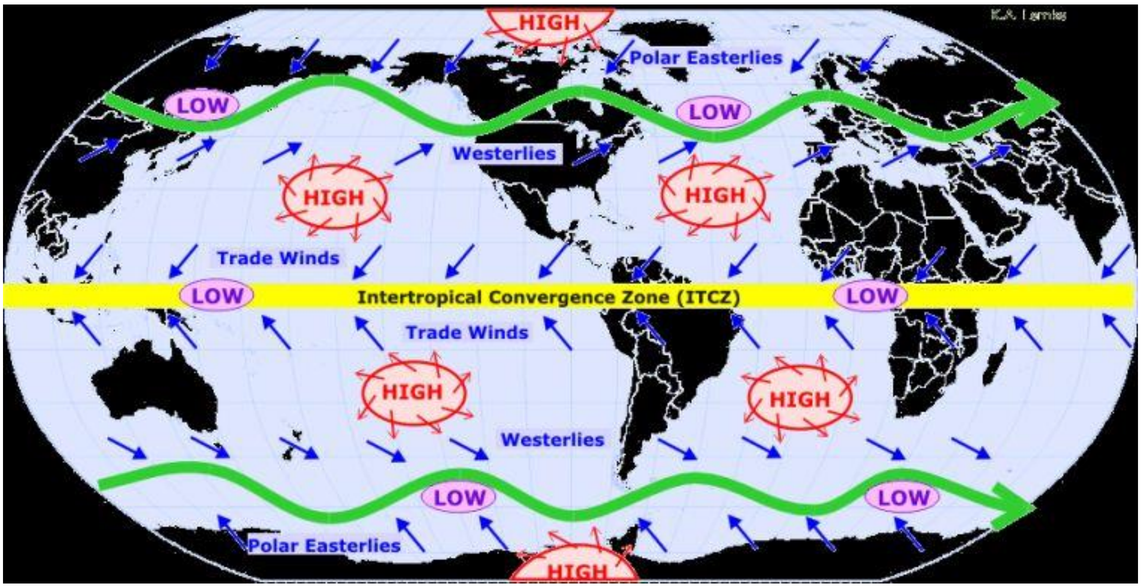


Figure 12.1.2 Prevailing winds and high and low pressure zones.

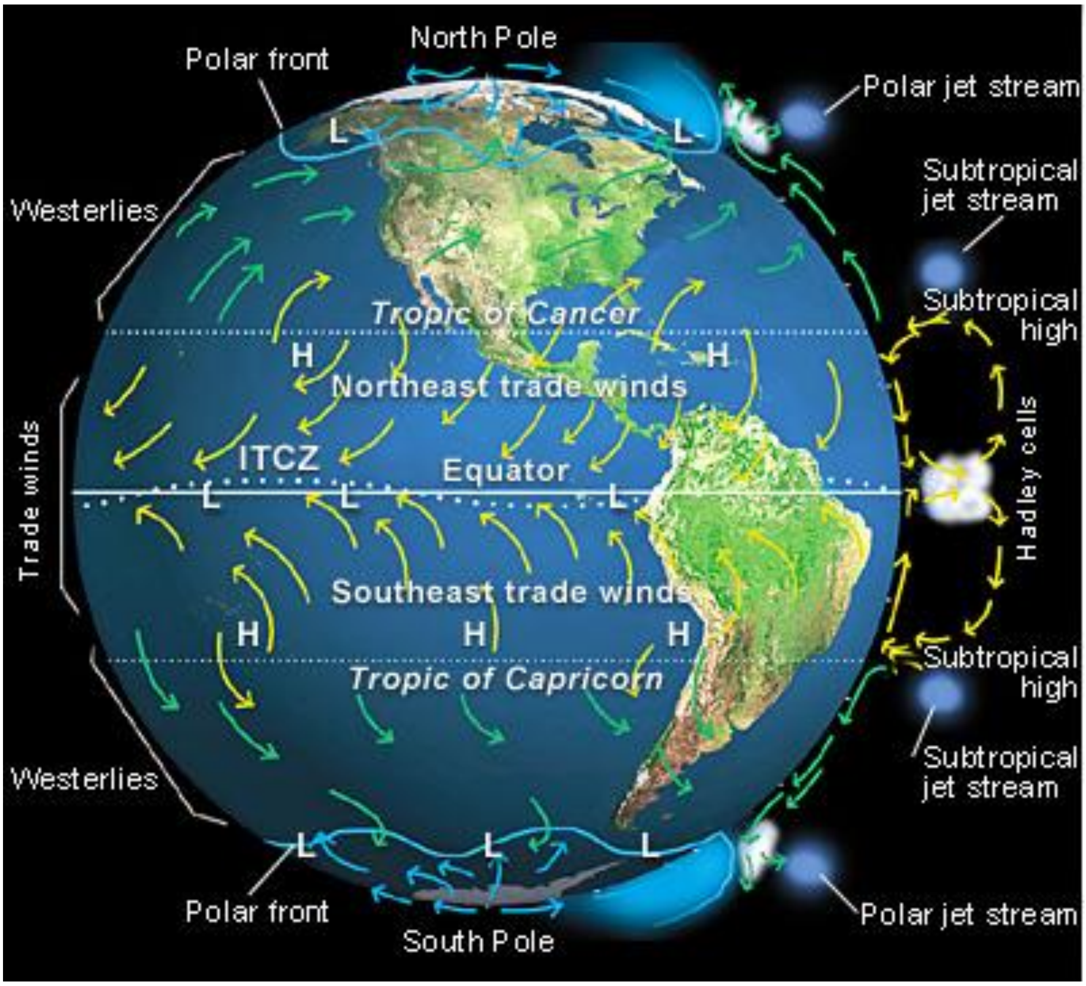


Figure 12.1.3 Driving force of trade winds to equator is the low pressure zone, which is caused by the sun, which is heating the air in the equator and coriolis force of the earth, which is caused by rotation of the earth.

In Atlantic Ocean low pressure zones are near equator and near Island. In the between is a high pressure zone which gives the wind rotating force which makes the winds to blow clockwise. Near Island is low pressure zone which makes the wind blow counterclockwise.

These trade winds are also driving force of the Gulf Stream. Gulf Stream will not stop as long as winds are blowing. They are blowing as long as the sun is shining near equator and causing a low pressure zone by heating the air.

12.2 Wind resources

Average wind speed during years 1976 – 1995 at 10 m show, where the wind can be used as power source (Figure 12.2.1). The highest wind speeds (red) can be found in the Roaring Forties in the Southern hemisphere and in North Atlantic and Pacific Oceans. The lowest wind speed areas are near the equator in South America and South Africa.

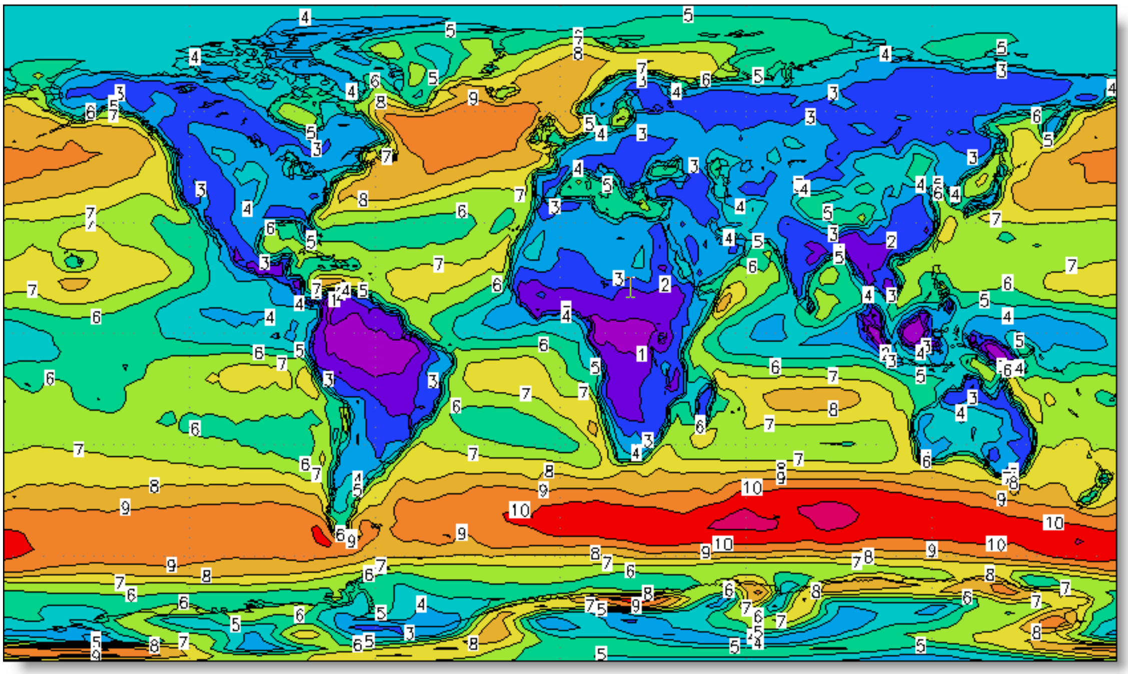


Figure 12.2.1 Average global wind speeds.

The average wind speeds are above 8 m/s in North Atlantic Ocean (yellow) from New York to Norway and in Pacific Ocean from Japan to Alaska. However, there are very good potential for wind power onshore site, which can be found, if the wind is measured at 80 m height (see chapter 12.3 Wind Resources in US).

12.3 Wind resources in US

Sailing boats are used to day for racing and fun, but winds are today used to generate wind power. US resources have been evaluated by National Renewable Energy Laboratory (NREL) in July 2012 at 80 m height (Figure 12.3.1). The best wind resources can be found in the middle of US from Texas (5600 TWh) to Kansas (3200 TWh) and trough Nebraska (3000 TWh) and South Dakota (2900 TWh) to North Dakota (2500 TWh).

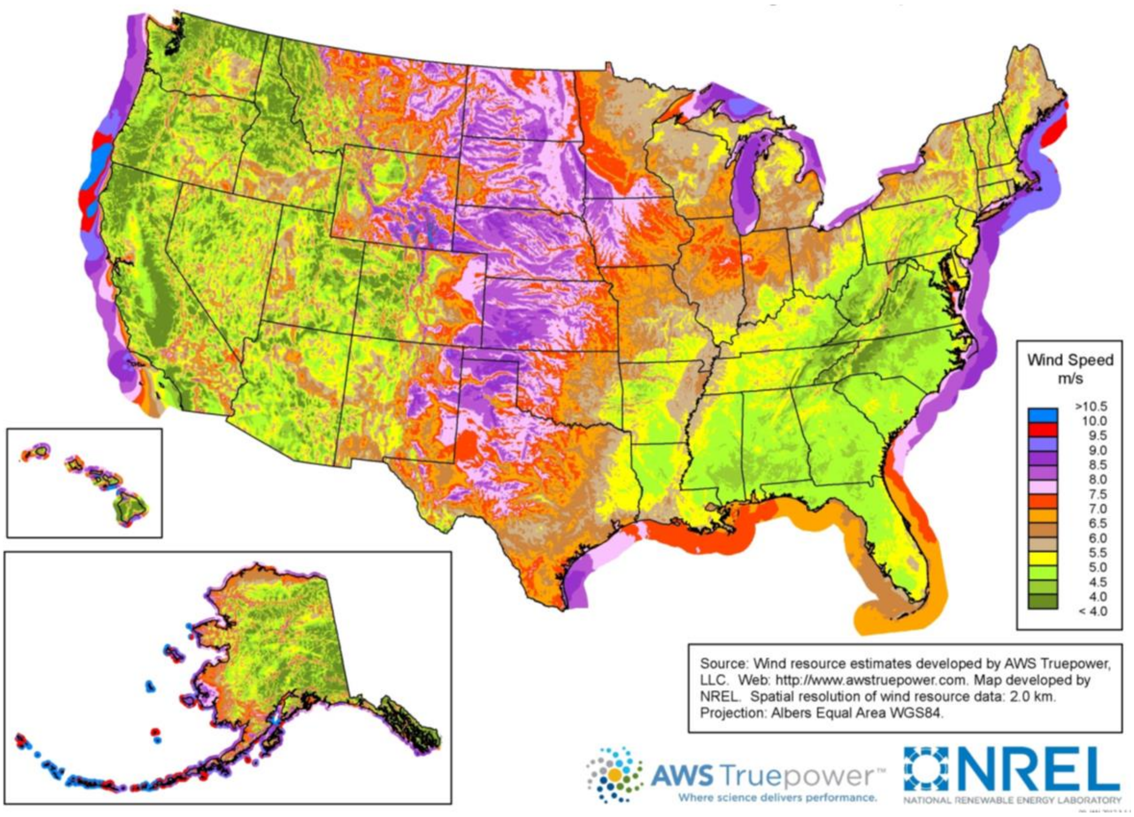
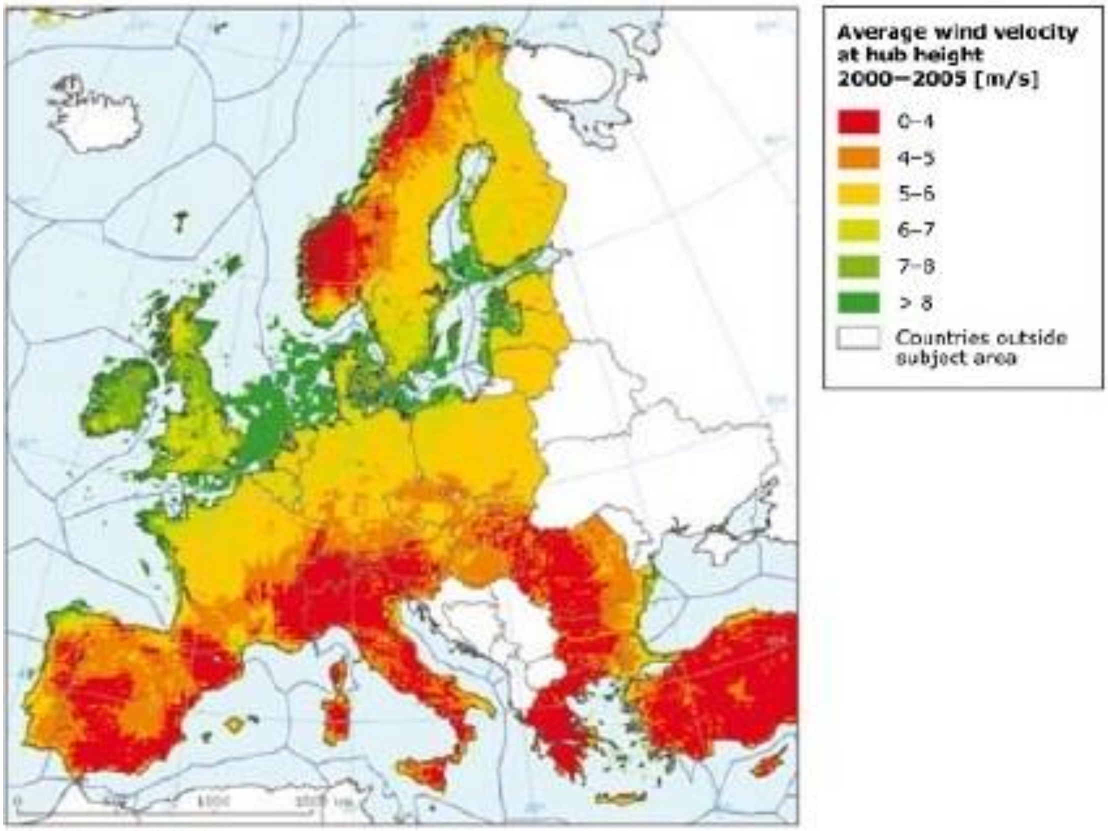


Figure 12.3.1 US wind power resource measured as average wind speed at 80 m height as evaluated by NREL).

The total theoretical wind potential in US on land is 38 800 TWh and off-shore 11 000 TWh. The total potential is 50 000 TWh, which is about 12 time US electricity generation 3800 TWh in the year 2014. However, only 180 TWh (0.3 %) the wind resource was used in 2014.

12.4 Wind resources in Europe

Wind resources in Europe can be found on the coastal areas of Atlantic Ocean, North Sea and Baltic Sea (Figure 12.4.1). The leading countries in wind energy generation have Germany (56 TWh in 2014), Spain (52 TWh), in UK (32 TWh), France (16 TWh), Italy (15 TWh) and Denmark (13 TWh). All of them except Italy are near the Atlantic coast areas.



Source: EEA, 2008.

Figure 12.4.1 Wind resources in Europe, where the green areas are the best suited for wind power generation (source: Characterization of the Wind Power Resource in Europe and its Intermittency. Report 258, March 2014)

12.5 Hurricanes

Hurricanes are formed in in the middle of Atlantic Ocean, when temperature of the sea is rising during autumn from August to October. The rising temperature of seawater means huge amount of thermal energy which will surge from the sea. The hurricanes hit on land typically in Caribbean Islands and in US east coast.

The 10 strongest US hurricanes measured by pressure have been listed in Table 12.5.1. The strongest of them, Labor Day, happened in the year 1935. The second strongest, Camille, happened in the year 1969 and third strongest, Katrina, in 2005. These have hit the land with about 35 year intervals.

Table 12.5.1 Ten strongest US hurricanes by pressure.

Rank	Hurricane	Season	Pressure mbar
1	Labor Day	1935	892
2	Camille	1969	900
3	Katrina	2005	920
4	Andrew	1992	922
5	Indianola	1886	925
6	Florida Keys	1919	927
7	Okeechobee	1928	929
8	Great Miami	1926	930
9	Donna	1960	930
10	Carla	1961	931

Source: HURDAT,[23] Hurricane

If we make a trend of US strongest hurricanes by year and pressure, we can find that their strength has been growing slightly because the pressure has becoming lower (Figure 12.5.1).

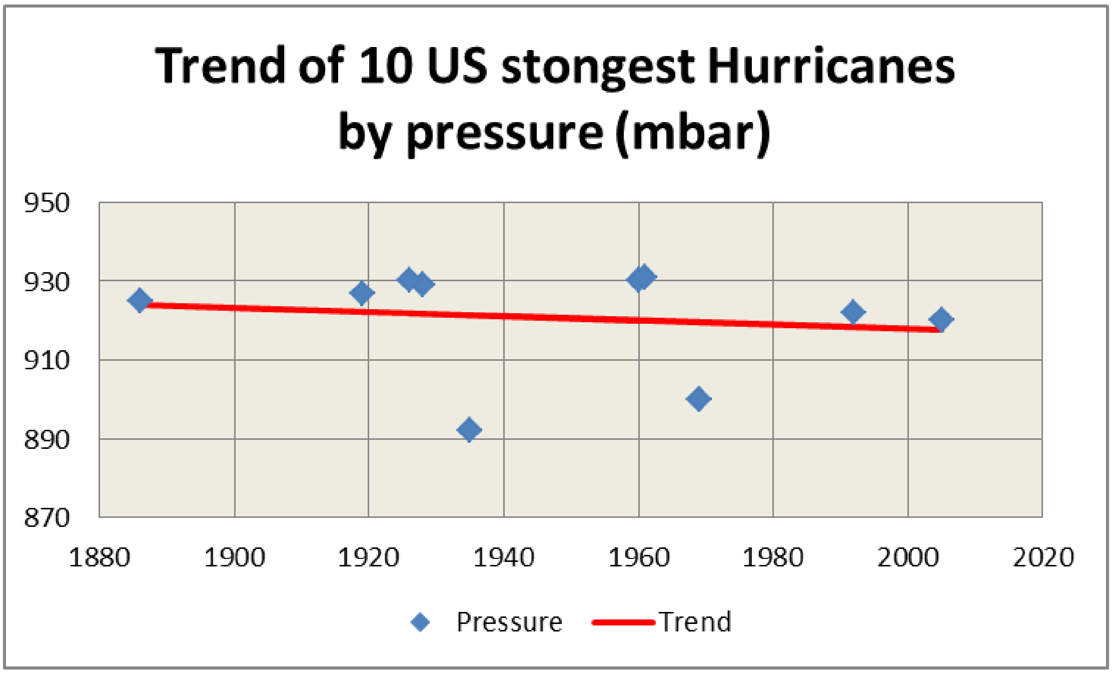


Figure 12.5.1 Trend of US Strongest hurricanes by pressure seems to be slightly decreasing, which means that their strength has been increasing.

The trend of the strongest (category 5) Atlantic hurricanes by pressure is also slightly decreasing and thus their strength has been increasing (Figure 12.5.2). Also the number of category 5 Atlantic hurricanes has been higher (8) during the last 15 years than ever before and they have been stronger than ever with average pressure of 910 mbar. The number was 7 during the years 1924 – 1939, but they were in average weaker (920 mbar) by strength.

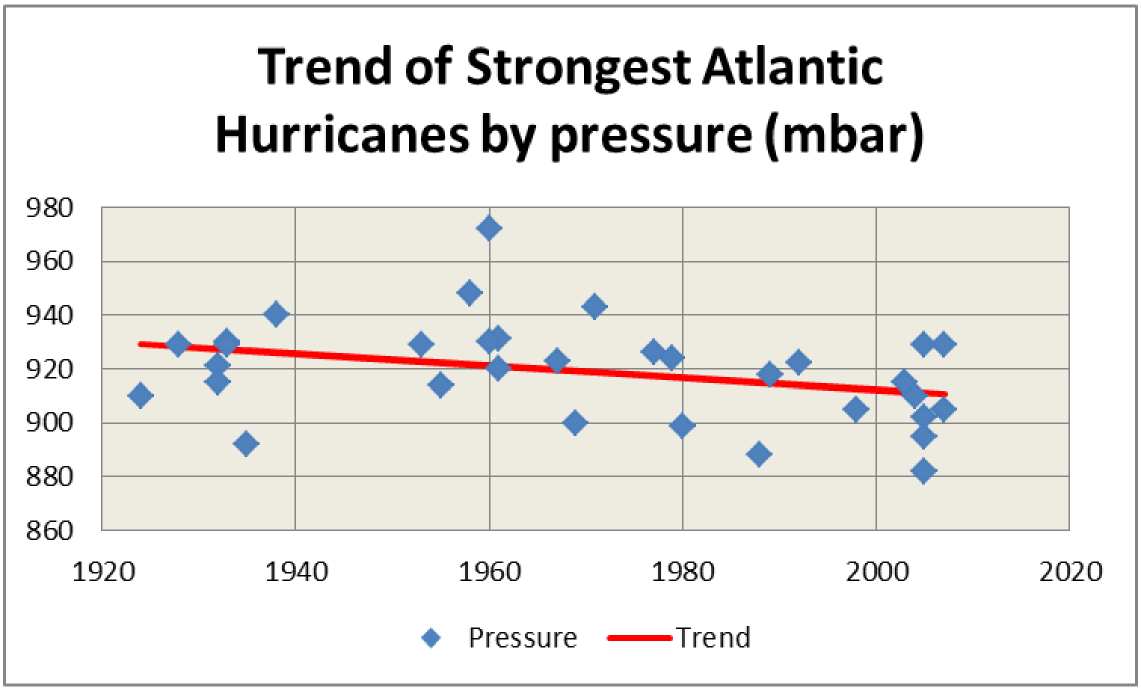


Figure 12.5.2 Trend of strongest (category 5) Atlantic hurricanes by pressure seems to be decreasing, which indicates that their strength has been increasing.

Increasing of the strength of the hurricanes is becoming from the fact that the seawater has been warming during the 20th century. The water should be about 30 deg. C from the surface to several meters below the surface. Seawater temperatures will be studied in the next chapter.

13 SEAWATER TEMPERATURES

13.1 Observations

Historical seawater temperature data can be downloaded from UK data bases (Cefas Data Hub). One of the longest records is Eastbourne site at English Channel. The data shows the warming trend since 1970 (Figure 13.1.1). Until then the ten-year average of annual temperature was about 11.2 deg. C +-0.3. The temperature of the seawater has risen with 1.05 deg. C, if we compare 30-year average figures from years 1901-1930 to years 1991-2012 (Figure 13.1.2).

Seawater temperatures in Isle of Mann are quite similar to Eastbourne, but the measurements start from the year 1904 (Figure 13.1.3). However, temperature has risen there only with 0.82 deg. C.

If we calculate the average values of these two sites, we will get an estimate of UK seawater temperature (Figure 13.1.4). From this figure we can conclude that seawater temperature has risen in UK with 0.92 deg. C. This rise has happened during the last 30 years.

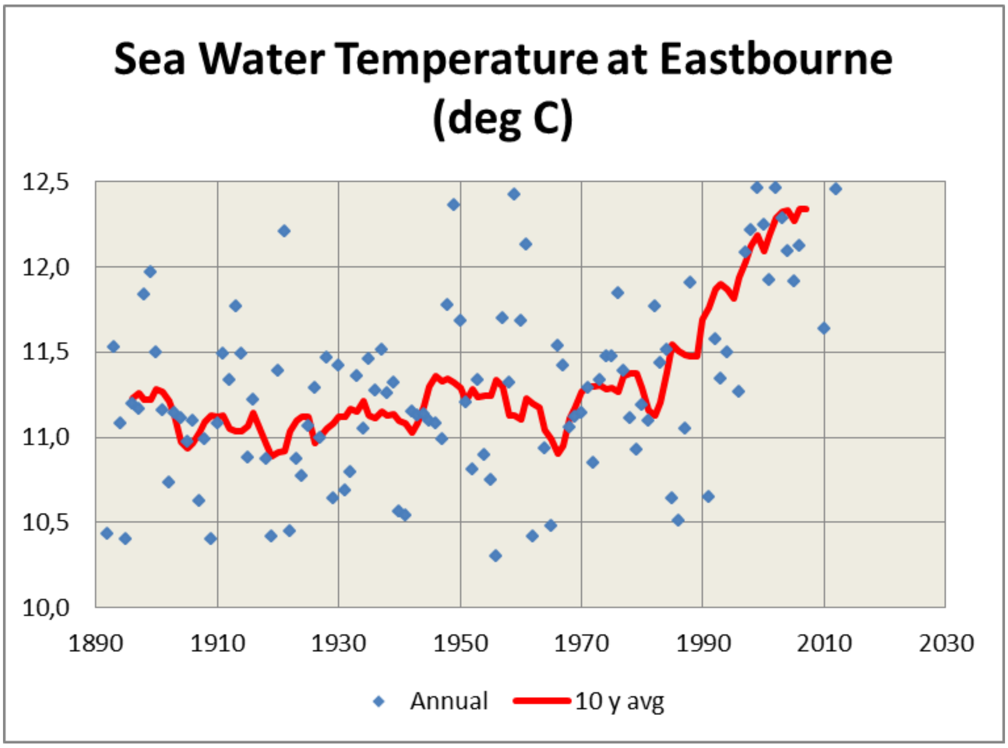


Figure 13.1.1 Temperature measurements at Eastbourne.

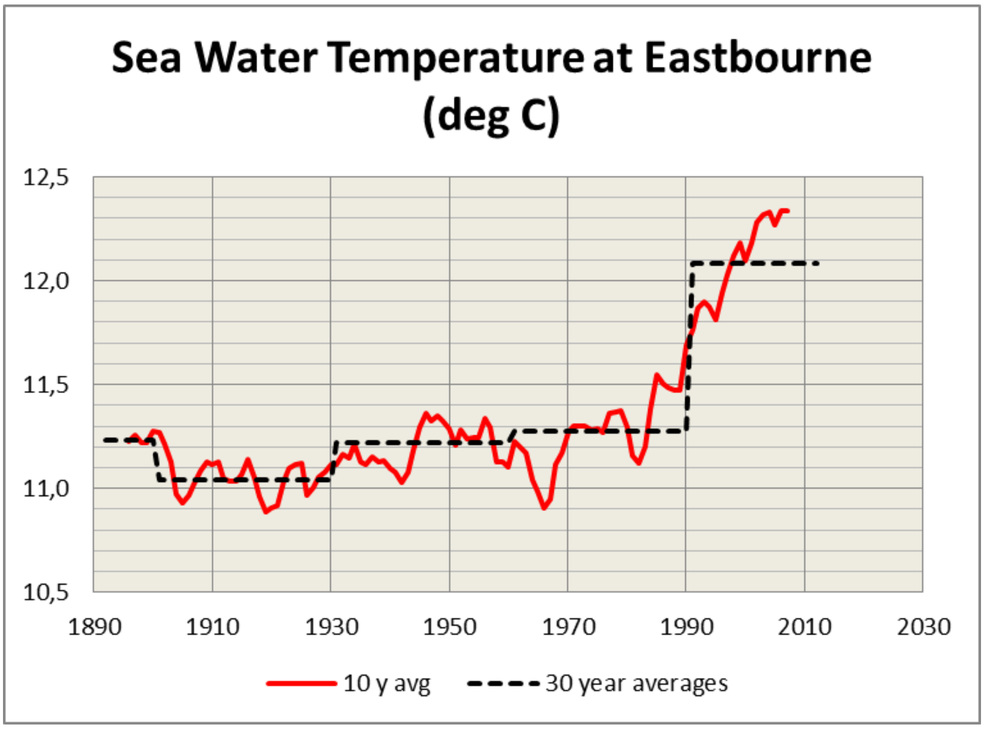


Figure 13.1.2 Temperature measurements at Eastbourne.

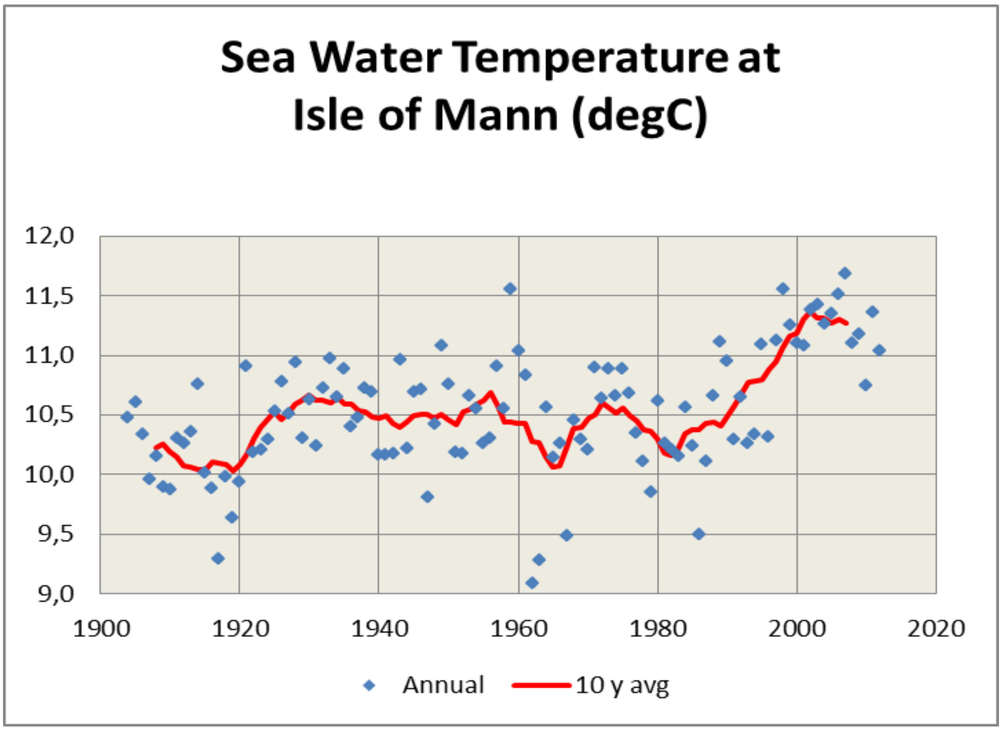


Figure 13.1.3 Temperature measurements at Isle of Mann.

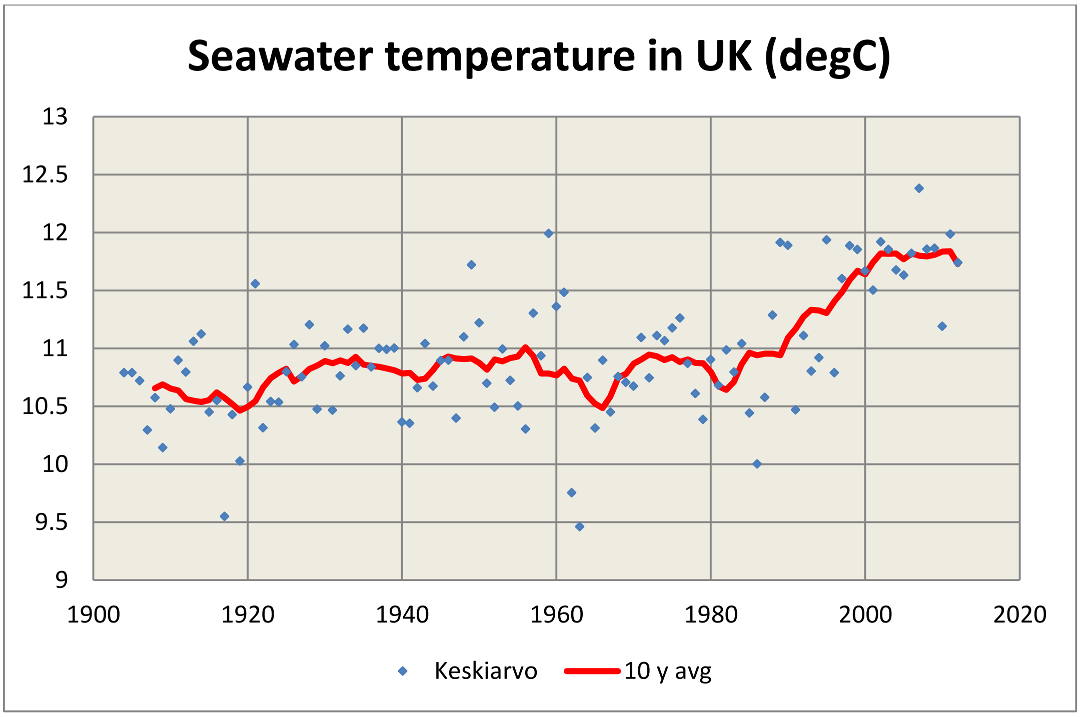


Figure 13.1.4 Temperature measurements in UK (average of Eastbourne and Isle of Mann).

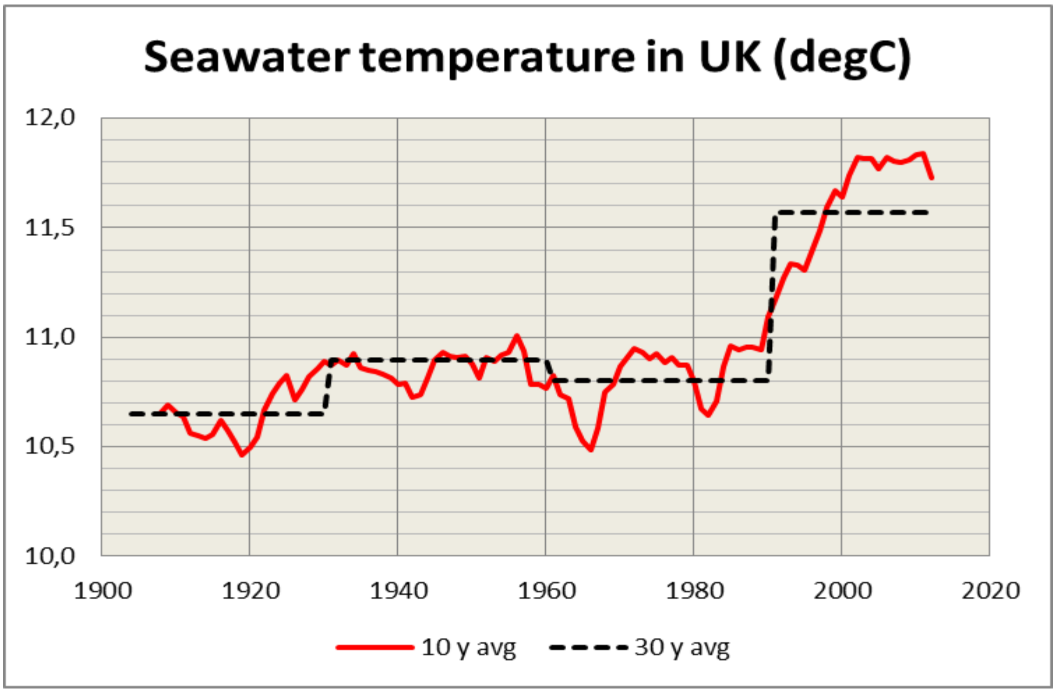


Figure 13.1.5 Temperature measurements in UK (average of Eastbourne and Isle of Mann).

13.2 Temperatures in Atlantic Ocean

Temperatures of the sea water can be downloaded from World Ocean Atlas (WOA), which is maintained by National Oceanic and Atmospheric Admininstration (NOAA). The temperature measurement curves during years 2005 – 2013 at 10 m depth show that average annual temperatures at 30^o lattitude are between 20 – 26 deg in the Atlantic and between 18 – 23 deg. C in the Pacific. At 60^o lattitude the temperaures are between 6 – 10 deg. C in the Atlantic and 4 – 5 deg. C in the Pacific (Figure 13.2.1).

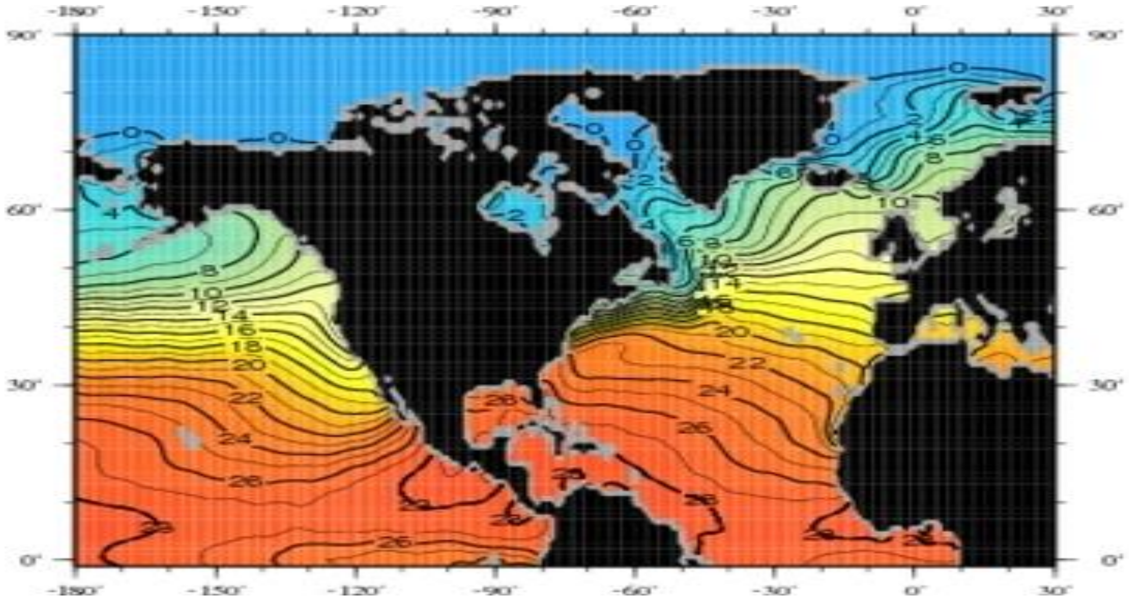


Figure 13.2.1 Annual temperatures at 10 m during 2004–2013 (WOA).

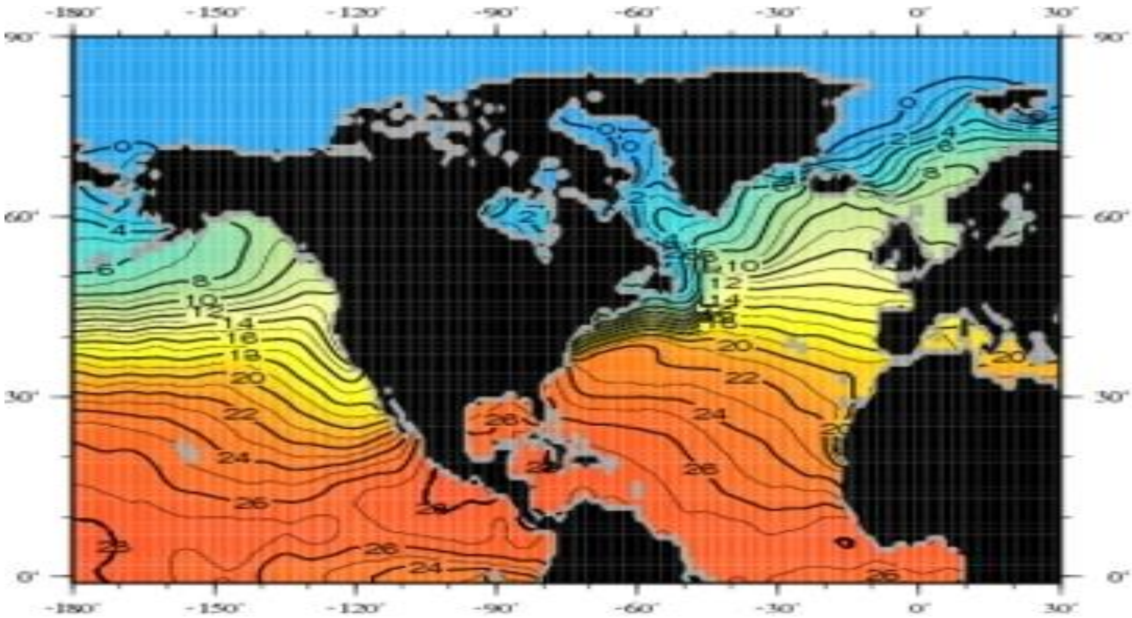


Figure 13.2.2 Annual temperatures at 10 m during 1955–1964 (WOA).

The same curves during years 1955 – 1964 show that average annual temperatures at 30° Lattitude are also between 20 – 26 deg. C in the Atlantic (Figure 13.2.2) and between 18 – 22 deg. C in the Pacific. At 60° Lattitude the temperatures are between 6 – 10 deg. C in the Atlantic and between 2 – 4 deg. C in Pacific. It is difficult to find warming during these 50 years.

However, temperature fluctuates considerably from January to July. Temperatures of the seas at 10 m depth are at 50° N are about 13 deg. C in Atlantic in average. During January the temperatures in Atlantic are at 50°N about 10 – 12 deg. C (Figure 13.2.3). During August they are at 15 – 17 deg. C (Figure 13.2.4). The difference is about 5 deg. C and it comes from the influence of the warming in the summer and cooling in the winter.

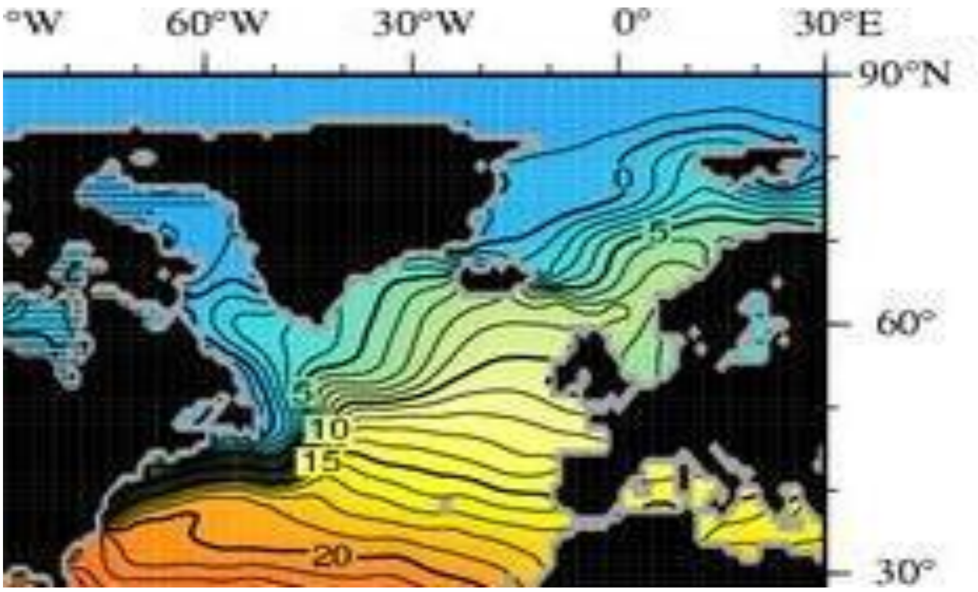


Figure 13.2.3 Temperatures in the seas at 10 m depth in January (WOA).

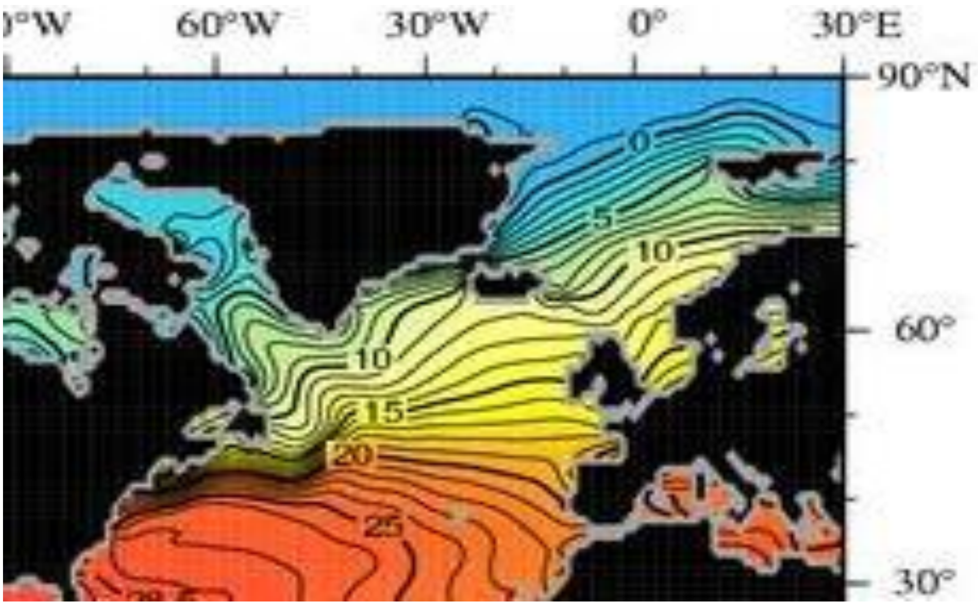


Figure 13.2.4 Temperatures in the seas at 10 m depth in August (WOA).

Size of North Atlantic is about 5000 km x 5000 km. It has about 2.5 E17 kg of water. If this water is heated with 5 deg. C, the energy needed is 5.25 million PJ (Peta Joule). Energy content of 5.2 million PJ corresponds to 124 000 million tons of oil equivalent (Mtoe). World is using about 13.000 Mtoe of primary energy. Thus the energy storage of North Atlantic corresponds to 10 times of annual world energy consumption. This is a factor which will influence to the climate in Europe remarkably. It will warm up the winters and cool the summers.

It has been estimated earlier that the air temperature will be in average 2.5 deg. C warmer in 2100 than in 1960, when the measurements of CO_2 were started. This will mean that seawater should be warming. However, in some areas water will be evaporating, which will cool the water and keep the surface temperature rather constant.

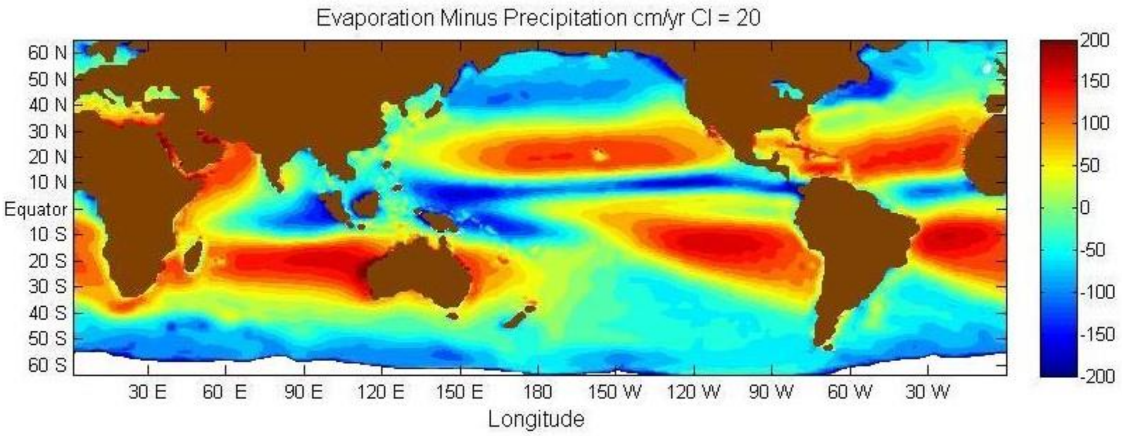


Figure 13.2.5 Evaporation minus precipitation in world oceans (Source: Wood Hole Oceanographic Institution).

13.3 Gulf Stream

We were told in the school that Finland and whole North Europe is warm because of the Gulf Stream. Gulf Stream was said to bring warm water to North Atlantic and thus warming North Europe. This theory of warming Gulf Stream was invented 150 years ago by Benjamin Franklin, who made a map of the stream in the late 1700s (Figure 13.3.1).

We were also told that the Gulf Stream has its origin from the rotation direction of the earth. The earth is moving rapidly to the east and the air is not. Thus prevailing winds blow to the East in the equator.

Figure 13.3.1 Map of the Gulf Stream made by Benjamin Franklin.

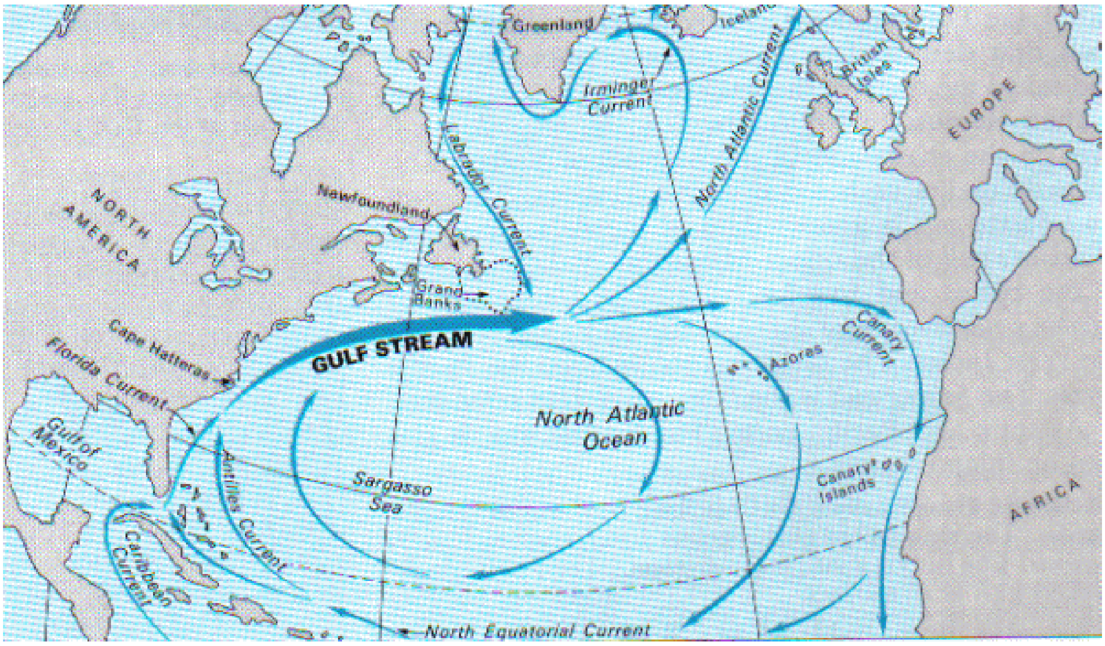


Figure 13.3.2 Gulf Stream.

A better picture of the Gulf Steam (Figure 13.3.2) shows how the Stream has its origin near Canary Islands. It is streaming from there to Caribbean islands, where the Gulf Stream is pumping warm water through the U.S. East coast and from there into North Atlantic and to Europe.

The influence of the Gulf Stream can be seen in January, when the sea water at 10 m depth in about 5 deg. C at 70^o Latitude near Norway (Figure 13.2.3). The same 5 deg. C line goes at 50^o latitude near Canada. The main cause of the North Atlantic current is the winds which blow counter clockwise in North Atlantic. The Low Pressure Center is typically near Island.

Some say that the Gulf Stream may stop completely. There was a movie "A day after Tomorrow", where this happened. However, this is very difficult to see, because Gulf Stream has been caused by the winds. They blow near the equator to west and in North Atlantic to Northeast. The driving force is the wind not the salt content of the sea.

The temperature may drop very soon only, if a meteor will hit the ground. This kind of crass happened 60 million years ago in Yucatan peninsula. There is still a crater known as the Chicxulub, which is 20 km deep by 180 kilometers wide. This collision killed about 80 % of known species on the earth.

13.4 ENSO

Changes in winds and sea currents happen in Pacific Ocean, which have El Nino oscillations or El Nino Southern Oscillation (ENSO). ENSO is a change in seawater temperatures, which happen periodically near the equator. Normally trade winds blow from east coast of South America to west and water becomes warmer in west side of Pacific Ocean.

El Nino

During El Nino the wind blow from west to east and bring warm water to the coast of South America and seawater surface temperature (SST) increases (Figure 13.4.1).

During El Nino months from December to February coast of South America becomes warm and wet (Figure 13.4.2) and during June to August dry and warm (Figure 13.4.3).

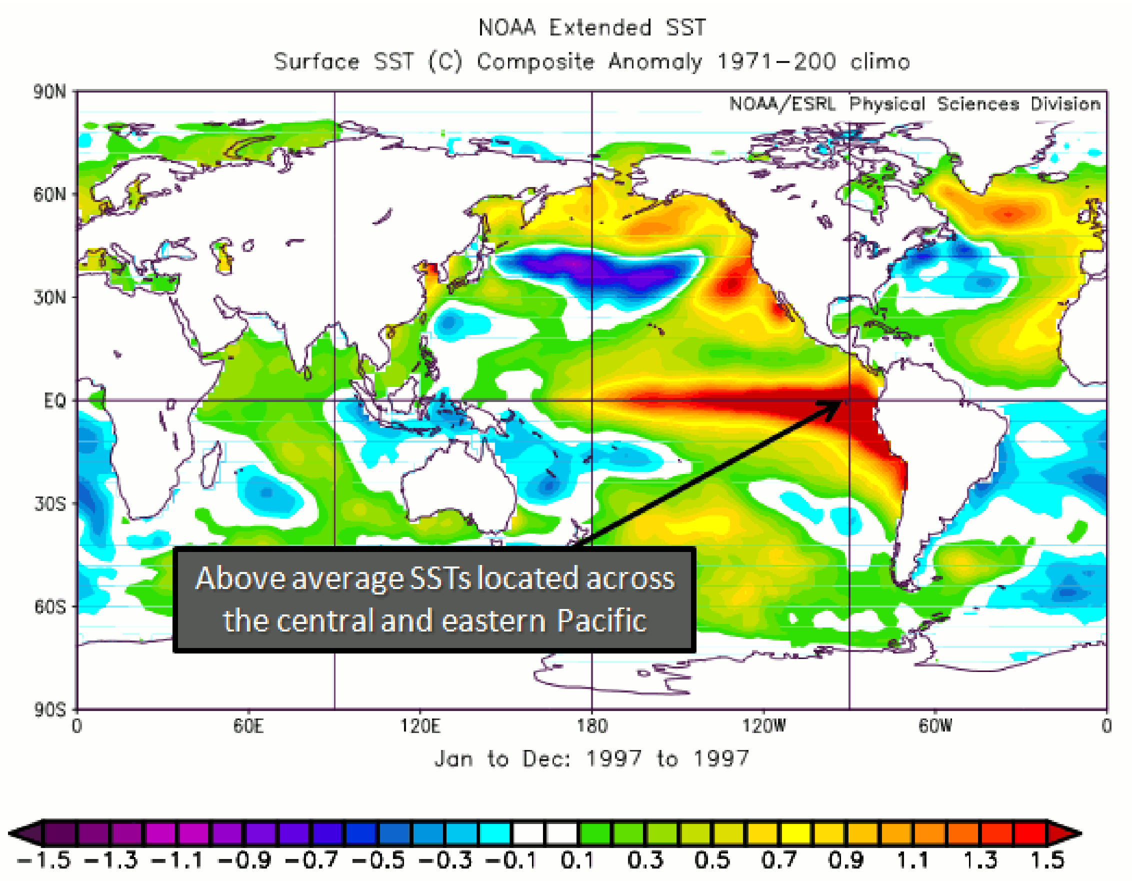


Figure 13.4.1 El Nino causes seawater surface temperature (SST) rise near the coast of South America (Source NOAA).

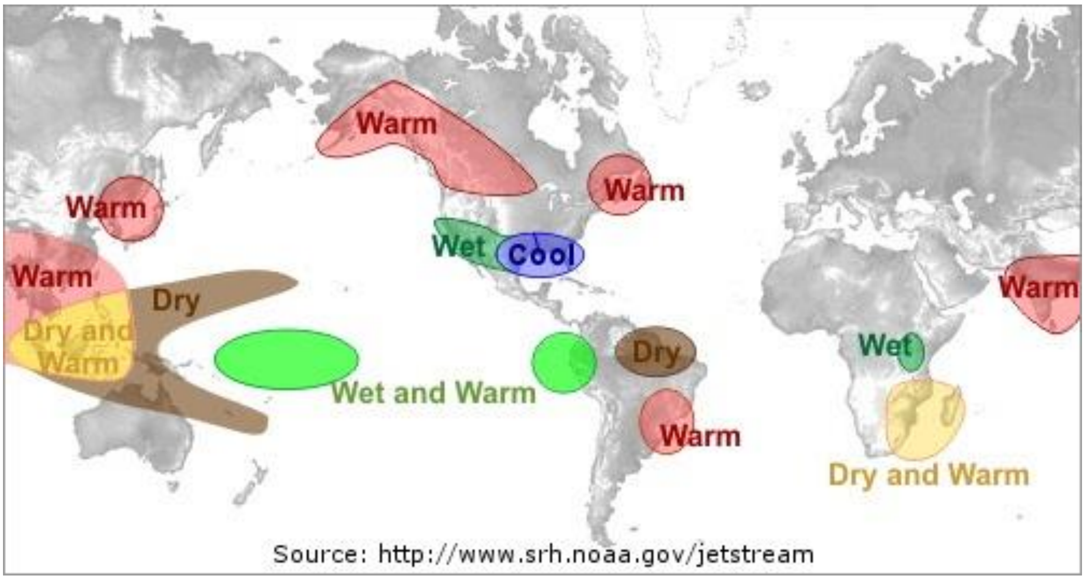


Figure 13.4.2 El Nino months from December to February (NOAA).

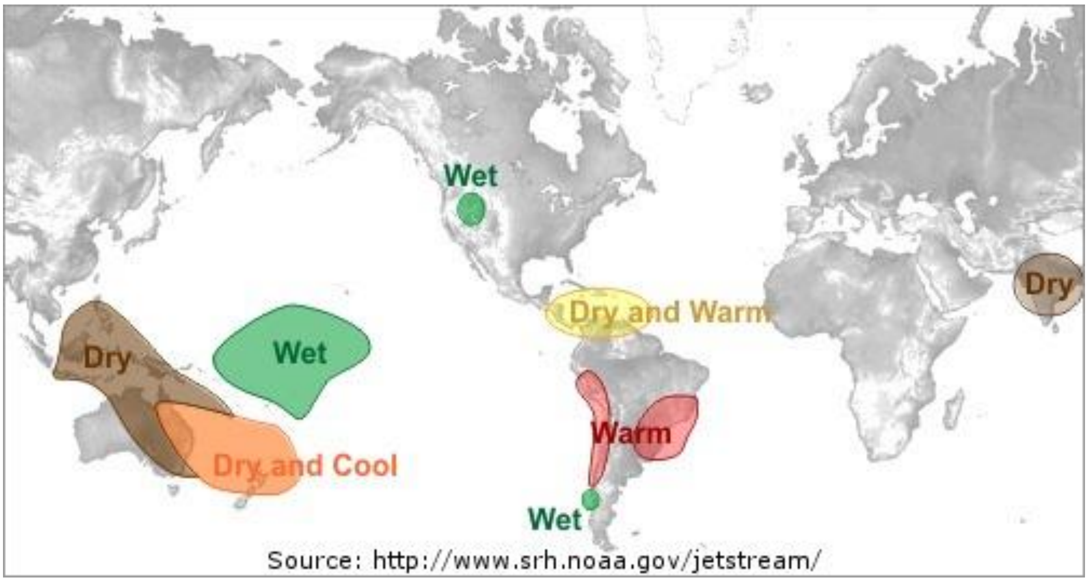


Figure 13.4.3 El Nino months from June to August (NOAA).

La Nina

Another phase of ENSO is La Nina, when the winds start to blow from east to west and seawater surface temperature becomes colder in the west coast of South America (Figure 13.4.4).

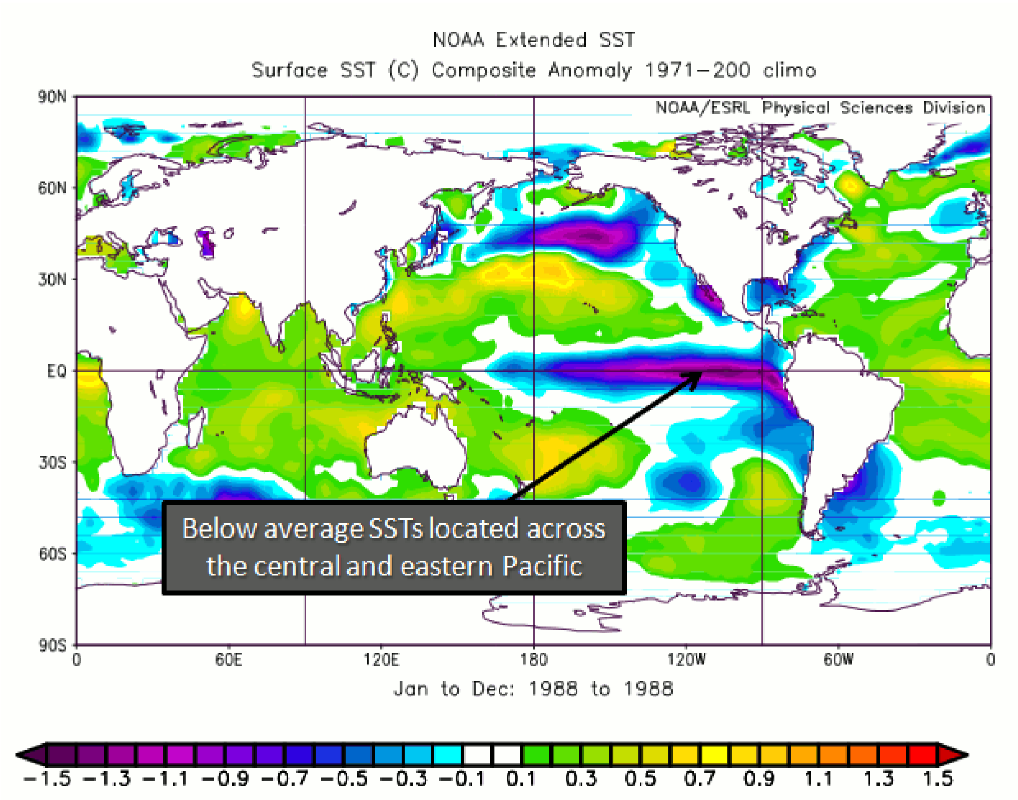


Figure 13.4.4 During La Nina seawater surface temperature (SST) becomes lower.

During La Nina months from December to February coast of South America becomes dry and cool (Figure 13.4.5) and during June to August wet and cool (Figure 13.4.3).

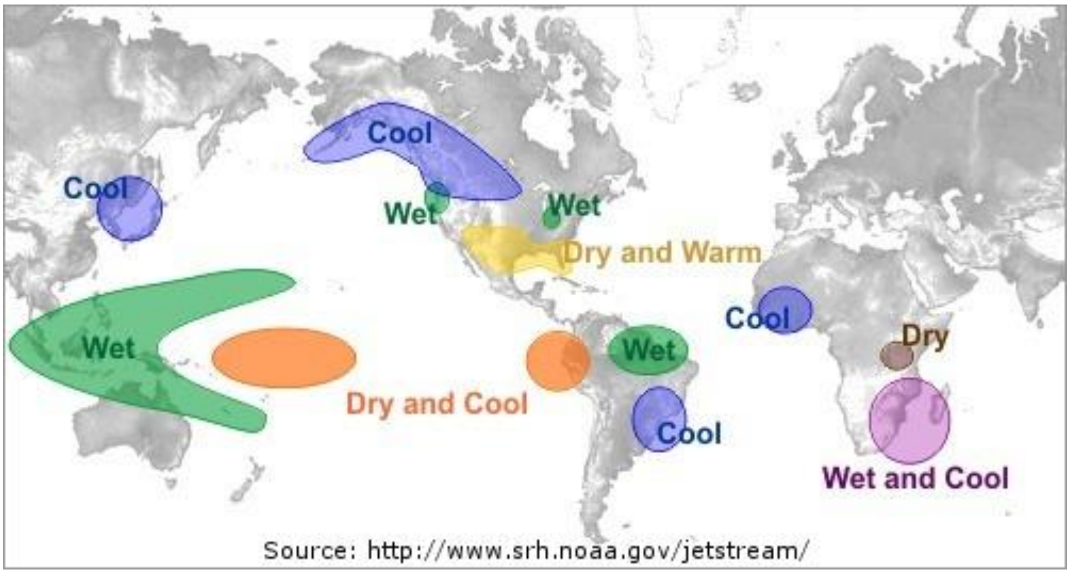


Figure 13.4.5 La Nina months from December to February (NOAA).

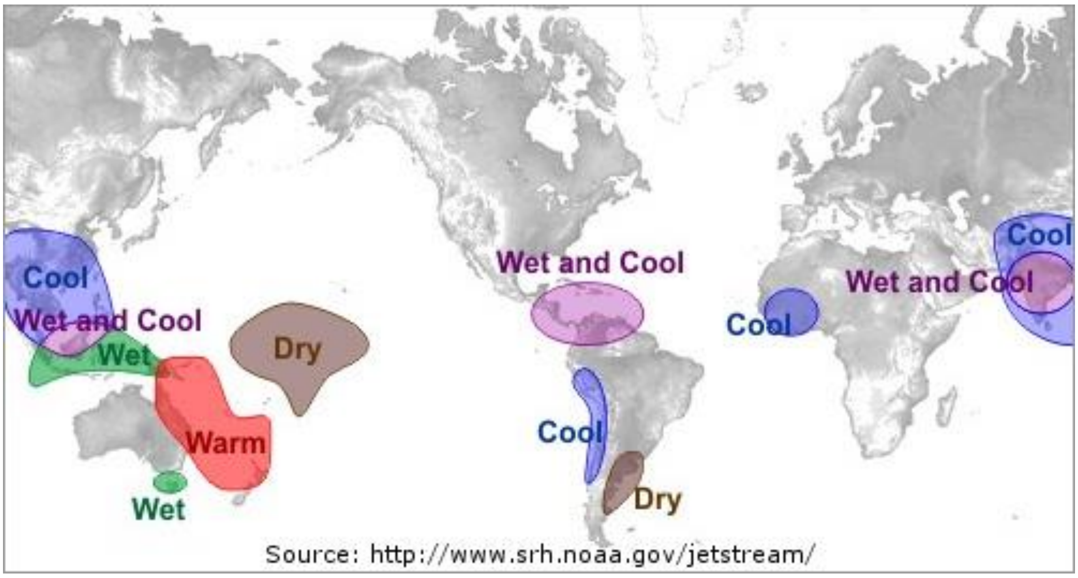


Figure 13.4.6 La Nina months from June to August (NOAA).

14 PRECIPITATION

14.1 Global trends

Global warning should make waters in the seas warmer and should therefore increase precipitation. Precipitation data has been collected by Environmental Protection Agency (EPA) (http://www3.epa.gov/climatechange/science/indicators/weather-climate/precipitation.html). This data shows that there has been a trend of 20 mm increase in precipitation within 113 years or 18 mm/century (Figure 14.1.1).

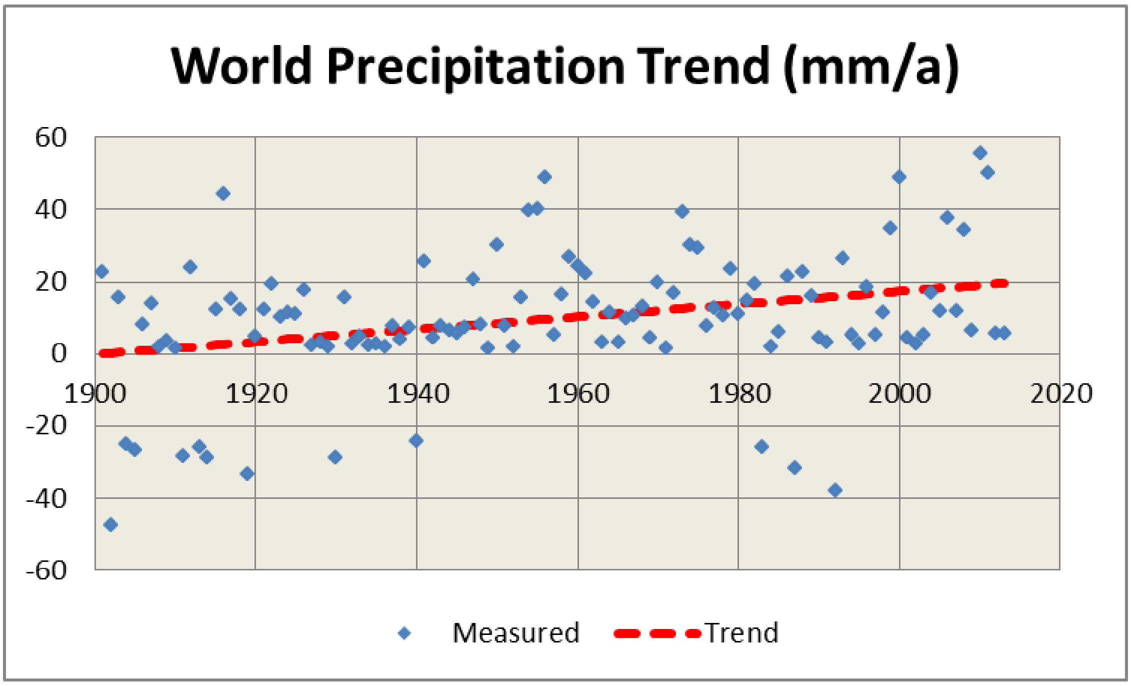


Figure 14.1.1 Trend in world precipitation since 1901 (EPA).

Increase in precipitation will mean that hydro power resources will be increasing. Today about 4000 TWh of electricity is generated by hydro (Figure 14.1.2). This is 16.5 % of total electricity consumption or 570 kWh per capita. In the year 1990 about 18 % of electricity was generated by hydro power. This means that the majority of future consumption should be generated by another sources. In Africa the resources are so large that many countries can satisfy the need totally with hydroelectricity.

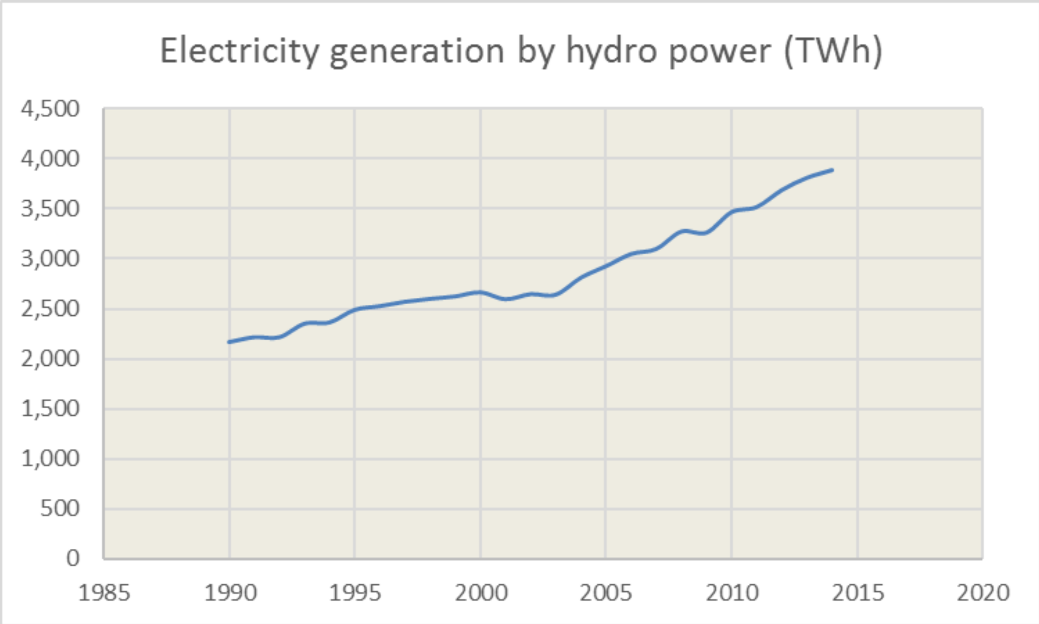


Figure 14.1.2 Electricity generation by hydro (BP).

14.2 Precipitation in US

US precipitation values have been downloaded from the same EPA site as global values given in chapter 14.1. The US trend shows clearly higher increase than the world (Figure 14.2.1). Precipitation has been increasing with 46 mm within 114 years or 40 mm in a century. However, there are states, where the annual precipitation is more than 30 inches (750 mm) (Green areas in Figure 14.2.2). In some areas the precipitation is less than 5 inches (250 mm red areas in Figure 14.2.2).

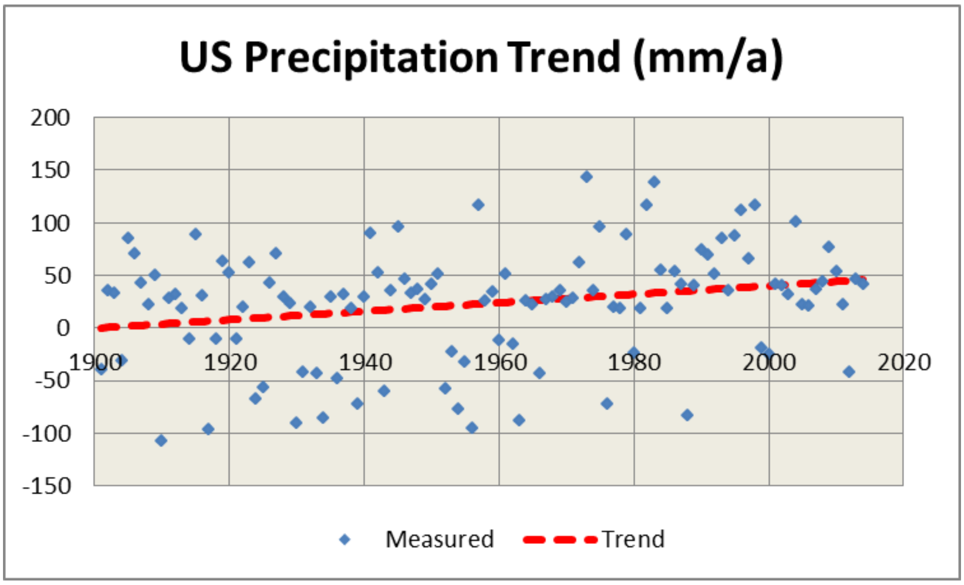


Figure 14.2.1 US precipitation trend since 1901 (EPA).

Figure 14.2.2 Average precipitation in USA 1961 – 1990. (Public Domain, https://commons.wikimedia.org/w/index.php?curid=666565).

There are areas in USA, where the drought has been increasing and decreasing. Increasing areas are in California and Texas and decreasing areas are from Florida to New York (Figure 14.2.3).

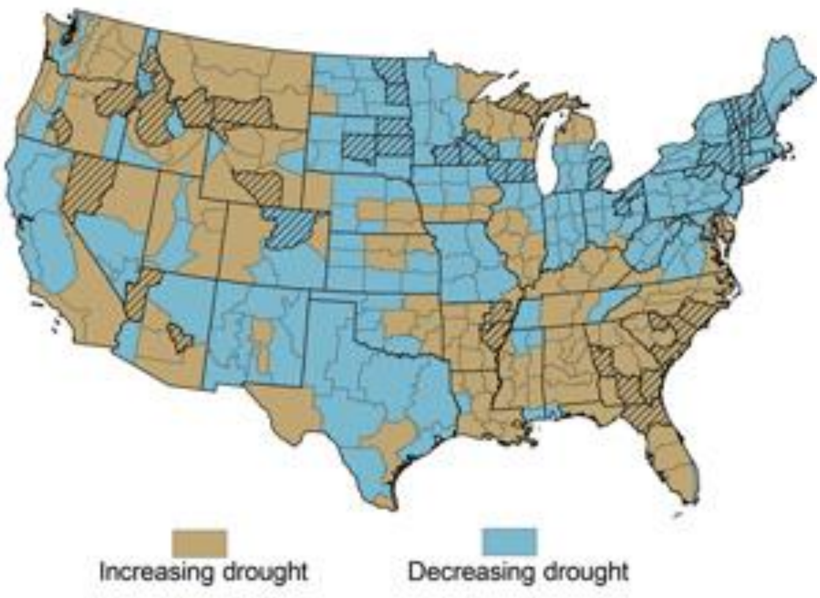


Figure 14.2.3 Impact of global warming to US states.

14.3 Precipitation in UK

Precipitation data from UK has been downloaded from MetOffice data base. It starts from the year 1853 in Oxford (Figure 14.3.1), from 1873 from the year 1973 in Stornoway (Figure 15.3.2) and from 1880 in Durham (Figure 14.3.3).

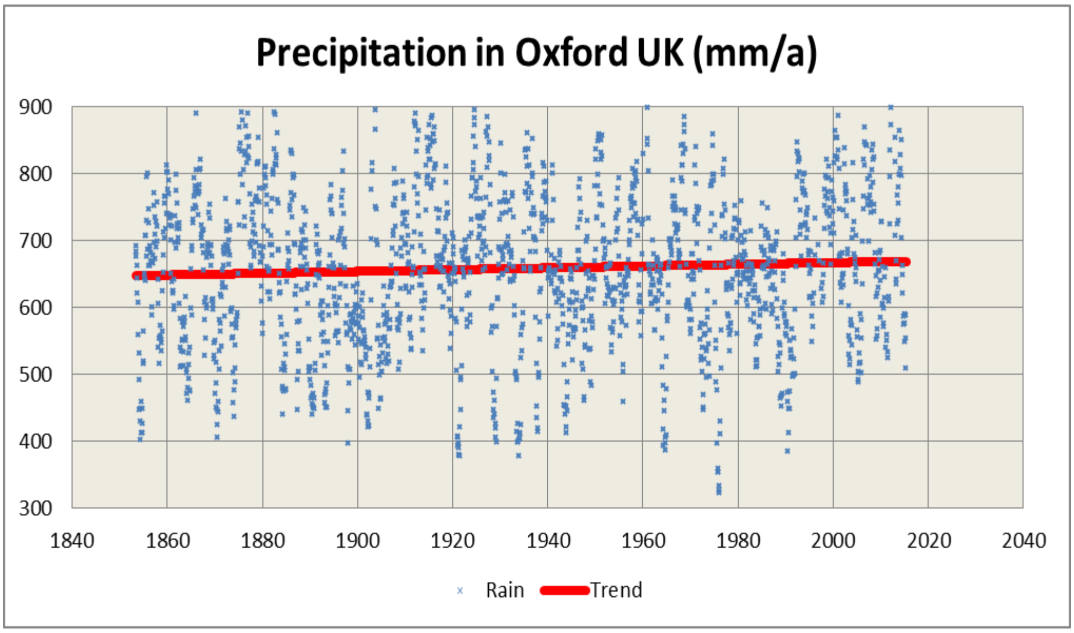


Figure 14.3.1 Precipitation in Oxford since 1853 (mm/y) (Source MetOffice).

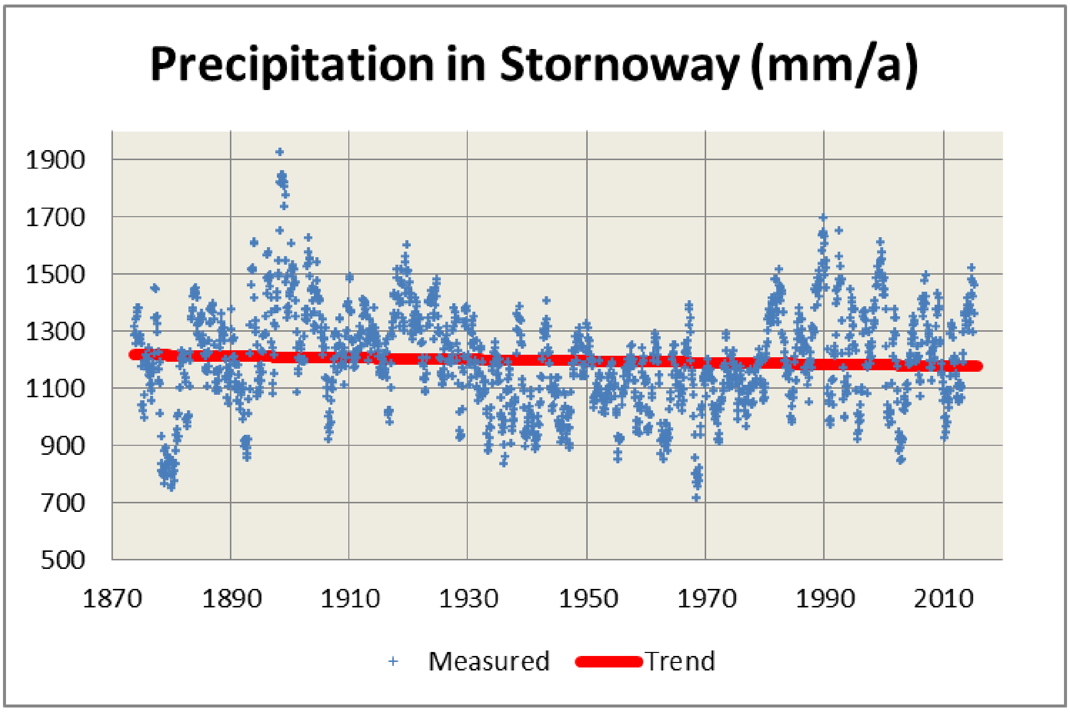


Figure 14.3.2 Precipitation in Stornoway since 1873 (mm/y) (Source MetOffice).

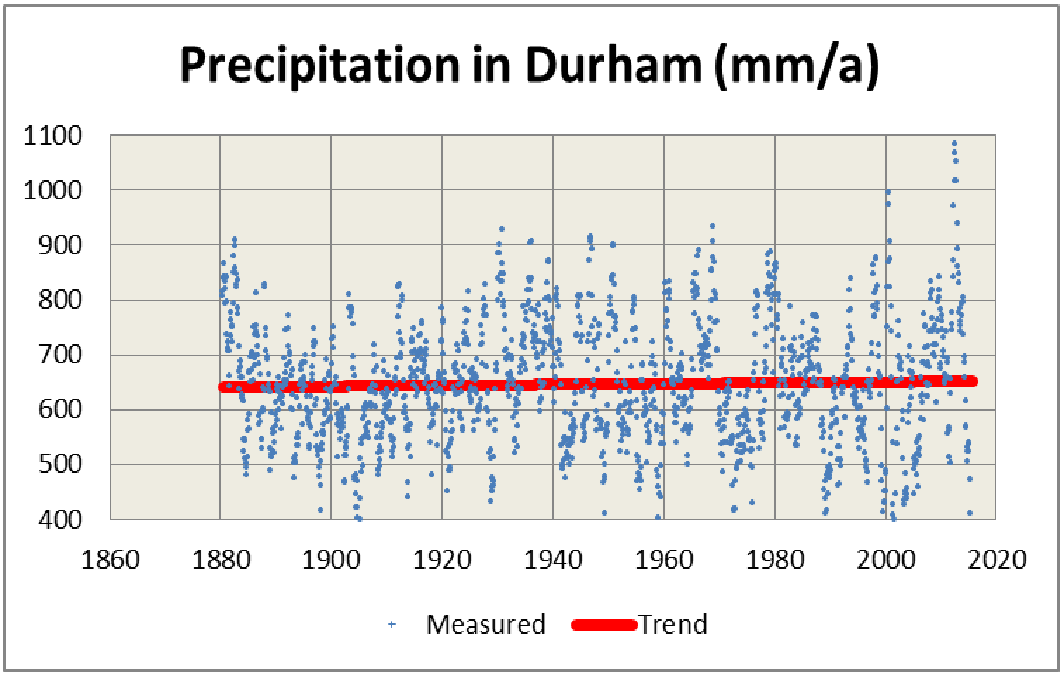


Figure 14.3.3 Precipitation in Durham since 1880 (mm/y) (Source MetOffice).

After the year 1900 precipitation has been slightly increasing in Oxford 32 mm and Durham 15 mm. Precipitation in Stornoway has been decreasing 42 mm. Average figures of the three site indicate that precipitation has been quite stable (Figure 14.3.4).

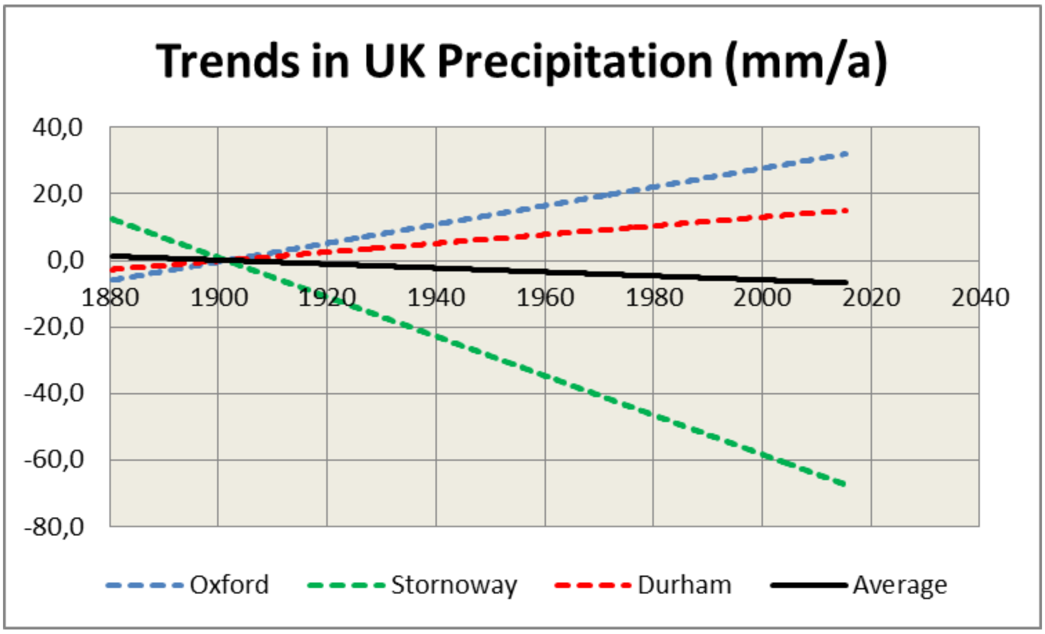


Figure 14.3.4 Precipitation in UK since 1880 (mm/y) (average from Oxford, Stornoway and Durham).

14.4 Precipitation in Africa

The hunger statistics indicate that Africa has been the most difficult area in the world, because about 20 % of people are still undernourished. This is caused by the fact that precipitation has been declining since 1968 (Figure 14.4.1) and there are large variations between the years by African Environmental Outlook by UNEP.

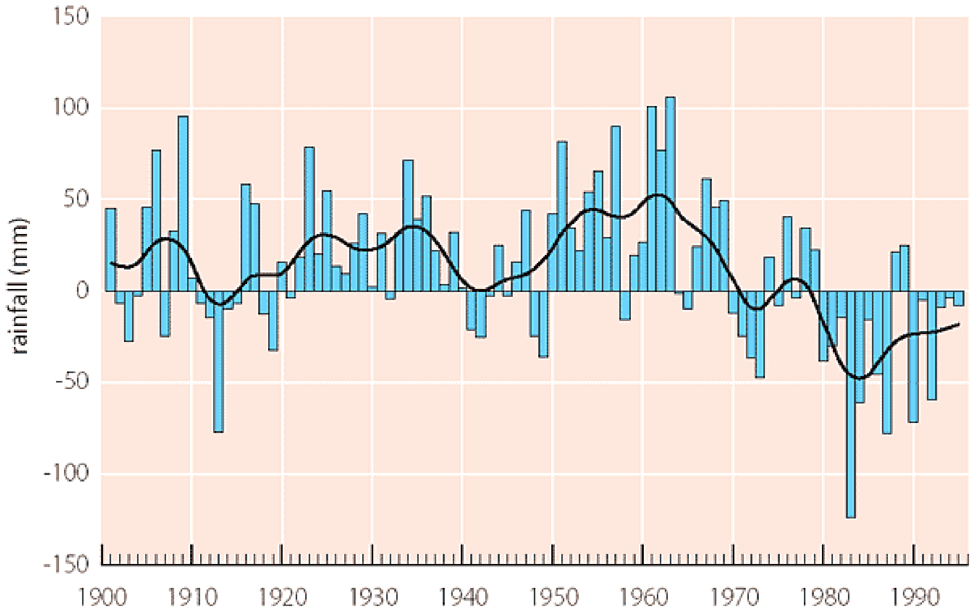


Figure 14.4.1 Precipitation changes in Africa since 1900 (UNEP).

The precipitation is also concentrated in Central Africa, but there are areas, where the annual precipitation remains below 200 mm (Figure 14.4.2). These areas can be found in North- and East Africa. In Ethiopia the 1984 draught caused 1 million deaths and 9 million affected.

The excess rains in 1997 caused floods in Kenia, which destroyed houses and roads. This was probably caused by ENSO phenomenon, which was described in chapter 13.4. The solution of the problem could be cereal storages, which would last over dry seasons.

Latest draught was experienced in East Africa from July 2011 to August 2012, when about 10 million people needed aid and about 50,000 – 200,000 people starved in Ethiopia, Somalia, Djibouti and Kenia.

The cause of the crises was unusual La Nina, which interrupted rains in the area for two consecutive seasons. The precipitation in some areas was 70 % lower than in normal years. Without water the crop was destroyed and cattle found nothing to eat. Thus the people started to eat their cattle and after the cattle was eat they started to move from their farms to population centers to search for food.

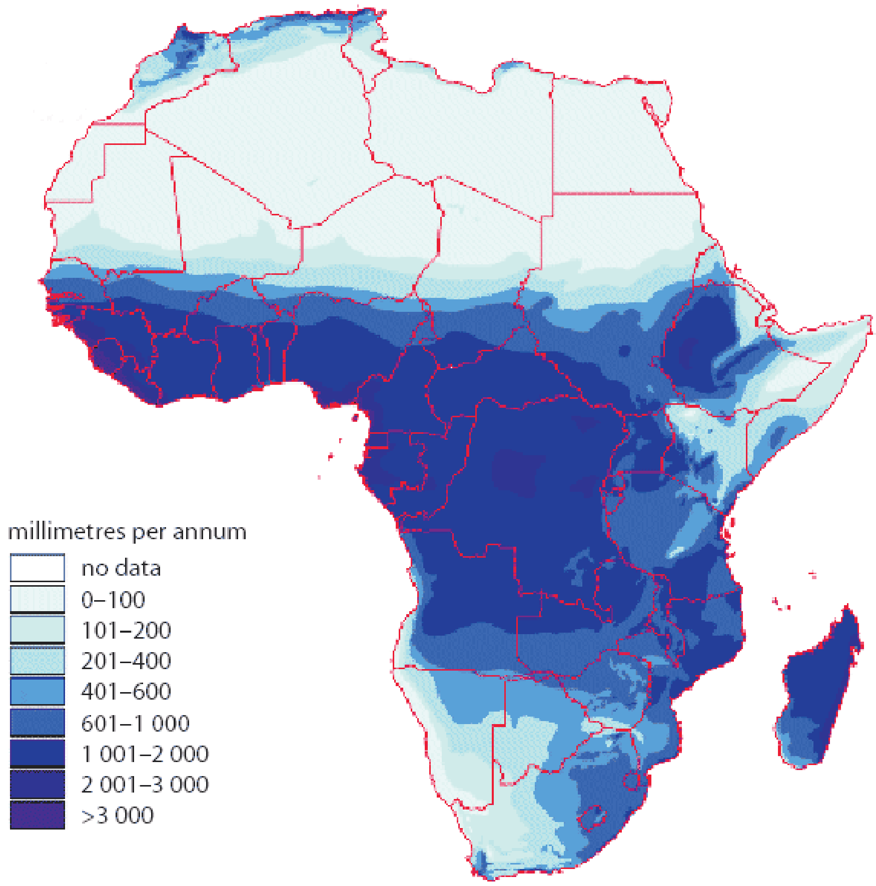


Figure 14.4.2 Precipitation map of Africa (UNEP).

Africa has large hydro power resources. One of the countries with large hydro resources is Democratic Republic of Congo. Today only 2400 MW of hydro is in operation and 4300 MW is under planning stage. Thus about 6700 MW of hydro capacity will be available and about 40 TWh of hydroelectricity will be generated in the near future. The largest potential has the River Congo, which could have the largest hydro plant in the world with 40 000 MW capacity.

Another country is Ethiopia, which has 660 MW hydro capacity in operation and 2150 MW under construction. There are 7500 MW capacity in various stages of planning. Thus in future about 10.000 MW of hydro power will be in operation and about 50 TWh of hydroelectricity can be generated.

Zambia and Ghana have 1730 MW and 1180 MW of hydro capacity in operation. Additionally, about same order of magnitude of new hydro capacity is on the planning stage. Thus only in these four countries will have 30,000 MW of hydro capacity in the near future and the hydro generation would be 150 TWh. This is almost the same as the whole Africa is generating today (155 TWh).

14.5 Precipitation in India

India is also a difficult area for food production. It has dry areas in west and wet areas in east (Figure 14.5.1). However, the dry areas with less than 20 inches (50 mm) of rain are mainly in Pakistan, which was part of India some years ago, before India was divided. On the other hand the east part of India is rainy and most of it belongs to Bangladesh.

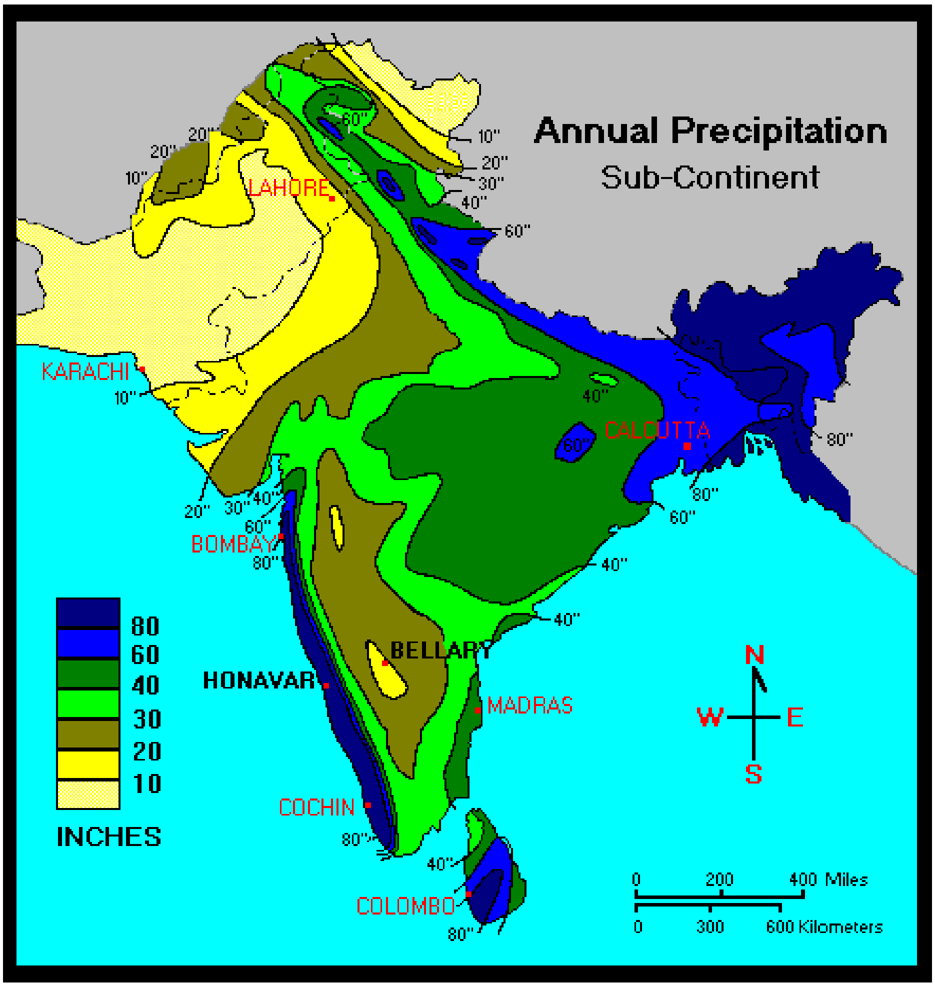


Figure 14.5.1 Precipitation map of India (Source: Prof. Paul R. Baumann Department of Geography State University of New York, College at Oneonta Oneonta, NY 13820).

The biggest problem there are the heavy monsoon rains, which might destroy the houses, roads and bridges every now and then. Monsoon is caused when the wet air from the Indian Ocean hits the mountains in the west coast and wind go up and the air comes cooler. Cooler air cannot hold the moisture, which causes heavy rains during the monsoon season from June to October (Figure 14.5.2).

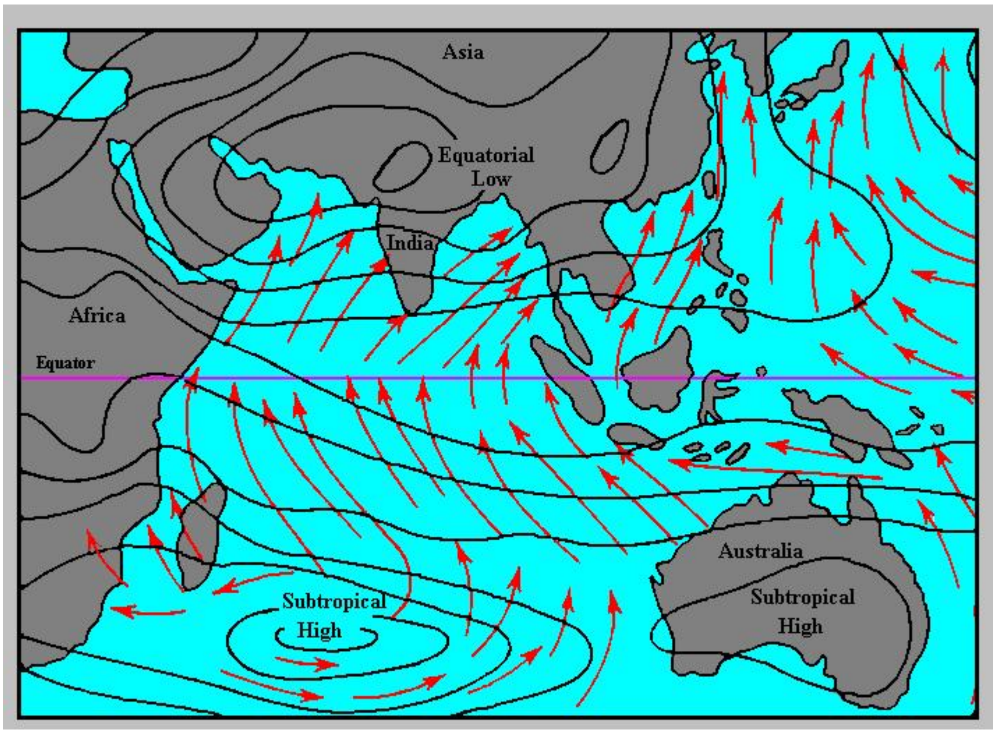


Figure 14.5.2 Winds in July in Indian Ocean.

India receives annually 4000 km^3 of fresh water with annual rainfall of 1170 mm. The water of the big rivers in India can be used for generating electricity, irrigation and potable water purposes.

India has 38,000 MW of hydro power capacity in operation and it is generating 131 TWh of electricity by hydro. Today only 11 % of electricity consumption of 1200 TWh can be satisfied with hydro power. Additionally, the economical feasible hydro capacity of India is 440 TWh. However, the consumption is increasing rapidly and will be about 3000 TWh by the year 2030 and less than 15 % of electricity consumption can be satisfied with hydroelectricity.

14.6 Precipitation in Finland

Precipitation data in Finland has been collected from the year 1886 at five sites by Finnish Meteorological office. They show that precipitation has been quite stable from the years 1886 – 1935 to years 1980 – 2010 (Table 14.6.1). The average figures indicate that the annual precipitation has increased in two sites and decreased in three sites. Thus the average figures show 9 mm decrease in precipitation from the year 1915.5 to 1995.5 or within 80 years. Thus the decrease is about 11 mm in a century.

Table 14.6.1 Precipitation in mm in Finland (Finnish Meteorological Institute).

Years 1886-1935	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	55,3	43,4	42,7	41,5	48,2	50,8	58,8	82,8	72,5	73,8	67,7	61,8	699,3
Tampere	40,1	33,1	33,8	34,5	44,7	62,5	72,8	78,9	65,7	64,7	48,9	47,9	627,6
Maarianhamina	40,0	30,3	30,2	32,2	38,9	36,0	53,0	70,9	56,6	66,1	52,6	50,6	557,4
Oulu	37,3	27,4	25,8	30,5	37,4	46,7	63,0	70,2	56,5	56,2	42,8	38,6	532,4
Sodankylä	26,8	25,0	19,5	29,7	38,5	56,4	75,2	75,0	53,4	47,2	39,5	33,9	520,1
Average	39,9	31,8	30,4	33,7	41,5	50,5	64,6	75,6	60,9	61,6	50,3	46,6	587,4

Years 1980-2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	52	36	38	32	37	57	63	80	56	76	70	58	655
Tampere	41	29	31	32	41	66	75	72	58	60	51	42	598
Maarianhamina	53	35	38	31	35	53	52	76	61	70	71	59	634
Oulu	31	26	26	20	37	46	71	65	44	45	36	30	477
Sodankylä	34	29	30	29	41	56	74	66	49	46	39	34	527
Average	42	31	33	29	38	56	67	72	54	59	53	45	578

Increase	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Helsinki	-3	-7	-5	-10	-11	6	4	-3	-17	2	2	-4	-44
Tampere	1	-4	-3	-3	-4	4	2	-7	-8	-5	2	-6	-30
Maarianhamina	13	5	8	-1	-4	17	-1	5	4	4	18	8	77
Oulu	-6	-1	0	-11	0	-1	8	-5	-13	-11	-7	-9	-55
Sodankylä	7	4	11	-1	3	0	-1	-9	-4	-1	-1	0	7
Average	2	-1	2	-5	-3	5	2	-4	-7	-2	3	-2	-9

There have been changes in monthly precipitation numbers but the annual average has not changed hardly at all (Figure 14.6.1). The precipitation curve follows monthly temperatures so that the smallest figures are found in February and March and highest numbers in August.

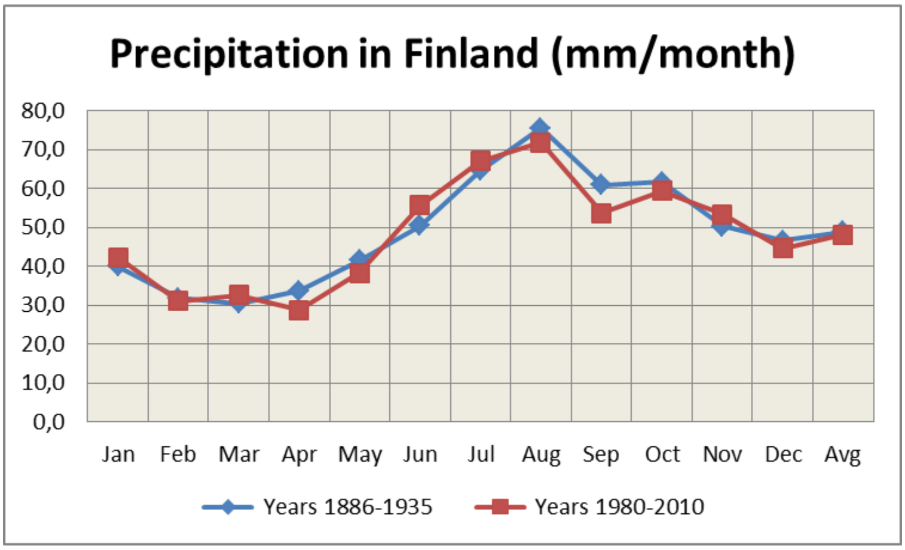


Figure 14.6.1 30-year average precipitation figures in five sites in Finland in years 1886 – 1991 and 1981 – 2010 show that precipitation has changed only in some months.

The annual average rainfall in Finland has been 600 mm. However, with this about 13 TWh of electricity (2400 kWh/capita) is generated annually. This is only 15 % of total electricity demand of the country today, but hydroelectricity could fulfill all the demand until the year 1965.

15 SMELTING OF ICE AND GLAZIERS

15.1 Glaziers

History of world climate is stored in glaziers, which have samples of water in form of ice from the last 100.000 years and even more. From this data we can find the last ice age, which was ending about 10.000 years ago. The temperature deviations from the ice can be read from O18/O16 ratio (Figure 15.1.1). Before the last ice age there were warm period 100 000 years ago, when temperature was higher than today.

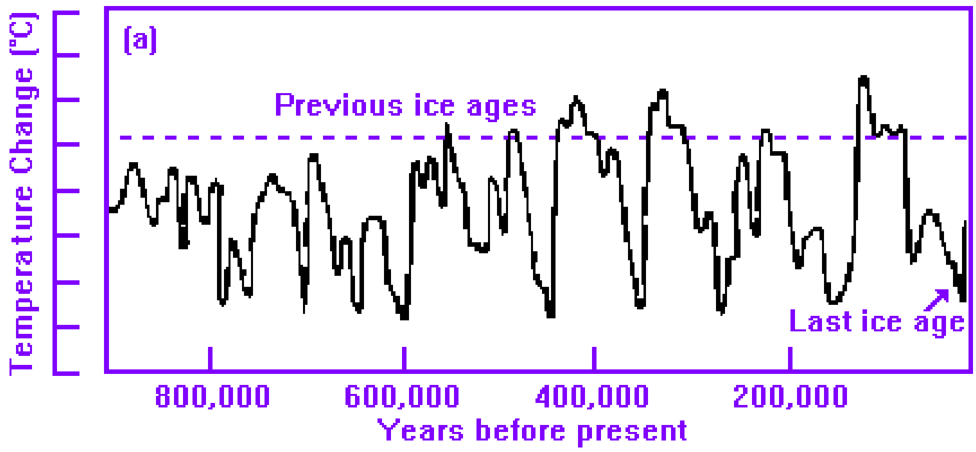


Figure 15.1.1 Last ice age ended about 10 000 years ago. Before it there has been many ice ages and warm periods.

The ice ages are following the Milankovitch cycles which depended on the orbit of the Earth on its path around the sun. The short term changes in tilt angle (obliquity) happen in 41 000/year cycle and Earth is now approaching the minimum value of the tilt angle after 11 800 years from now. This means that the north side of the globe will be cooling until the year 13 800 and warming again after this for the next 20 000 years.

Earth's orbit is changing its orbit in an ellipse in about 400 000/year cycle, where the orbit is changing from elliptical to circular orbit constantly. This will change the distance of the earth from the sun and also radiative force. Additionally, the tilt of the earth is changing such a way that the northern hemisphere is nearest the sun in summer, autumn, winter and spring after many years in row.

15.2 Changes in the ice cover

Local warming has been followed here in Finland for quite some time in a form of keeping records of dates when is cover has disappeared from the lakes and rivers. The data from ice loss from the River Tornio start from the year 1693. It is the longest separate data set of this kind climate change. The ice loss has been happening earlier than before. The linear trend of shows (Figure 15.2.1) that ice loss was 141.8 days from the first of January in 1693 and 126.8 days from the first of January in 2015. The change has been 15 days in 322 years or 4.66 years in a century.

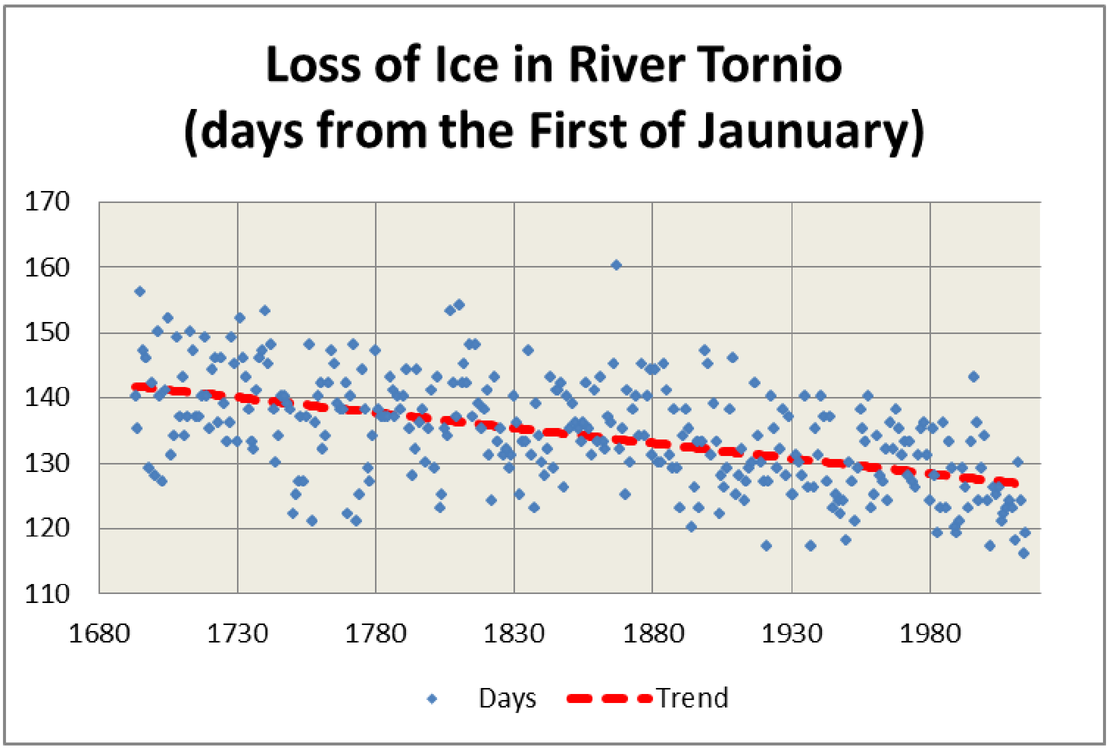


Figure 15.2.1 Days from the first of January of loss of ice in River Tornio (Source: Esko Kuusisto, Finnish Environmental Center)

If we divide the series in three separate phases, we can find that the change has been getting faster during the latest years. Form the year 1693 to 1880 the trend of change (Trend 1) was smaller than the overall trend (Figure 15.3.2). During years 1881 – 1970 the change (Trend 2) was following the overall trend. During years 1971 – 2015 the change in trend (Trend 3) was much faster than the overall trend. This indicates that the warming has been happening even faster during the last 45 years.

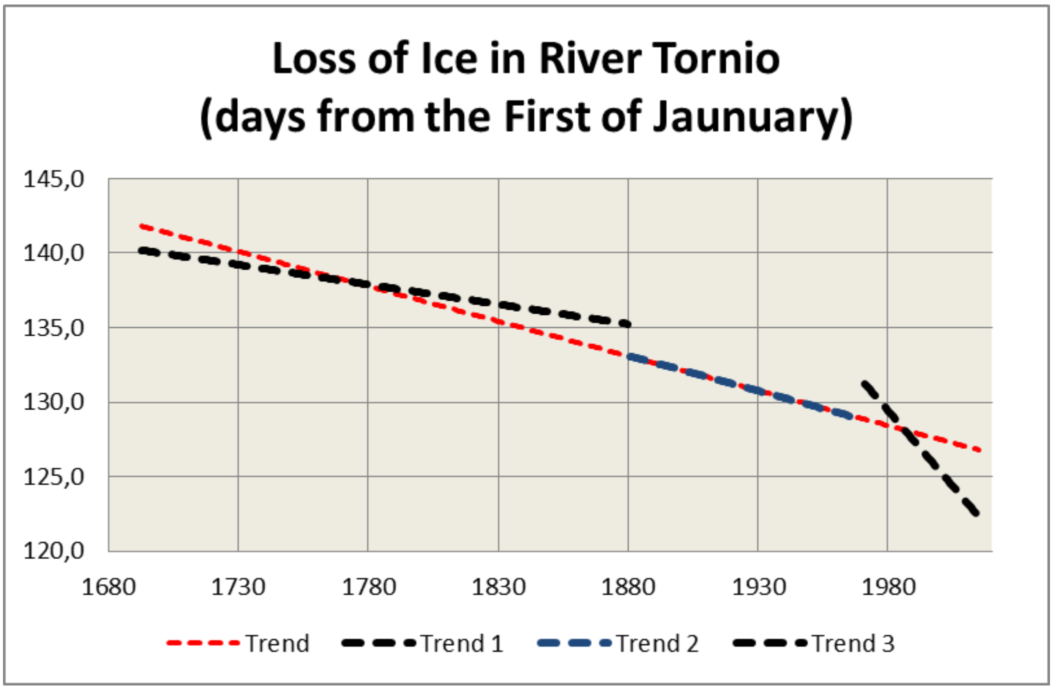


Figure 15.2.2 Trends in ice loss of River Tornio.

Temperature in Sodankylä has been measured since 1901. If we look the Sodankylä temperature data and loss of ice data from River Tornio, we find strong correlation (Figure 15.2.3). If temperature rises with 2.5 deg. C, the ice release date will change with 30 days.

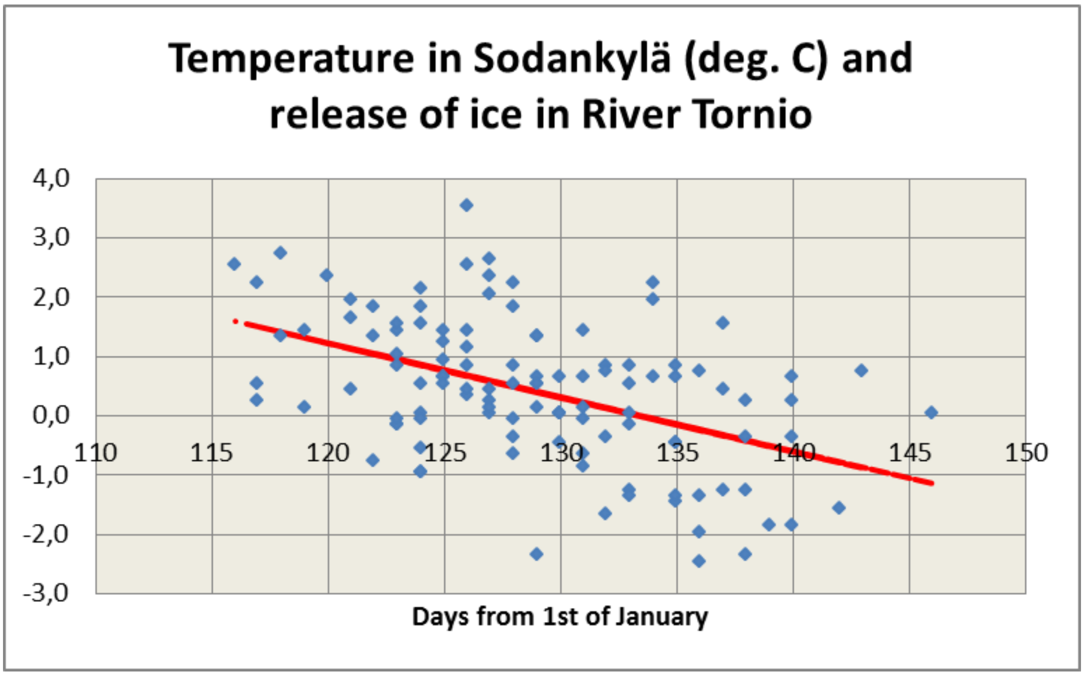


Figure 15.2.3 Sodankylä temperature and ice release day in River Tornio.

If we use this correlation, we could reconstruct the temperature anomaly to Sodankylä data until the year 1693 (Figure 15.2.4). The trend value of extrapolated data (Trend 1) indicated warming with 0.56 deg. C from the year 1693 – 1900 within 207 years. This corresponds to 0.27 deg. C in a century. The trend after the year 1900 shows warming of 0.86 deg. C in hundred years.

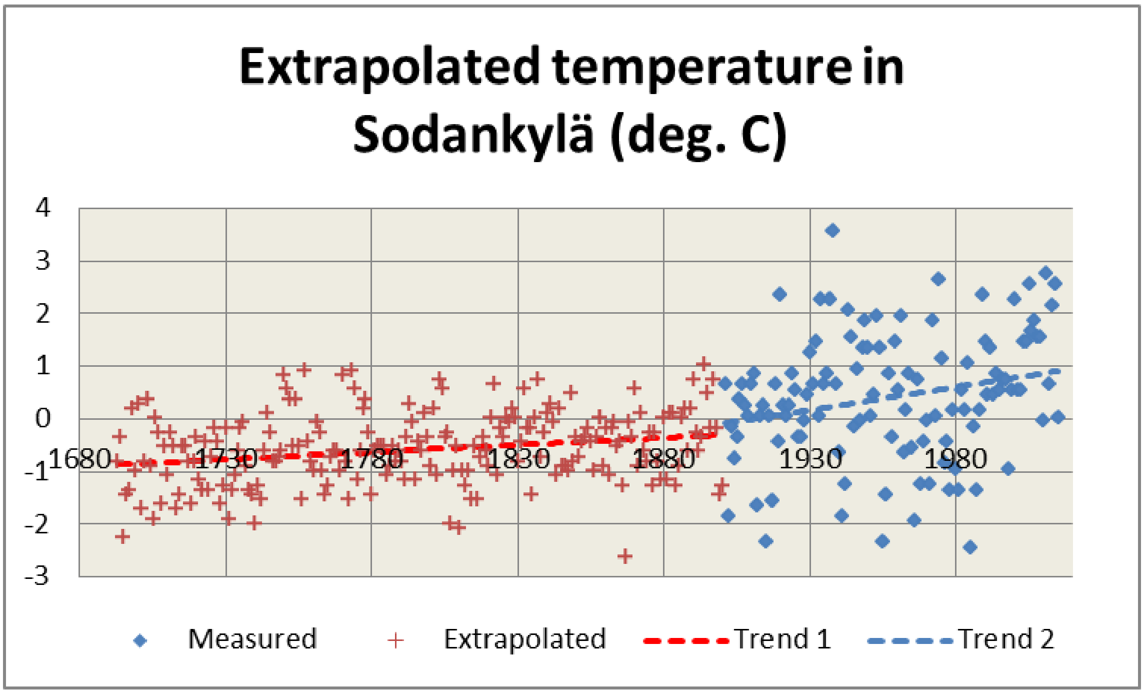


Figure 15.2.4 Extrapolated temperature in Sodankylä using ice release data from River Tornio.

One of the other the long time series exists from the Lake Kallavesi in the Eastern Finland. The trend of data shows that the ice cover loss has moved 6.4 days earlier in a century (Figure 15.2.5). The same kind of series exists about freezing date of Lake Kallavesi (Figure 15.2.6). The average freezing of Kallavesi date has been shifting to later date 8.7 days in a century.

The days during which the lake has ice cover is declining in average 15 days in a century. Today the Kallavesi has ice from 10th of December to 10th of May or 150 days. Thus if this trend continues the ice will disappear completely within 1000 years from now.

The data from ice period of the Lake Kallavesi demonstrates that the Northern part of the globe has been warming at least for 200 years from the beginning of the 19th century. This trend should go back until the Little Ice age, when in Finland in the year 1696 about 25-30 % of Finnish 500.000 population died for hunger and deceases caused by hunger.

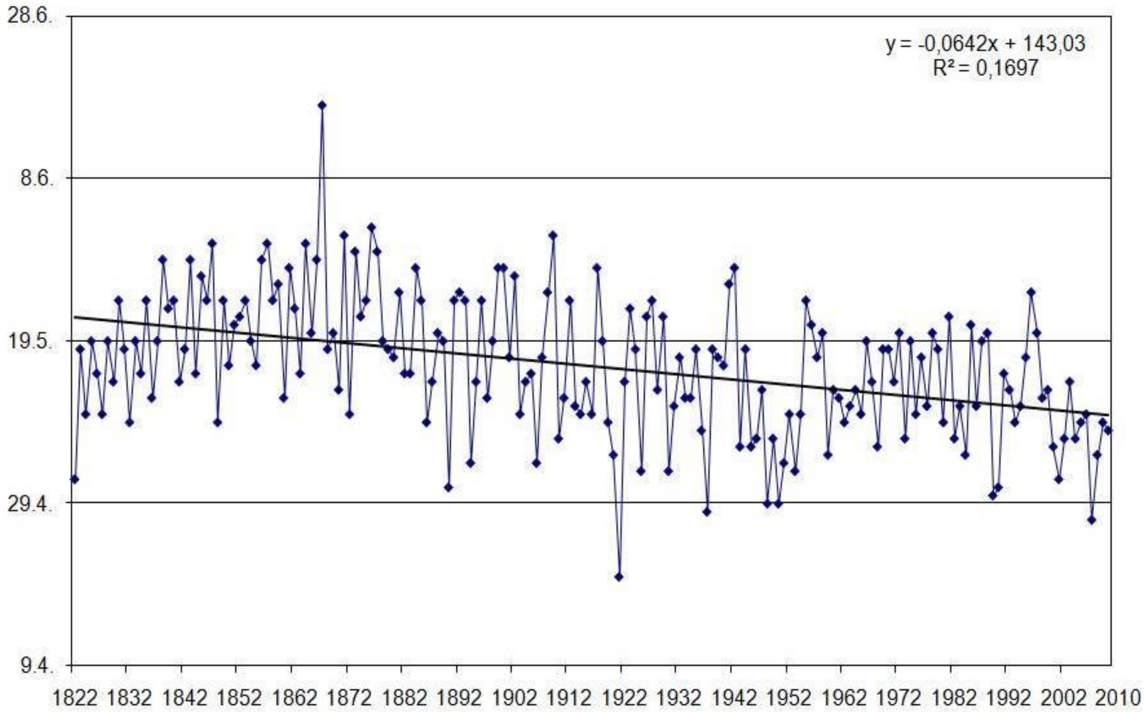


Figure 15.2.5 Loss of ice from Lake Kallavesi (Source: SYKE).

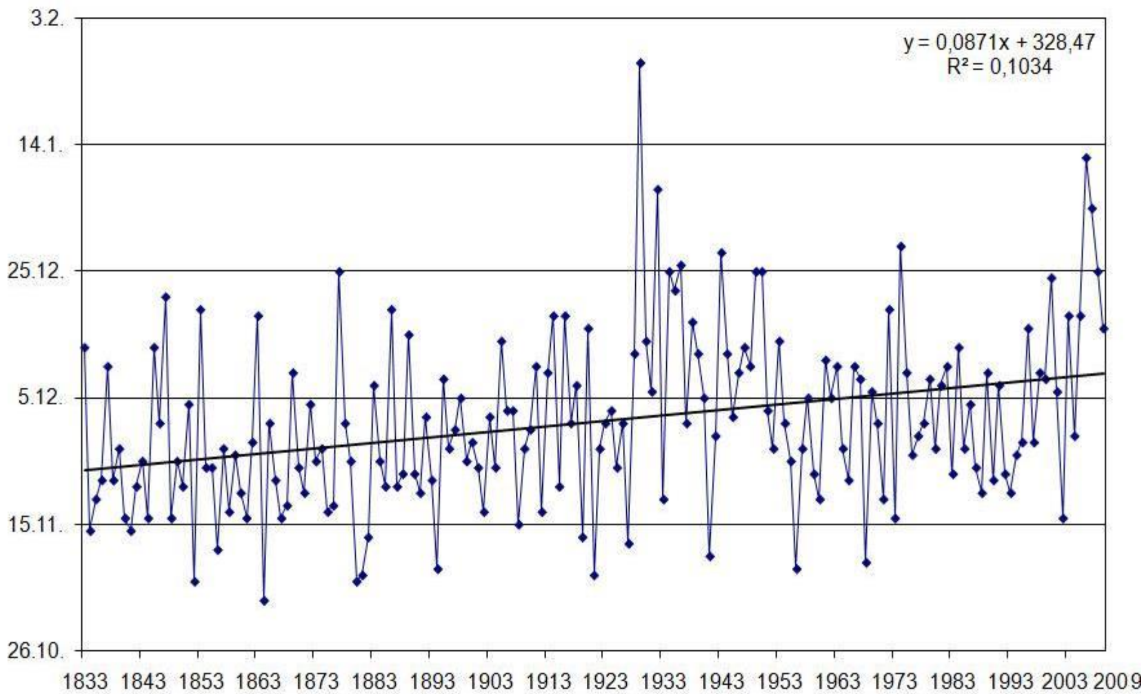


Figure 15.2.6 Freezing date of ice in Lake Kallavesi (source SYKE).

Another change has been noticed in Arctic sea ice minimum, which has been followed by satellites during the last 35 years. The values processed by Meteorological Office (MetOffice) show that the minimum ice cover has been declining from 7.6 to 4.5 million square kilometers from the year 1980 until the year 2015 (Figure 15.2.7). If this trend continues the ice cover the ice cover will be lost completely within 50 years from now (year 2066). The ice sheet minimum from the year 2014 is seen in Figure 15.2.8.

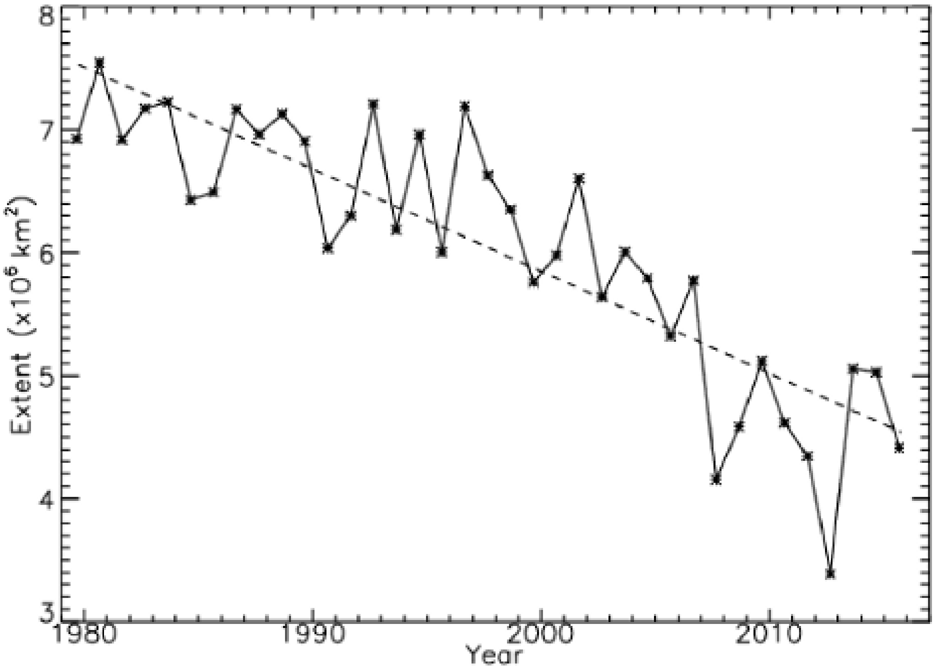


Figure 15.2.7 Area of ice cover on the Arctic Sea (Met Office).

Figure 15.2.8 NASA satellite picture from the year 2014 has taken during ice sheet minimum.

Opening of the Arctic seas means also new opportunities to transportation goods from Asia to Europe and vice versa. The route from Atlantic to Alaska (Northeast passage) was sailed for the first time in Helsinki born scientist **Adolf Erik Nordenskiöld** (1832 – 1901). His expedition started on 22nd of June in 1878 from Karlskrona, Sweden. His sail and steam ship Vega had 21 men on board. His voyage was interrupted for ten months because of ice. Finally, he reached Gulf of Alaska on 20th of August in 1879. Today the route is used mainly to transport oil and gas.

Norwegian scientist **Roald Amundsen** (1892 – 1928) sailed for the first time Canadian Northwest Passage during years 1903 – 1906. He spent two winters on the ice. He led also Antarctic expedition 1910 – 1912 and he was the first man to reach the South Pole on December 1911. However, the south passage around the world has been open for sailors and expeditors since Columbus times.

15.3 Sea Level Rise

Warming is been causing smelting of glaziers. This can be noticed by rising sea level. On the other hand the sea level is rising because it is warming. After the peak of the last ice age 22000 year ago the sea level has risen by 130 m (Figure 15.3.1).

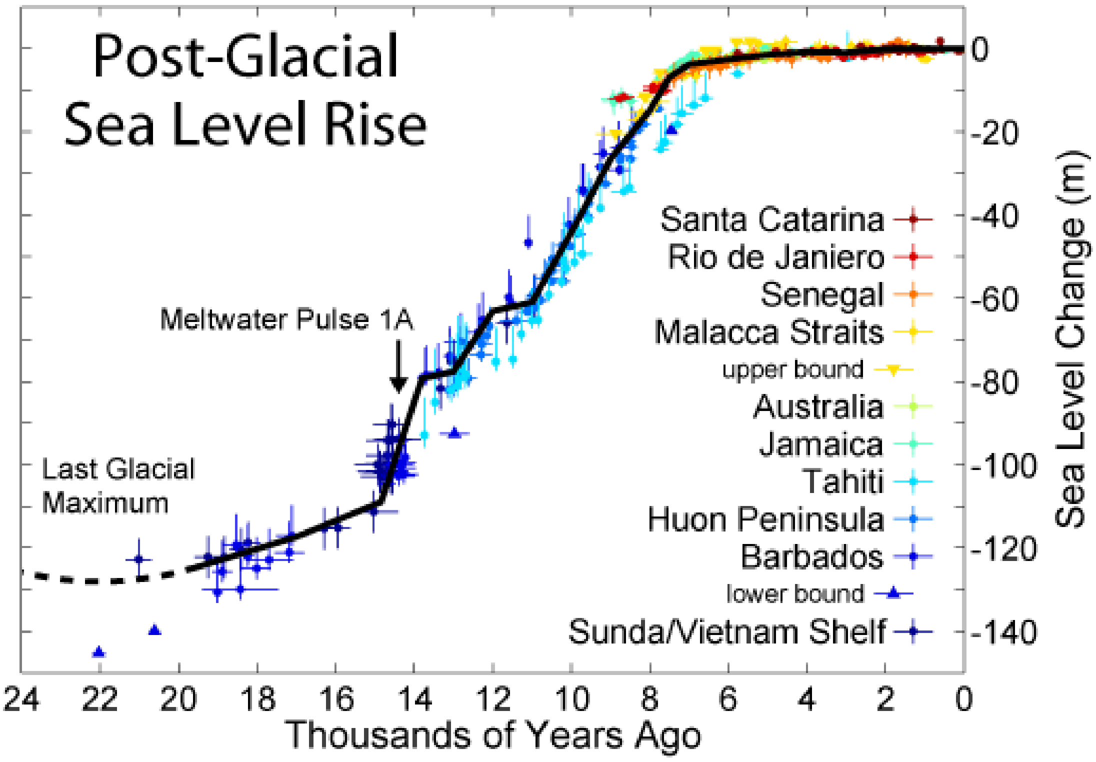


Figure 15.3.1 Sea level rise after last ice age.

In Europe one could go from the continent to Britain just by walking during the last glacial maximum. We have been told by IPCC (Fifth assessment report) that the sea level rise is rising about 3 mm annually. From this 1.1 mm from warning of the sea water, 0.8 mm comes from glacier melt, 0.6 mm from Greenland and Antarctic ice melt and 0.4 mm from the changes in water storages in the land.

Greenland has 2400 km long, 1000 km wide ice sheet and about 1 – 2 km high, which contains 2.85 million cubic kilometers (285 Gt) of ice. If it will melt the sea level will rise with 7.2 meters. With 0.3 mm seawater rising rate, it would take 24 000 years until the Greenland will be out of ice.

However, the latest satellite data shows that temperatures in Greenland have not been rising during the last 70 years (Figure 15.3.2). Thus this story might be false.

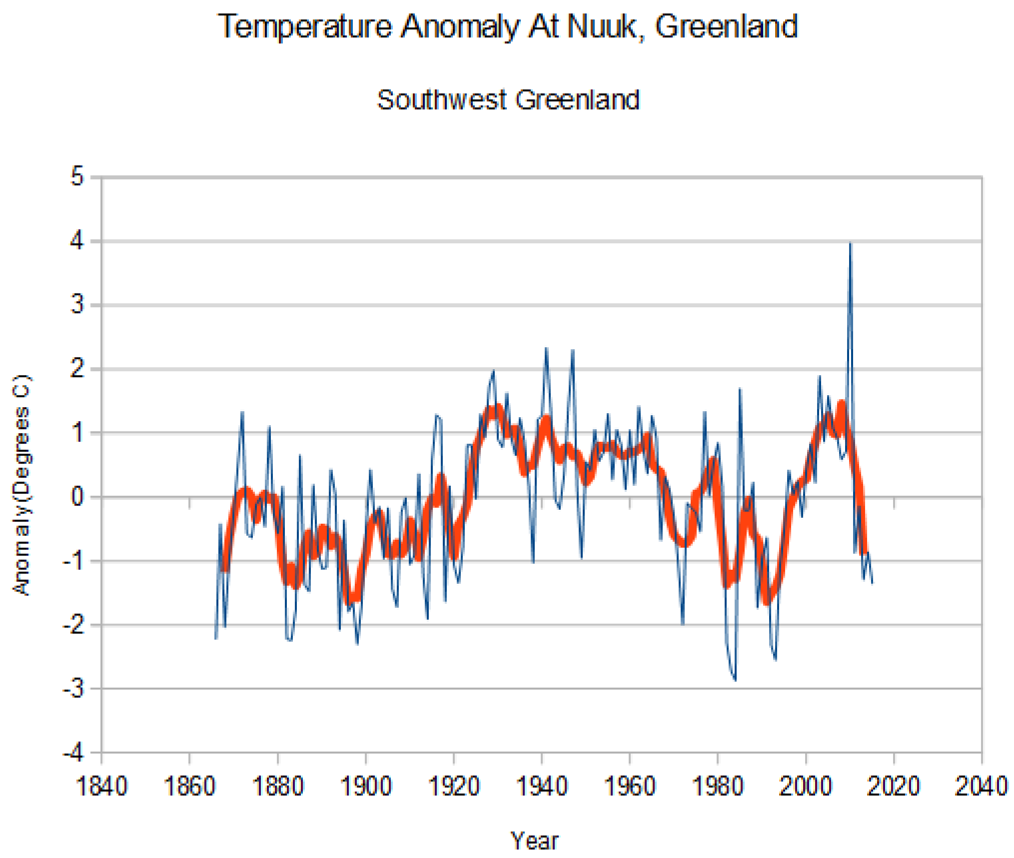


Figure 15.3.2 Temperature data from Nuuk (NOAA data base).

The loss of ice mass has been about 280 Gt annually during last 20 years, but the latest studies of NOAA (2015 Arctic Report Card) show that during 2015 Greenland ice mass was growing with 200 Gt. One millimeter rise in seawater corresponds to about 360 Gt melt of ice. Thus the rising of seawater level has been about 280 Gt/360 Gt or 0.78 mm annually from the year 1993 until the year 2013.

After the year 2013 sea water level has remained stable. Actually, in the year 2015 sea level was sinking with 200 Gt/360 Gt or with 0.55 mm. Thus it will be difficult to estimate melting of Greenland in the future.

Antarctic has almost ten times bigger ice mass compared with Greenland. NASA studies are also showing that Antarctic ice mass has been increasing during years 2003 – 2008 with 82 Gt annually (Figure 15.3.3). This amount ice causes sea water sinking with 0.2 mm annually instead of rising with 0.3 mm according to IPCC. Summing up the Greenland and Antarctic will not cause seawater rising with 0.6 mm annually, but remaining quite stable.

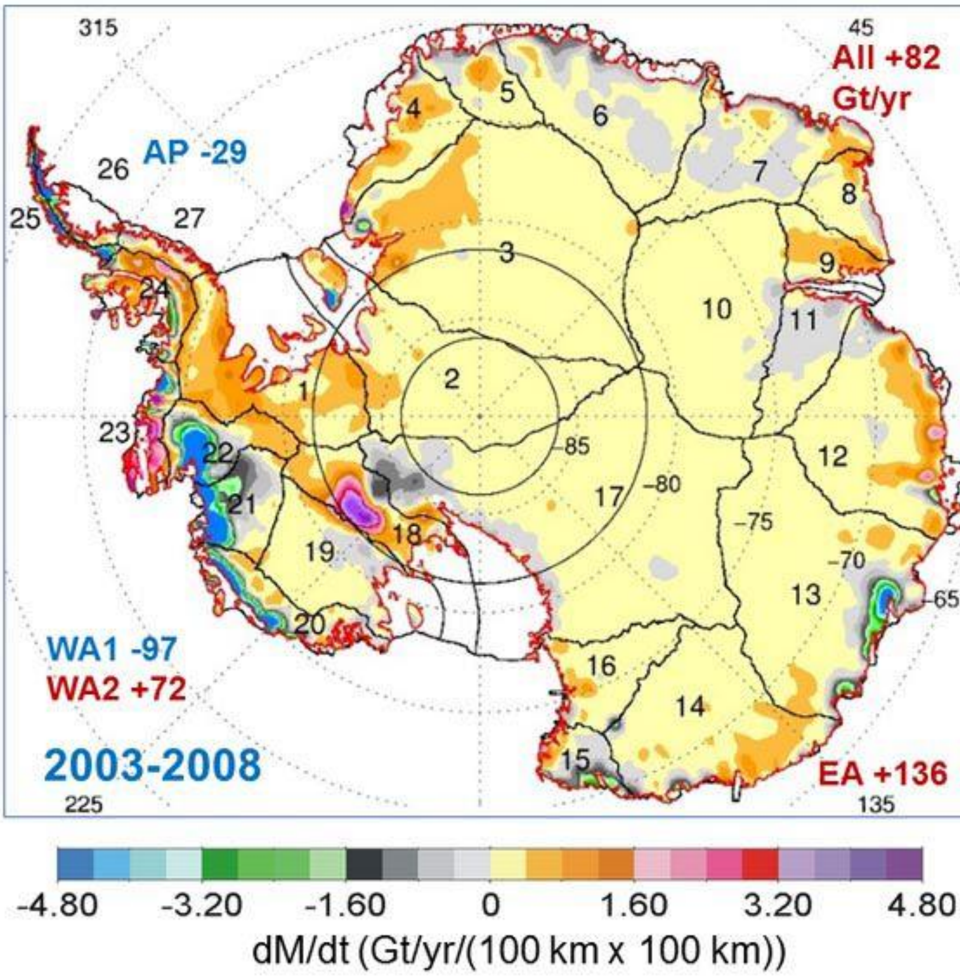


Figure 15.3.3 Antarctic ice mass seems to be growing annually with 82 Gt according to a NASA study.

Main reason to stable seawater level is increasing precipitation with global warming. The average precipitation has been increasing 20 mm in a century (Figure 14.1.1). Thus the snowing in Antarctic will be increasing the ice cover correspondingly.

There are 233 sites where the sea level has been measured many years. The data collected by NOAA shows a median trend of sea level rise of 128 mm in a century (Figure 15.3.4). This 128 mm rise is much less than the 300 mm rise estimated by IPCC. These measurements show that it would take 800 years before the sea level rise will reach on meter (three feet).

Why now sea level is sinking in some places. Very good examples are all sites in Western Finland. This is because during the last ice age these areas were covered with some five kilometers of ice. Now the land is rising to get its original shape.

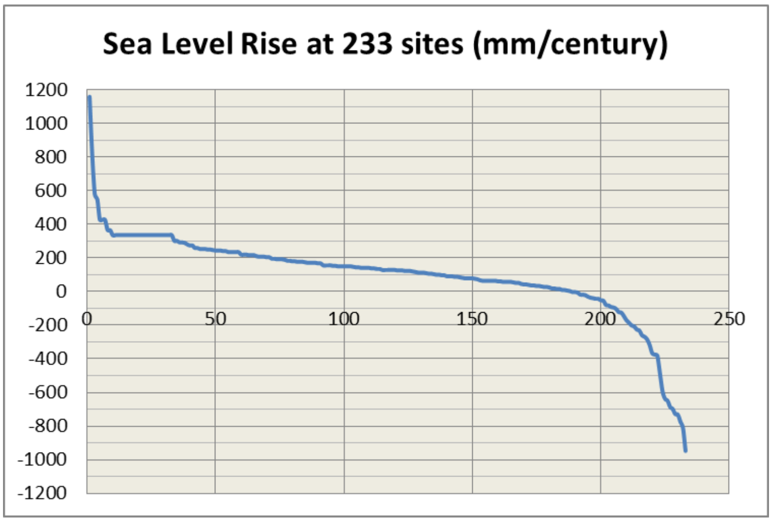


Figure 15.3.4 Sea level rise in 233 sites as measured by NOAA.

Table 15.3.1 Near medium sea level rise

Site	mm/century
Quarry Bay/North Point, China	134
Abashiri, Japan	134
Kolobrzeg, Poland	128
Cascais, Portugal	128
Trieste, Italy	128
Ulsan, South Korea	128
Wonsan, North Korea	128
Auckland II, New Zealand	128
Warnemunde, Germany	125
Marseille, France	125
Sevastopol, Ukraine	125

One of the places in Finland is Vaasa, which can be found in NOAA files is in the place 230 (if the 233 sites will be sorted from largest to smallest rise) with water level sinking with 732 mm in a century. The good thing is that coastal landowners are constantly getting more land free of charge. Old city of Vaasa was on the coast line some 500 years ago, but now it is about 5 kilometers from the coast line.

15.4 Difficult areas

South Pacific Ocean

If sea level is continuing its rising some islands in the Pacific Ocean may disappear. The islands groups to the North East from Australia, Tuvalu, Kiribati and Tokelau are in danger areas. Australian Bureau of Meteorology has forecasted that the sea level will rise with 87 cm by 2090. This is more than the highest scenario by IPCC (Figure 15.4.1).

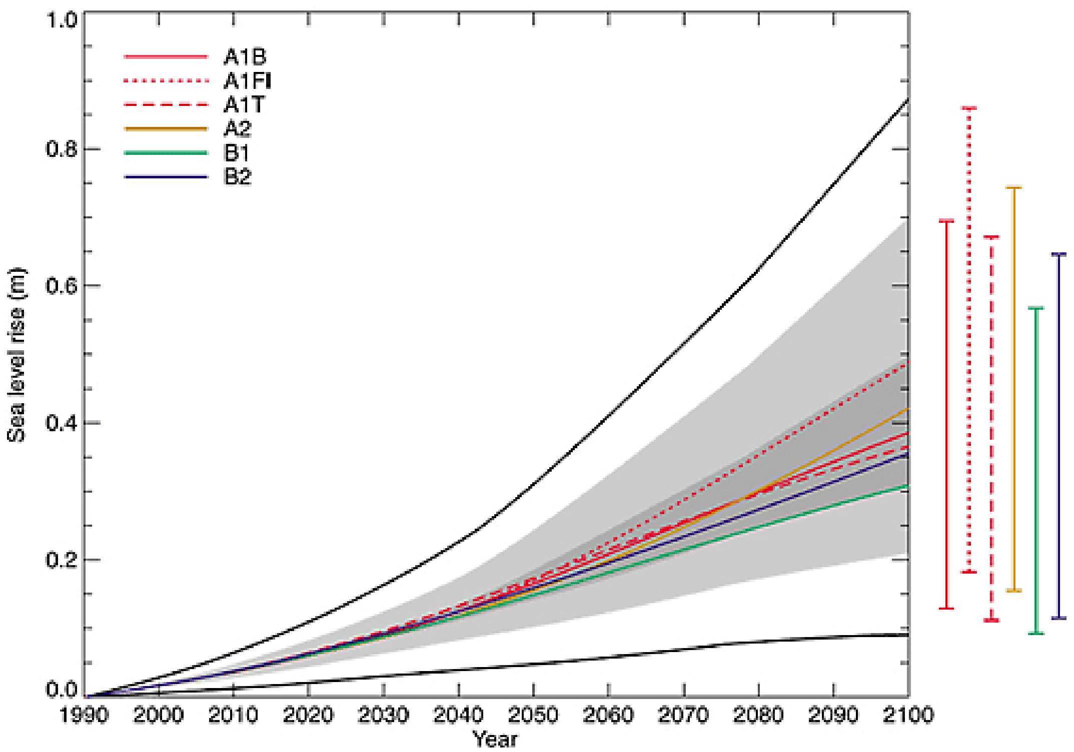


Figure 15.4.1 IPPC scenarios about sea level rise.

Tuvalu

Funafuti is a small island with 2.4 square kilometer land area. Its population of 6200 people, which is 57 % of the total population of Tuvalu. The first sea level measurement gauge was installed in Funafuti in 1978. Since then the sea water level has been risen 1.2 mm annually. This would correspond to 120 mm within hundred years or much less than measured by the Australian Bureau of Meteorology. This is the same as the lowest scenario of IPCC (Figure 15.4.1). NOAA has made the same order of magnitude estimates for the South Pacific area with media sea level rise of 1.4 mm/year (Figure 15.4.2).

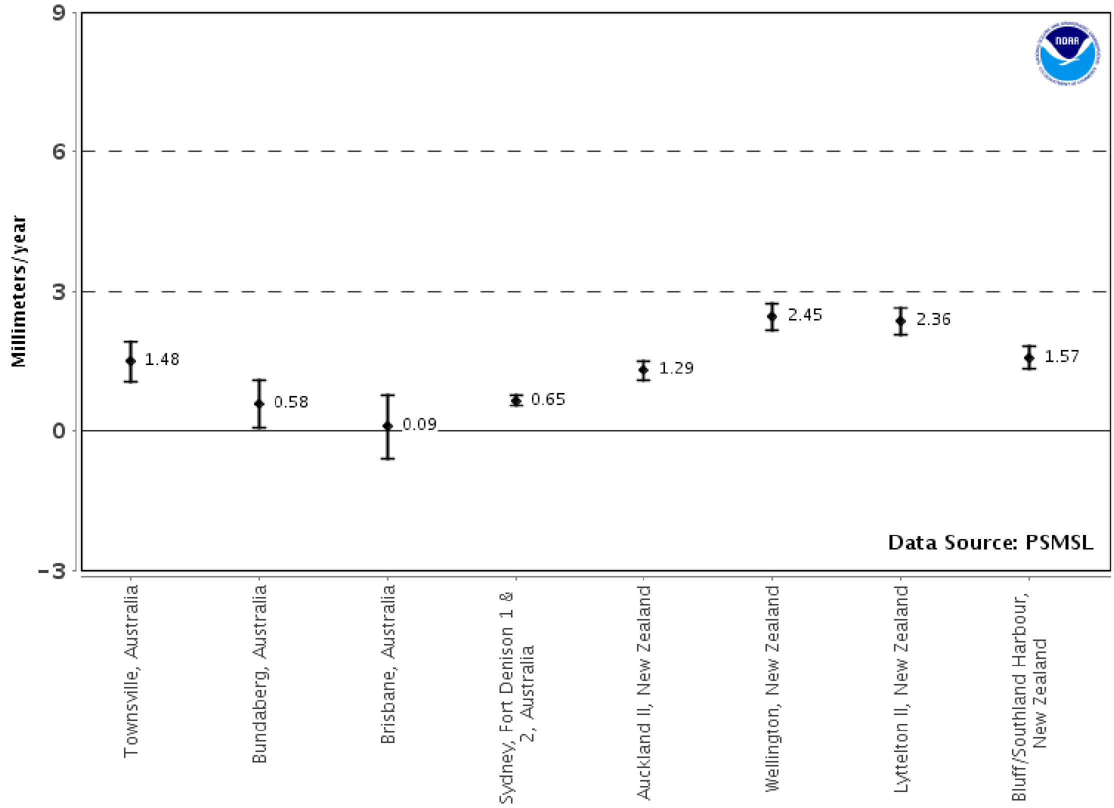


Figure 15.4.2 Sea level rise in South Pacific Ocean (NOAA).

Figure 15.4.3 Tuvalu islands

Tuvalu is in danger zone of sea level rise, while the average height of the islands is about 2 meters above sea level. One of the most difficult islands is Niulakita, which has its highest point at 4.6 meters above sea level. The population of the island was 35 in 2002 census. Thus it would not be a huge problem to rehabilitate people from all of those to the other islands.

Islands in the Indian Ocean

Some island groups in the Indian Ocean are also in danger of being vanished. One of them is Maldives islands, which are in average 1.5 meters above sea level. The average population is about 320 000 including 100 000 foreign workers. Maldives include 1192 islands and 200 of them has been inhabited. Medium sea level is rising in Indian Ocean with about 1.5 mm/year (Figure 15.4.4), thus within 1000 years most of the islands in Maldives may be submerged.

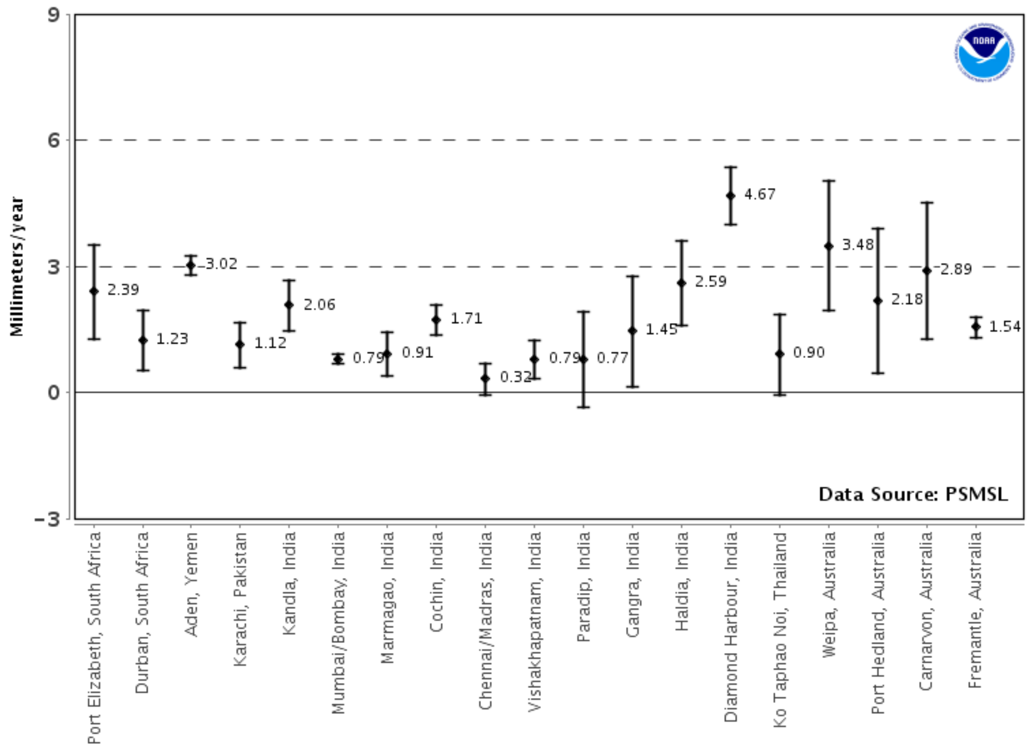


Figure 15.4.4 Sea level rise in Indian Ocean (NOAA).

Coastal areas

Many coastal areas are also in danger. One of them is Bangladesh, where about 18 million people live in Delta of River Ganges, which might be submerged by rising of sea level and floods in the river. The Ganges Delta area has totally about 160 million inhabitants in a quite small area. The evacuation of the most difficult regions in the area have already started.

16 FOOD PRODUCTION

16.1 Agricultural products

FAO statistics (http://faostat.fao.org/site/339/default.aspx) indicate that worlds supply of agricultural commodities has been growing steadily since the year 1961 (Table 16.1.1). The most 20 important products were produced 6900 million tons in 2010 and the population was 6900 million. Fifty years earlier the production was 2400 million with 3000 million people. Food production has been growing from 0.8 ton per capita to 1.0 ton per capita in the year 2010.

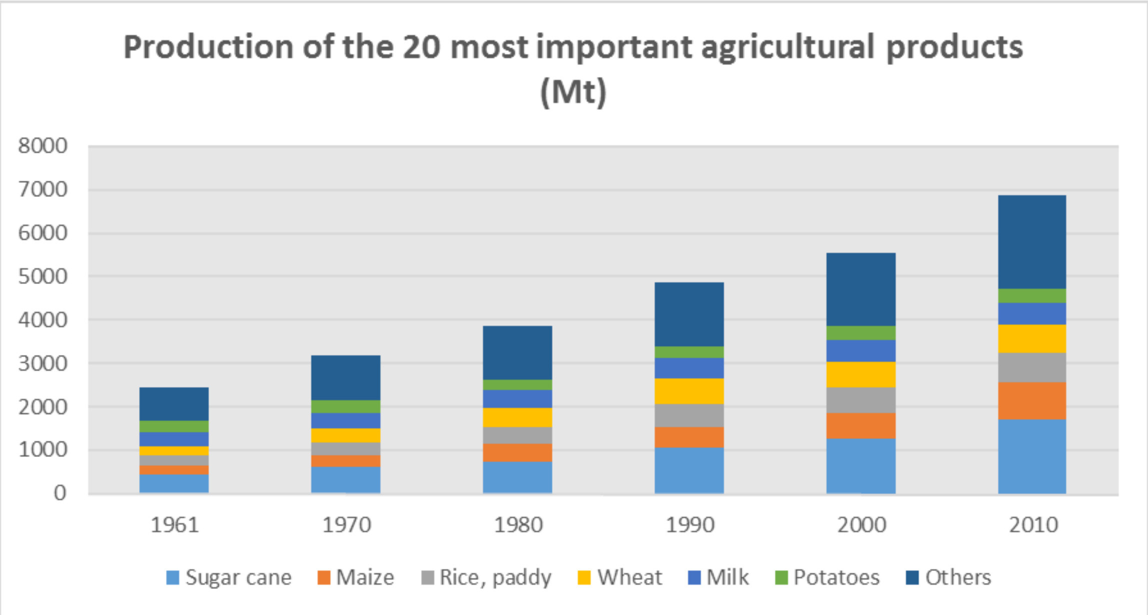


Figure 16.1.1 Production of the 20 most important agricultural products (FAO).

The main reason for production growth is the average yield per hectare, which has been growing continuously since the year 1960 (Figure 16.1.2). The yield in corn production has risen from 2 to 5 tons per hectare, rice production from 2 to 4.2 and wheat production from 1 to 2.8 tons per hectare. In average the yield has grown about 100 – 200 %.

Area of cultivated land has increased from 1400 million in 1970 to 1600 million hectares today. There are now 0.2 hectares of cultivated land per capita. Africa has also 0.2 hectares per capita, but its problem is yield. In average world is using 69 kg of nitrogen, 26 kg phosphates and 15 kg of potash per hectare, but Africa is using only 11 kg of nitrogen, 4 kg of phosphates and 1.5 kg of potash per hectare. However, the irrigated land has increased from 13 % (182 million hectares) in 1970 to about 21 % (330 million hectares) of total area in (Figure 16.1.3).

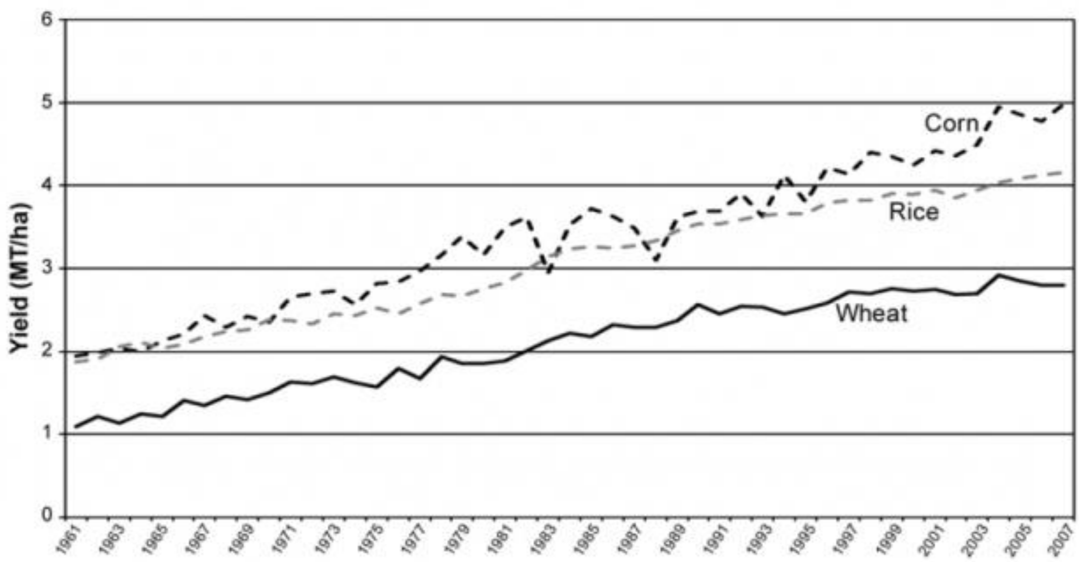


Figure 16.1.2 Yield per hectare of corn, rice and wheat (Source: Max Rosen 2015).

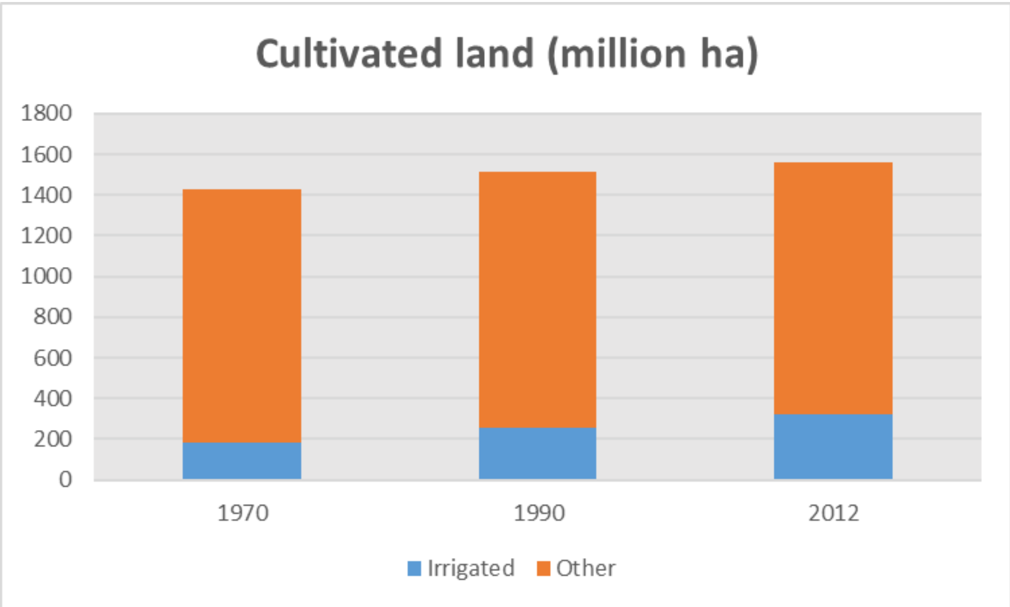


Figure 16.1.3 Cultivated land and irrigation.

Land used for cereals production was 693 million hectares in 2010. This is 0.1 hectares per capita. Less than average (0.1 ha) has been used in Asia (0.08), most parts of Africa and Latin America (Table 16.1.1).

Cereals production in the world was 2500 million tons or 0.36 tons per capita in 2010. Most difficult countries produce less than 0.3 tons per capita (Table 16.1.1). These countries can be found in Asia (India, Pakistan and Philippines) and in Africa (Ethiopia, Nigeria, Marocco and Egypt). Average production in African countries is 0.16 tons per capita.

Table 16.1.1 Land used for production of cereals in 40 largest producer countries (hectares/capita).

	ha/capita		ha/capita		ha/capita
1 Australia	0.86	22 Ethiopia	0.11	1 Central Asia	0.29
2 Canada	0.38	23 Nepal	0.11	2 North America	0.21
3 Ukraine	0.31	24 Nigeria	0.10	3 Europe	0.15
4 France	0.28	25 Viet Nam	0.10	4 Americas	0.13
5 Denmark	0.27	26 Mexico	0.09	5 Africa	0.10
6 Hungary	0.26	27 Others	0.08	6 Southern Asia	0.10
7 Kazakhstan	0.24	28 Germany	0.08	7 World	0.10
8 Romania	0.23	29 Bangladesh	0.08	8 North Africa	0.09
9 Argentina	0.23	30 India	0.08	9 Eastern Africa	0.09
10 Russia	0.22	31 Pakistan	0.08	10 Western Asia	0.09
11 Cambodia	0.22	32 Philippines	0.07	11 Latin America	0.08
12 Serbia	0.21	33 Indonesia	0.07	12 Asia	0.08
13 Poland	0.21	34 China	0.07	13 Southern Africa	0.07
14 Thailand	0.19	35 South Africa	0.07	14 Middle Africa	0.06
15 Myanmar	0.19	36 Italy	0.06	15 Eastern Asia	0.06
16 USA	0.18	37 Uzbekistan	0.05		
17 Turkey	0.16	38 Brazil	0.05		
18 Marocco	0.16	39 United Kingdo	0.05		
19 Spain	0.13	40 Egypt	0.04		
20 Iran	0.13	41 Japan	0.01		
21 Tanzania	0.11				

16.1.2 Production of cereals per capita in 40 most important countries (FAO).

	t/capita		t/capita		t/capita
1 Denmark	1.57	22 Indonesia	0.35	1 North America	1.29
2 Australia	1.48	23 Bangladesh	0.35	2 Americas	0.68
3 Canada	1.32	24 United Kingdo	0.33	3 Southern Africa	0.64
4 USA	1.29	25 Italy	0.31	4 Europe	0.55
5 Hungary	1.23	26 Mexico	0.30	5 Southern Asia	0.41
6 Argentina	1.15	27 Iran	0.30	6 Central Asia	0.40
7 France	1.04	28 South Africa	0.29	7 World	0.36
8 Serbia	1.02	29 Nepal	0.26	8 Eastern Asia	0.33
9 Ukraine	0.85	30 Uzbekistan	0.25	9 Latin America	0.33
10 Romania	0.78	31 Marocco	0.24	10 Asia	0.29
11 Myanmar	0.72	32 Egypt	0.23	11 Western Asia	0.20
12 Poland	0.70	33 Philippines	0.23	12 North Africa	0.17
13 Cambodia	0.63	34 India	0.22	13 Africa	0.16
14 Thailand	0.59	35 Pakistan	0.20	14 Eastern Africa	0.15
15 Germany	0.54	36 Kazakhstan	0.19	15 Middle Africa	0.06
16 Viet Nam	0.51	37 Tanzania	0.19		
17 Turkey	0.45	38 Ethiopia	0.18		
18 Russia	0.42	39 Others	0.16		
19 Spain	0.42	40 Nigeria	0.15		
20 China	0.39	41 Japan	0.07		
21 Brazil	0.38				

The average yield in production of cereals in the world was 3.6 tons per hectare in 2010. However, yield was less than 2 tons per hectare in most part of Africa (1.5 tons/hectare). These countries include Ethiopia (1.68), Tanzania (1.65), Marocco (1.58) and Nigeria (1.53 t/capita) (Table 16.1.3). However, the yield was less than 2 tons in Russia, Australia and Kazakhstan, where the land in not critical factor and they had more than 0.2 hectares per capita in cereals production.

Table 16.1.3 Yield in cereals production in 2010 in 40 largest producer countries (FAO)

	t/ha		t/ha		t/ha
1 Brazil	7.65	22 Poland	3.38	1 Southern Africa	8.79
2 USA	7.05	23 Romania	3.34	2 North America	6.30
3 United Kingdom	6.97	24 Spain	3.22	3 Eastern Asia	5.48
4 Germany	6.71	25 Philippines	3.20	4 Americas	5.34
5 Egypt	6.50	26 Thailand	3.11	5 Southern Asia	4.03
6 Denmark	5.87	27 Cambodia	2.90	6 Latin America	3.88
7 China	5.53	28 Ukraine	2.73	7 Europe	3.70
8 Italy	5.37	29 Turkey	2.71	8 Asia	3.65
9 Viet Nam	5.19	30 India	2.68	9 World	3.57
10 Argentina	5.01	31 Pakistan	2.62	10 Western Asia	2.28
11 Serbia	4.89	32 Nepal	2.36	11 North Africa	1.85
12 Indonesia	4.89	33 Iran	2.36	12 Eastern Africa	1.65
13 Japan	4.84	34 Others	1.97	13 Africa	1.54
14 Hungary	4.73	35 Russia	1.90	14 Central Asia	1.37
15 Uzbekistan	4.63	36 Australia	1.73	15 Middle Africa	0.99
16 Bangladesh	4.29	37 Ethiopia	1.68		
17 South Africa	4.20	38 Tanzania	1.65		
18 Myanmar	3.84	39 Marocco	1.53		
19 France	3.66	40 Nigeria	1.53		
20 Mexico	3.49	41 Kazakhstan	0.80		
21 Canada	3.49				

16.2 Hunger statistics

Also number of undernourished people in the world has been reducing both in absolute numbers and in percent of world total population (Table 16.2.1). However, undernourishment in Africa has been growing in absolute numbers. Today about 20 % of the people in Africa is suffering from undernourishment. In Asia the percent of undernourished people has dropped from 24 % in 1990 to 12 % in 2014.

Table 16.2.1 Number of undernourished people by UN (millions).

Continent	1990-92	2000-02	2005-07	2010-12	2014-16	Change	Percent
Africa	181.7	210.2	213.0	218.5	232.5	50.8	20.0%
Asia	741.9	636.5	665.5	546.9	511.7	-230.2	12.1%
Latin America	66.1	60.4	47.1	38.3	34.3	-31.8	<5%
Oceania	1.0	1.3	1.3	1.3	1.4	0.4	14.2%
Developed countries	19.9	21.2	15.4	15.7	14.7	-5.2	<5%
World	1010.6	929.6	942.3	820.7	794.6	-216.0	10.9%
Percent of total	18.6%	14.9%	14.3%	11.8%	10.9%		

FAO hunger map indicates the most difficult countries in hunger statistics in the year 2015 (Figure 16.2.1). The red countries in which the situation has been worsening are mostly in Africa. However, most of the developing countries have achieved their targets (green) and others have progresses slowly (yellow).

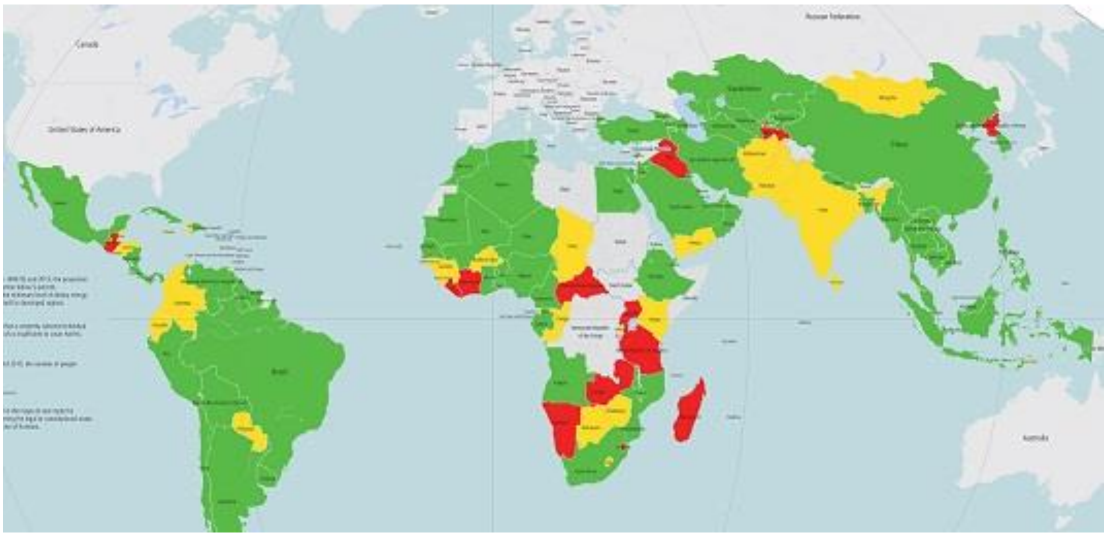


Figure 16.2.1 FAO hunger map 2015 shows progress in undernourishment development. The green countries have developed as planned. Hunger situation in the red countries has worsen.

The life expectancy of world people at birth is 70 years. However, it is 60 years or less in Africa (Table 16.2.2). There are 28 countries with 60 year or less life expectancy and all of them can be found in Africa (Table 16.2.3). Additionally, there are 33 countries with 80-year or more life expectancy (Table 16.2.4) and 27 of them can be found in Europe.

Table 16.2.2 Life expectancy of people at birth in 40 countries, which are the largest producers of cereals (2010 FAO).

	years		years		years
1 Japan	83.0	21 Egypt	73.0	1 North America	78.0
2 Australia	82.0	22 Romania	73.0	2 Europe	77.0
3 Spain	82.0	23 Serbia	73.0	3 Americas	76.0
4 Italy	82.0	24 Marocco	72.0	4 Latin America	74.0
5 France	81.0	25 Ukraine	70.0	5 Eastern Asia	74.0
6 Canada	81.0	26 Indonesia	69.0	6 Western Asia	73.0
7 Germany	80.0	27 Russia	69.0	7 North Africa	71.0
8 United Kir	80.0	28 Bangladesh	69.0	8 Asia	70.0
9 Denmark	79.0	29 Philippines	68.0	9 Southern Asia	70.0
10 USA	78.0	30 Kazakhstan	68.0	10 World	70.0
11 Mexico	77.0	31 Nepal	68.0	11 Central Asia	68.0
12 Argentina	76.0	32 Uzbekistan	68.0	12 Africa	57.0
13 Poland	76.0	33 India	65.0	13 Eastern Africa	56.0
14 Viet Nam	75.0	34 Pakistan	65.0	14 Southern Africa	52.0
15 Thailand	74.0	35 Myanmar	65.0	15 Middle Africa	49.0
16 Turkey	74.0	36 Cambodia	63.0		
17 Hungary	74.0	37 Ethiopia	59.0		
18 China	73.0	38 Tanzania	57.0		
19 Brazil	73.0	39 South Africa	52.0		
20 Iran	73.0	40 Nigeria	51.0		

Table 16.2.3 Countries with life expectancy of 60 years or less in the year 2013 (WHO).

No	Years	No	Years
1 Malawi	60	15 Equatorial Guinea	56
2 South Africa	60	16 South Sudan	56
3 Benin	59	17 Nigeria	55
4 Burkina Faso	59	18 Guinea-Bissau	54
5 Congo	59	19 Mozambique	54
6 Niger	59	20 Somalia	54
7 Uganda	59	21 Cote d'Ivoire	53
8 Zimbabwe	59	22 Swaziland	53
9 Guinea	58	23 Angola	52
10 Togo	58	24 Chad	52
11 Zambia	58	25 Democratic Rep. of Congo	52
12 Cameroon	57	26 Central African Republic	51
13 Mali	57	27 Lesotho	50
14 Burundi	56	28 Sierra Leone	46

Table 16.2.4 Countries with life expectancy of 80 years or more in the year 2013 (WHO).

No		Years	No		Years	No		Years
1	Japan	84	12	Iceland	82	23	Greece	81
2	Andorra	83	13	Israel	82	24	Ireland	81
3	Australia	83	14	Luxembourg	82	25	Malta	81
4	Italy	83	15	Monaco	82	26	Netherlands	81
5	San Marino	83	16	New Zealand	82	27	Portugal	81
6	Singapore	83	17	Norway	82	28	United Kingdom	81
7	Spain	83	18	Republic of Korea	82	29	Belgium	80
8	Switzerland	83	19	Sweden	82	30	Chile	80
9	Canada	82	20	Austria	81	31	Denmark	80
10	Cyprus	82	21	Finland	81	32	Lebanon	80
11	France	82	22	Germany	81	33	Slovenia	80

The life expectancy has been growing from less than 50 years in the year 1900 to 81 years in 2014 (Figure 16.2.1). Life expectancy of newborn boys was 78.2 years and 83.9 years for girls in 2014. The average life expectancy in Finland is still 3 years behind Japan, which has the highest life expectancy of 84 years (Figure 16.2.2).

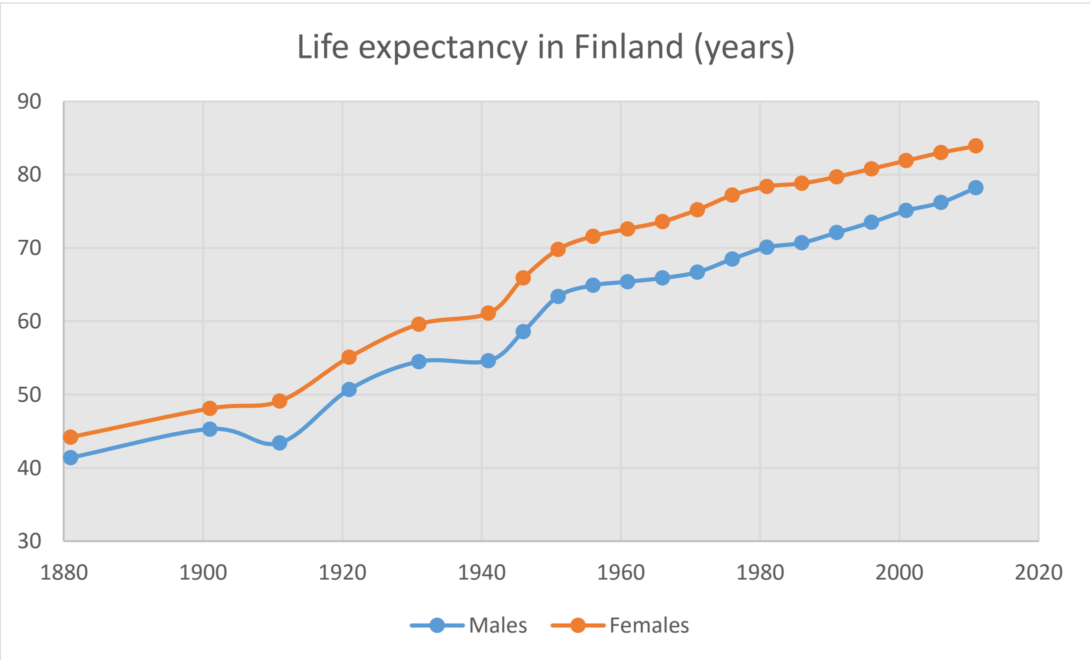


Figure 16.2.2 Life expectancy of newborn Finnish boys and girls (Statistics Finland).

However, the average life expectancy of 81 years is 7 years more than the median life expectancy of 74 years of all countries in the world. Finland had the same 46 -year life expectancy than the worst country today (Sierra Leone) 120 years ago. Thus it is possible to make the world better in every country, if the development will be the same as in Finland.

Life expectancy is dependent on food and clean water availability and living standard. Dependency of life expectancy seems to be depended also on the availability of cereals (Figure 16.2.3). The life expectancy seems to be less than 60 years in only in countries which produce less than 0.3 ton cereals per capita. However, there are countries like Japan, which have the highest life expectancy and lowest cereals production capacity. Thus the cereal demand can also be satisfied by imports.

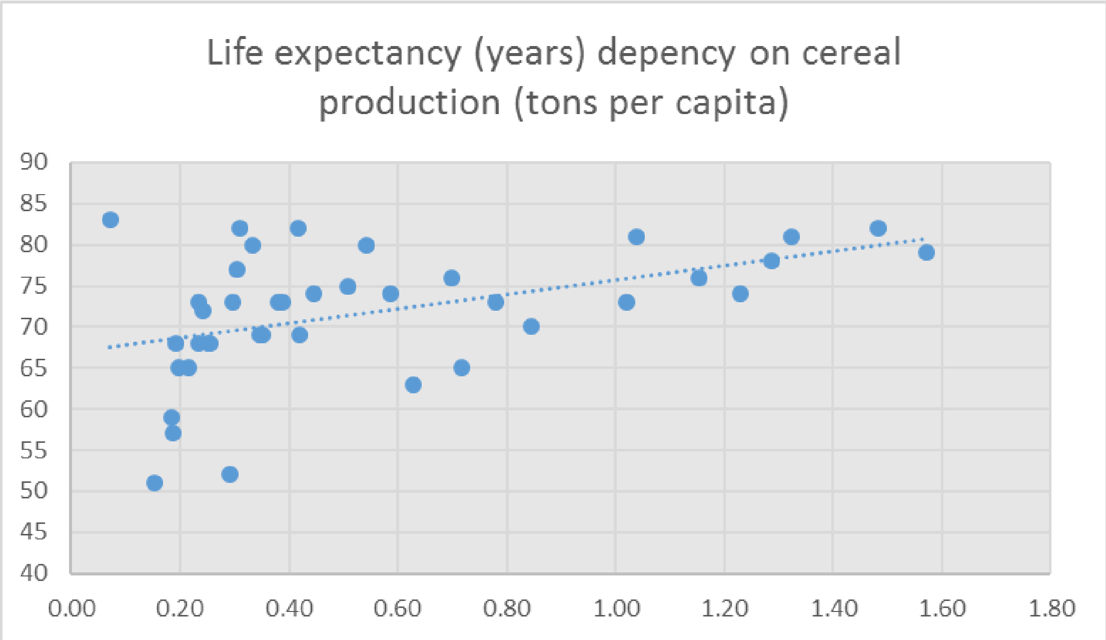


Figure 16.2.3 Life expectancy (years) dependency on cereal production (tons/capita).

16.3 Africa

The number of undernourished people in Africa has been increasing from 182 million to 233 million from the year 1990. There are countries like Nigeria and Tanzania, where situation is becoming better but many more like Tanzania, Uganda, Kenya, Madagascar, Zambia, Zimbabwe and Chad, where the number of undernourished people has increased (Table 16.3.1).

Today 20 % of African people suffer from undernourishment. In the worst countries more than 30 % of the people are undernourished. They can be found in East Africa: Ethiopia, Tanzania, Madagascar, Rwanda, Zambia, Zimbabwe, in Middle Africa: Chad, Congo, South Africa: Namibia and in West Africa: Liberia.

Table 16.3.1 Undernourished people in Africa in millions (FAO).

Country	1990-92	2000-02	2005-07	2010-12	2014-16	Change	Percent
Ethiopia	37.3	37.3	34.3	32.1	31.6	-5.7	32.0%
Tanzania	6.4	13.0	14.1	16.1	16.8	10.4	32.1%
Nigeria	20.8	11.2	9.3	10.2	12.9	-7.9	7.0%
Uganda	4.2	7.1	6.6	8.7	10.3	6.1	10.1%
Kenya	7.9	10.4	10.4	10.0	9.9	2.0	21.2%
Madagascar	3.3	5.8	6.6	6.9	8.0	4.7	33.0%
Zambia	2.7	4.7	6.0	6.9	7.4	4.7	47.8%
Mozambique	7.8	7.9	8.0	7.3	6.9	-0.9	25.3%
Zimbabwe	4.6	5.5	5.1	4.5	5.0	0.4	33.4%
Chad	3.6	3.5	4.1	4.8	4.7	1.1	34.4%
Total	98.6	106.4	104.5	107.5	113.5	14.9	

Africa has experience several famine years since the television age, where hungry people has entered into western television screens. During two worst years (1973 – 1974 and 1983 – 1985) about 200,000 and 400,000 people in Ethiopia and Eritrea died because of undernourishment. The reason was the drought, which destroyed crops and also most of the cattle (Figure 14.4.1). However, the population in Ethiopia has been growing fast from about 26 million in 1973 to about 100 million to day.

In Somalia about 220,000 – 260,000 people have died because of the drought during years 2010 – 2012. The horn of Africa was hit by the most difficult drought year in 2011, which destroyed crops of about 13 million people in the area. The civilian war happening at the same time has made difficult to provide help in the area.

Ethiopia

Today in 2016 Ethiopia is suffering from drought again and 10 million people need for food aid. Even in normal years 7 – 8 million Ethiopians need food help. Totally, 32 million Ethiopian are undernourished. About 60 % of export income of Ethiopia will be used to import food.

Only 2 % (300 000 hectares) of the arable land has irrigation system. This is much less than 22.5 % of world average or 28.5 % irrigation in North Africa. Ethiopia is in the area, where the River Nile has its origins. The precipitation is more than 1000 mm annually in the west part of Ethiopia, but less than 250 mm in eastern Ethiopia (Figure 6.3.1). Thus irrigation might be the possible solution as was discovered by the Egyptians already some thousand years ago.

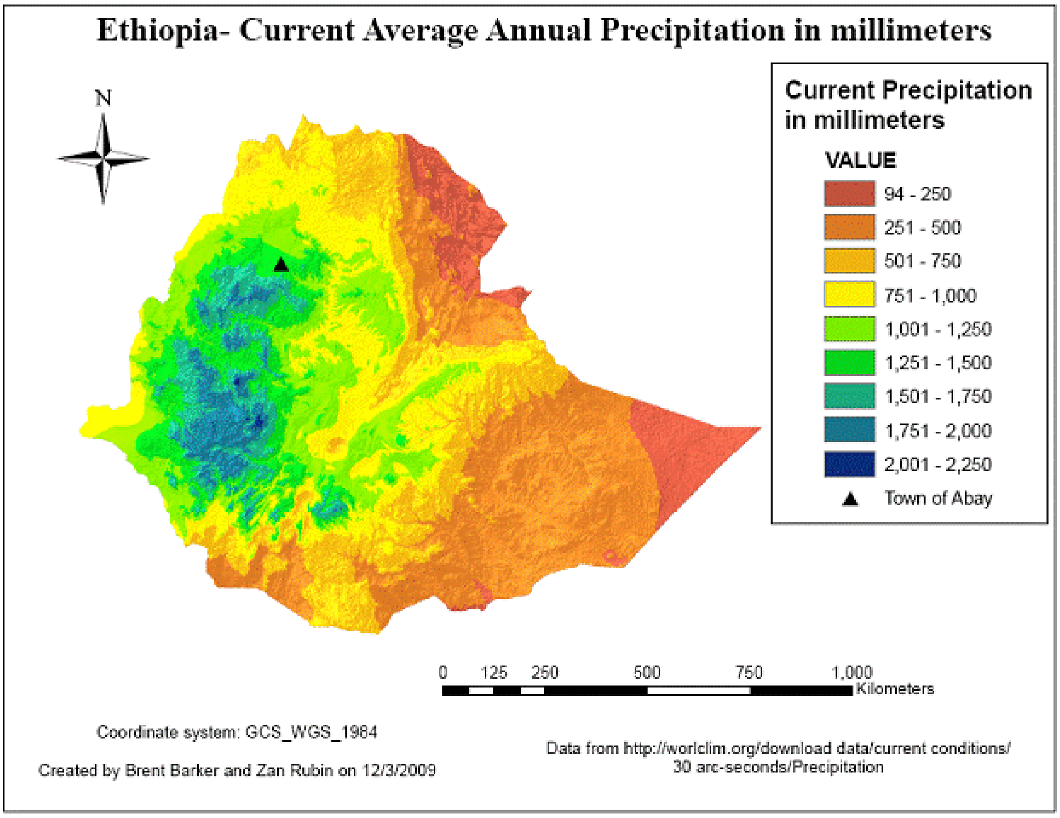


Figure 16.3.1 Precipitation map of Ethiopia (Source: Brent Barker and Zan Rubin).

The land area in Ethiopia is 1.1 million square kilometers. The water runoff of the rivers is 124 billion cubic meters (1500 m^3/capita) and potential irrigable land area is 3.7 million hectares (Working paper 123). This is 13 times the existing area of irrigated land.

16.4 Asia

India is on the top of list of number of undernourished people. It has 194.6 million people undernourished or 15.2 % of the population (Table 16.4.1). China was on the top in 1990, but since then its undernourished people have dropped more than 50 %. However, still 9.3 % of Chinese people suffer from undernourishment.

The change in number of undernourished in India has been also declining but less than 10 % during the same time. In Pakistan the number of undernourished people have increased with 12.7 million. Today 22 % of the people of Pakistan suffer from undernourishment. However, the number of undernourished people in five countries has declined with 184 million or 30 % and situation in whole Asia is becoming better.

Table 16.4.1 Number of undernourished people (millions, FAO).

Country	1990-92	2000-02	2005-07	2010-12	2014-16	Change	Percent
India	210.1	185.5	233.8	189.9	194.6	-15.5	15.2%
China	289.0	211.2	207.3	163.2	133.8	-155.2	9.3%
Pakistan	28.7	34.4	38.1	38.3	41.4	12.7	22.0%
Bangaldesh	36.0	27.7	24.3	26.5	26.3	-9.7	16.4%
Indonesia	35.9	38.3	42.7	26.9	19.4	-16.5	7.6%
Total	599.7	497.1	546.2	444.8	415.5	-184.2	

16.5 Famine years in Finland

Famine has happened during the years 1695 – 97, when about 150,000 people, 25 – 30 % of the population of Finland, starved or died because of the diseases caused by hunger and undernourishment. This was caused by the cold summers in Northern Europe and especially in Finland, Estonia and North Sweden. The frosts game in August and destroyed crops. People have to eat their cattle and dogs to survive. After the cattle was eaten the people started to move to population centers and spreading diseases.

Famine years were happening for the second time 1865 – 1868, when also about 150,000 lives (8 % of population) were lost for hunger and diseases caused by hunger. The crop was mainly destroyed in 1865 in North Finland and people started to move to Sweden and Russia. In 1866 summer was wet and potatoes were rotten in the fields. In 1867 summer was short, when the ice cover from the lakes was removed in June and frost game in August. In the beginning of the year 1868 hunger was devastating and 100,000 people died during the first half of the year. However, the summer was warm and crop was good for the first time after 1865.

Reason for the famine in Finland was the cold and wet summers, which destroyed crop during many years. The climate change has caused summers to become longer and risks of losing crop smaller. Additionally, the policy of Finnish government was devastating. Finland was exporting rye in 1867, while its own population was starving. There were also individuals who helped Finland. One of them was a banker C. Rothschild who gave Finland a loan from his own cash to buy 40,000 barrels of barley from other countries.

Since these years there has been enough food for living. Only during the war years in 1939 – 1944 there were times when hunger was back. Men were in the war against Soviet Union, which tried to occupy the land. All imports of food were stopped because the seas were full of mines and warships.

Today a Finland produces almost 100 % of its need of food with only 0.5 hectares per capita cultivated land in 60 000 farms. The yields per hectare have been variating 3.3 – 4.1 tons for wheat, 2.2 – 2.9 tons for rye, 3.2 – 3.6 tons for barley, 3.0 – 3.5 tons for oats and 21 – 28 tons for potatoes after year 2000.

16.6 Emissions of food production

Greenhouse gas emissions of food production have been estimated by FAO to be about 5 – 6 million tons of CO_2 equivalent (Table 16.6.1).

Table 16.6.1 Greenhouse gas emissions of food 2010 (Source FAO Statistics 2013).

Emission source	Mt CO2-eq
Fermentation	2019
Manure	1215
Rice cultivation	499
Synthetic fertilizers	683
Crop residues	154
Cultivated organic soils	97
Burning crop	22
Others	800
Total	5489

FAO estimates does not give emission factors for individual food sources, but FAO gives production figures of nine most important food products. The food production of food was about 4700 million tons in 2010. Combining this data with 5.5 Gt emission estimates we can get CO_2 emission caused by each food production (Table 16.6.2).

Table 16.6.2 Estimating greenhouse gas emissions of food production (CO_2 eq.).

Food	World Production Mton	kg per person kg	CO2 content kgCO2/kg	CO2 Emissions Mton	CO2 per person kgCO2
Beef	68	10	10	680	96
Pork	119	17	5	595	84
Chicken	112	16	4	448	63
Eggs	68	10	3	204	29
Fish	148	21	1.5	222	31
Milk	553	78	1	553	78
Cereals	1100	155	0.7	770	108
Fruits	583	82	0.7	408	57
Vegetables	966	136	0.7	676	95
Others	1000	141	1	1000	141
Total	4717	664	1.2	5556	**783**

The 5.5 Gt greenhouse gas emissions caused by food production have not divided between CO_2, CH_4 and N_2O. However, large share of greenhouse gas emissions is coming from CH_4 (animals) and N_2O (fertilizer), which have mainly short term influence to the global warming.

16.7 Summary

Food production can be managed in the warming world. Actually, the conditions for food production have been becoming better in the Nordic countries like Finland. Finland has experienced two famine periods starting in year 1695 and 1865, when about 150.000 people starved and 30 % and 8 % of people lost they lives because of lost crops caused by cold periods.

However, global warming has caused changes in precipitation. Several droughts in Africa have caused famine in East Africa. Today about 20 % of African people suffer from undernourishment. To feed millions of undernourished people means investments in irrigation systems, which could protect crops from draughts.

Greenhouse gas emissions caused by food production are 5 – 6 Gt of CO_2 equivalent. About half of the 2.5 – 3 Gt emission are CO_2 and other half CH_4 and N_2O. Thus food production corresponds about 8 % of global CO_2 emissions of 35 Gt annually.

17 FORESTS

17.1 Forest area

Forests cover about 31 % of earth ground area (Figure 17.3.1). There are regions where more than 60 % is covered by forests like Finland, Sweden and Brazil. Some regions in Africa, Middle East and Australia have practically no forests.

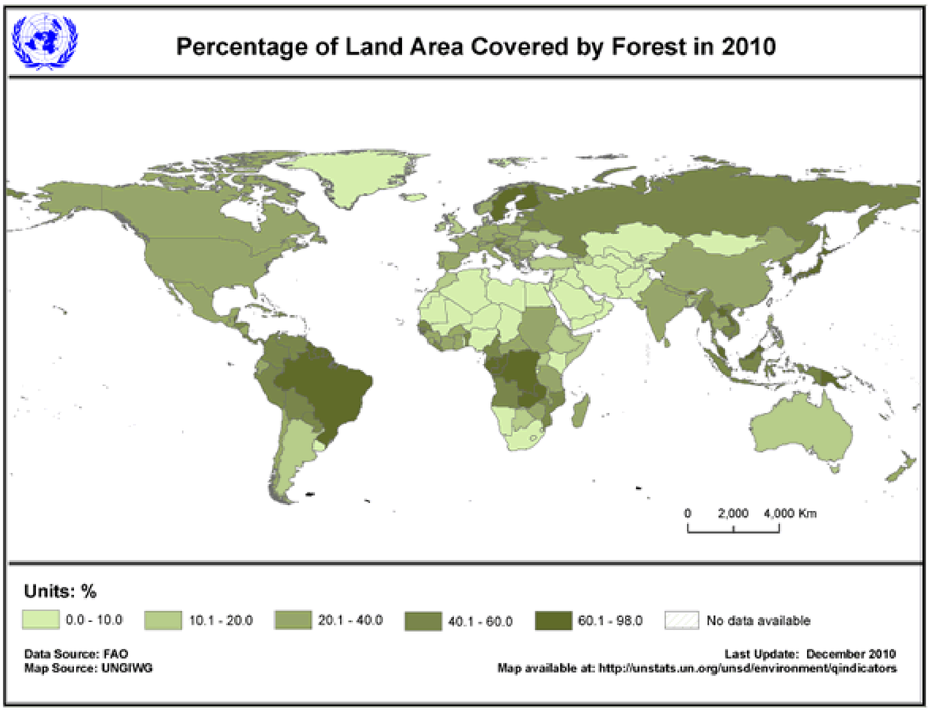


Figure 17.1.1 Forests cover in average about 31 % of land area.

The forest area is about 4 000 million hectares and 39 % of this is in Americas (Table 17.1.1). The total area of forests has been declining 135 million hectares (4 %) from the year 1990. About 85 million hectares have diminished only in in Americas and 75 million hectares (10 %) in Africa. However, the forest area has been growing in Asia and Europe.

Table 17.1.1 Forest area in million hectares (FAO).

	Forest area (M ha)			Change in forest area (M ha)				
	1990	2000	2010	Percent	1990-00	2000-10	Total	Percent
Africa	749	708	674	17%	-41.0	-34.0	-75.0	-10%
Asia	577	571	593	15%	-6.0	22.0	16.0	3%
Europe	989	998	1005	25%	9.0	7.0	16.0	2%
Americas	1655	1610	1570	39%	-45.0	-40.0	-85.0	-5%
Oceania	198	198	191	5%	-0.4	-7.0	-7.4	-4%
	4168	4085	4033	100%	-83.4	-52.0	-135.4	-3%

The Brazil and China have had large changes in their forest area (Table 17.1.2). The forest area in China has been growing almost as fast as it has been declining in Brazil.

Table 17.1.2 Countries with largest forest area (FAO).

	Forest area (M ha)			Change in forest area (M ha)		
	1990	2000	2010	1990-00	2000-10	Total
Russia	809	809	809	0.0	0.0	0.0
Brazil	575	546	520	-29.0	-26.0	-55.0
USA	296	300	304	4.0	4.0	8.0
Canada	310	310	310	0.0	0.0	0.0
China	157	193	207	36.0	14.0	50.0
DR Congo	160	157	154	-3.0	-3.0	-6.0
Total	2307	2315	2304	8	-11	-3

17.2 Carbon stock

Decline in the forest area has also followed by decline in growing stock of wood in the forests. Since 1990 forest stock has declined with 2900 million cubic meters (Table 17.2.1). There has been growth in Europe and Asia, but reduction is Africa and Americas.

Table 17.2.1 Growing stock of world forests,

	Growing stock (Mm3)			Change (Mm3)			Change
	1990	2000	2010	1990-00	2000-10	Total	%
Africa	83,035	79,904	76,951	-3131	-2953	-6084	-7%
Asia	51,336	52,543	53,685	1207	1142	2349	5%
Europe	103,849	107,757	112,052	3908	4295	8203	8%
Americas	270,592	264,849	263,631	-5743	-1218	-6961	-3%
Oceania	21,293	21,415	20,885	122	-530	-408	-2%
Total	530,105	526,468	527,204	-3637	736	-2901	-1%

Carbon stock of forest has been declining with 19 Gt of carbon in 20 years from the year 1990 (Table 17.2.2). The forests have emitted carbon dioxide 70 Gt (19 x 44/12) during 20 years or 3.5 Gt per year. This is about 10 % addition to 34 Gt annual CO_2 emissions of fossil fuels during years 2013 – 2015.

Table 17.2.2 Carbon stock of world forests.

	Carbon stock (Gt)			Change (Gt)		
	1990	2000	2010	1990-00	2000-10	Total
Biomass	299	294	289	-5	-5	-10
Dead wood	34	33	33	-1	0	-1
Litter	39	39	39	0	0	0
Soil	300	295	292	-5	-3	-8
Total	672	661	653	-11	-8	-19

Countries have large variations in their carbon stock development in forests. The largest positive changes have USA, China and India (Table 17.2.3). Also many European countries like Nordic countries have increased their carbons socks. Thus using food as fuel has not caused CO_2 emissions in those countries.

Table 17.2.3 Countries with largest changes in carbon stock of forests.

	Countries	Carbon stock (Gt)			Change (Gt)		
		1990	2000	2010	1990-00	2000-10	Total
1	USA	17.0	18.0	19.3	1.0	1.3	2.3
2	China	4.4	5.2	6.2	0.8	1.0	1.8
3	India	2.2	2.4	2.8	0.2	0.4	0.6
4	Germany	0.98	1.19	1.41	0.21	0.22	0.43
5	Malaysia	2.8	3.4	3.2	0.54	-0.15	0.39
6	Poland	0.7	0.8	1.0	0.12	0.16	0.28
7	France	1.0	1.1	1.2	0.08	0.16	0.24
8	Norway	0.28	0.32	0.40	0.04	0.08	0.12
9	Finland	0.72	0.80	0.83	0.08	0.03	0.11
10	Sweden	1.18	1.18	1.22	0.00	0.04	0.04
11	UK	0.12	0.12	0.14	0.00	0.02	0.02
12	Russian Fed.	32.5	32.2	32.5	-0.34	0.34	0.00
13	Congo Dem R.	3.5	3.5	3.4	-0.03	-0.02	-0.05
14	Colombia	7.0	6.9	6.9	-0.1	0.0	-0.1
15	Zambia	2.6	2.5	2.4	-0.1	-0.1	-0.2
16	Angola	4.6	4.5	4.4	-0.1	-0.1	-0.2
17	Papua New G.	2.5	2.4	2.3	-0.1	-0.1	-0.2
18	Peru	8.8	8.7	8.6	-0.1	-0.1	-0.2
19	Mexico	2.2	2.1	2.0	-0.1	-0.1	-0.2
20	Argentina	3.4	3.2	3.1	-0.2	-0.1	-0.3
21	Myanmar	2.0	1.8	1.7	-0.2	-0.1	-0.3
22	Canada	14.3	14.3	13.9	0.0	-0.4	-0.4
23	Tanzania	2.5	2.3	2.0	-0.3	-0.2	-0.5
24	Bolivia	4.9	4.7	4.4	-0.2	-0.3	-0.5
25	Cameroon	3.3	3.0	2.7	-0.3	-0.3	-0.6
26	Nigeria	2.0	1.6	1.3	-0.4	-0.3	-0.7
27	Congo Dem R.	20.4	20.0	19.6	-0.4	-0.4	-0.8
28	Nigeria	2.0	1.6	1.1	-0.5	-0.5	-0.9
29	Indonesia	16.3	15.2	13.1	-1.1	-2.1	-3.2
30	Brazil	68.1	65.3	62.6	-2.8	-2.7	-5.5
Sum of 30 countries		234.2	230.0	225.7	-4.2	-4.3	-8.5
Rest of the world*		437.8	431.0	427.3	-6.8	-3.7	-10.5
	World*	672.0	661.0	653.0	-11.0	-8.0	-19.0

* Does not include all countries

The largest negative changes have Brazil, Indonesia and Congo (Dem. Rep.). Also many other countries in Africa and South America have decreasing their carbon stocks in forests. Thus any use of wood for energy will cause increase in CO_2 emissions in these countries.

17.3 Africa

Forest area in Africa has been declined in most of the countries. In 16 countries with the largest forest area have had a loss of forest area with 50 million hectares (8 %) from the year 1990 (Table 17.3.1). In Tanzania, Ethiopia, Zimbabwe and Botswana the forest area has declined with 20 % or more.

Table 17.3.1 Forest area in 16 countries in Africa in million hectares (FAO).

	Forest area (M ha)			Change in forest area (M ha)			Change
	1990	2000	2010	1990-00	2000-10	Total	%
DR Congo	160	157	154	-3.0	-3.0	-6.0	-4%
Sudan	76	70	70	-6.0	0.0	-6.0	-8%
Angola	61	60	58	-1.0	-2.0	-3.0	-5%
Zambia	53	51	49	-2.0	-2.0	-4.0	-8%
Mozambique	43	41	39	-2.0	-2.0	-4.0	-9%
Tanzania	41	37	33	-4.0	-4.0	-8.0	-20%
Centr. Afr. Rep	23	23	23	0.0	0.0	0.0	0%
Congo	23	23	22	0.0	-1.0	-1.0	-4%
Gabon	22	22	22	0.0	0.0	0.0	0%
Cameroon	24	22	20	-2.0	-2.0	-4.0	-17%
Zimbabwe	22	19	16	-3.0	-3.0	-6.0	-27%
Madagascar	14	13	13	-1.0	0.0	-1.0	-7%
Ethiopia	15	14	12	-1.0	-2.0	-3.0	-20%
Chad	13	12	12	-1.0	0.0	-1.0	-8%
Botswana	14	13	11	-1.0	-2.0	-3.0	-21%
Cote d'ivore	10	10	10	0.0	0.0	0.0	0%
Total	614	587	564	-27	-23	-50	-8%

17.4 South America

The forest area has been declining also in the most South American countries. The decline from the year 1990 has been 88 million hectares (9 %) in the ten countries with the largest forests (Table 17.4.1). The decline has been more than 10 % in Peru, Venezuela, Argentina and Paraguay.

Table 17.4.1 Forest area in 10 countries in South America in million hectares (FAO).

	Forest area (M ha)			Change in forest area (M ha)			Change
	1990	2000	2010	1990-00	2000-10	Total	%
Brazil	575	545	520	-30.0	-25.0	-55.0	-10%
Peru	79	69	68	-10.0	-1.0	-11.0	-14%
Colombia	63	62	60	-1.0	-2.0	-3.0	-5%
Bolivia	63	60	57	-3.0	-3.0	-6.0	-10%
Venezuela	52	49	46	-3.0	-3.0	-6.0	-12%
Argentina	34	32	29	-2.0	-3.0	-5.0	-15%
Paraguay	21	19	18	-2.0	-1.0	-3.0	-14%
Chile	15	16	16	1.0	0.0	1.0	7%
Guyana	15	15	15	0.0	0.0	0.0	0%
Surinam	15	15	15	0.0	0.0	0.0	0%
Total	932	882	844	-50	-38	-88	-9%

Forests in Brazil have carbon stock of 63 Gt (gigaton), which in almost 10 % of carbon stock of all forests in the world. This carbon stock has been declining 0.6 Gt annually, which corresponds almost the total carbon stock of Finnish forests.

In Brazil industrial round wood production and fuel wood production has been both about 120 million m^3 annually (Table 17.4.2). This is not a sustainable level, because the forest area in Brazil has been declining 55 million ha during last 20 years or about 2.8 million hectares annually.

Table 17.4.2 Largest producers of industrial round wood (FAO).

	Industrial round wood (Mm3)			Fuel wood (Mm3)		
	1990	2000	2005	1990	2000	2005
USA	499	496	481	97	52	51
Canada	189	212	214	7	3	3
Russia	268	104	135	68	48	51
Brazil	115	92	117	162	121	123
Sweden	56	65	76	4	7	11
China	64	56	64	64	76	64
Germany	37	56	55	8	12	17
Finland	44	56	55	3	5	6
Total	1272	1137	1197	413	324	326

17.5 USA

USA has been the largest producer of industrial round wood with about 480 million cubic meters annually. Additionally, it has been using 50 million cubic meters of fuel wood. However, the carbon stock of US forests has been growing because of reforestation. The forest area has been growing 8 million hectares during last 20 years (Table 17.1.2).

17.6 Finland

Finland is one of the countries, where the stock of forests has been growing. The volume was 1500 million cubic meters in the years 1964 – 1970 (Figure 17.6.1), but in years 2009 – 2010 the volume was 2280 million cubic meters. Growth has been 780 million cubic meters in 40 years or about 20 million cubic meters per year.

The forests have acted as carbon sink and in the year 33 million tons of CO_2 was sequestrated (Figure 17.6.2) by the forests in the year 2010. This was net sequestration of about 40 million tons of growing trees and mineral soil minus peatland emissions of 7 million tons of CO_2 equivalent. The gross CO_2 emissions of Finland were 74.6 million tons and with the forest sequestration of 32.8 Mt the net CO_2 emissions were 41.8 Mt.

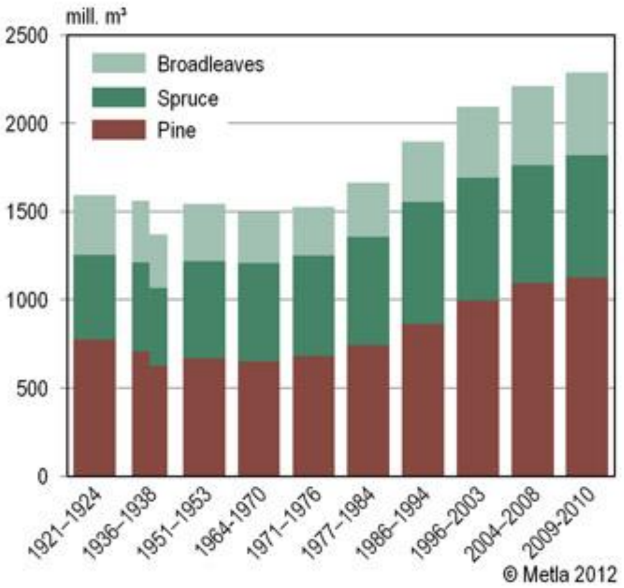


Figure 17.6.1 Growing stock of Finnish forests (State of Finnish Forests. Metla 2012).

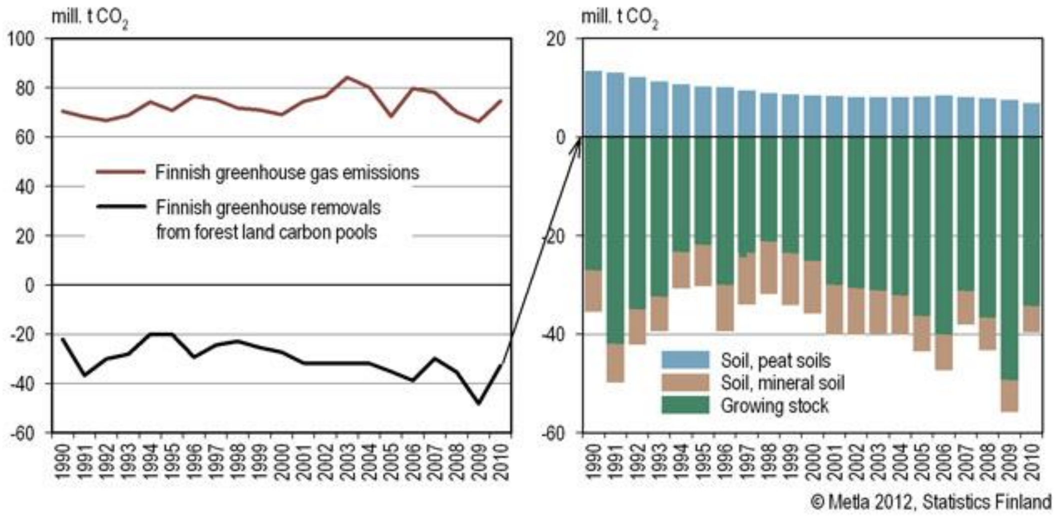


Figure 17.6.2 Greenhouse gas sequestration by forest land in Finland (State of Finnish Forests. Metla 2012).

Removals of industrial wood in Finland has been 55 million m^3 and fuel wood 5 – 6 million m^3 annually after year 2005. This is less than the 100 million m^3 annual growth rate of forests. This comes from the active reforestation of Finnish forests.

17.7 Summary

The forests have stored 650 Gt of carbon, which consists of 289 Gt in biomass, 72 Gt in dead wood and litter and 292 Gt in soil. If this mass will be burned the CO_2 emissions will be 3.7 x 650 or 2400 Gt of CO_2. The same amount of cumulative emissions will be achieved by 2040 with fossil fuels (Figure 10.2.6).

The carbon stock of forests has been declining after year 2000 with about 8 Gt per decade or about 3 $GtCO_2$ annually. This has caused about 9 % addition to 35 Gt annual CO_2 emissions of fossil fuels. However, some of the carbon in forest will be stored in houses and structures made by mankind.

The loss or gain of carbon stock should be counted into the CO_2 balance of each countries. Then we could note that some countries like China, USA and Finland have been increasing their carbon stocks in forests and buildings.

18 PLANNING OF ZERO EMISSION FUTURE

18.1 Zero emission houses

Single family homes

Planning of zero emissions houses starts from the selection of building materials. Net CO_2 emissions are negative, if the house will be built using logs. Typical Finnish log houses acts as CO_2 storage, which have net storage content of 35 – 61 tons of CO_2 (Table 18.1.1).

Table 18.1.1 Net CO_2 storage content of log houses during construction phase (Source: Karja Behm, Tarja Häkkinen, VTT 2010).

Log houses	Floors	1	1	2	2
	Logs (mm)	180	270	180	270
Wood content					
Area of walls	m2	90	90	193	193
Volume of walls	m3	38	48	51	70
Other wood	m3	8	8	13	15
Total wood	m3	46	56	64	85
CO2-emissions	tons	3	4	5	6
CO2-storage	tons	-38	-46	-52	-67
Net CO2 emissions	tons	-35	-42	-47	-61

The CO_2 emissions during the living phase can be minimized by using heat pumps for generating the heat. Typical heat consumption of a modern log house varies from 10 – 12 MWh (33 – 40 kWh/m^3) in 1-floor buildings to 15 – 18 MWh (30 – 36 kWh/m^3) in 2-floor buildings (Table 18.1.2).

Table 18.1.2 Net CO_2 emissions of log houses in Finland.

Log houses	Floors	1	1	2	2
	Logs (mm)	180	270	180	270
Heat consumption	MWh	12	10	18	15
Electricity consumption					
Household	MWh	4	4	5	5
Heat pump	MWh	4	3	6	5
Total	MWh	8	7	11	10
CO2 emissions					
CO2 content	kg/MWh	100	100	100	100
CO2 emissions	tons	0.8	0.7	1.1	1.0
Break even years	years	44	57	43	61
Emissions in 50 years	tons	5	-5	8	-11

Because of the heat will be produced with heat pump, 2/3 parts of heat is pumped from the ground and only 1/3 of energy is taken from the electricity. Additionally, electricity is needed for household consumption for lighting and home appliances.

It has been assumed that the average CO_2 content of electricity in Finland will be 100 g/kWh during the next 50 years. If the house will be built with 270 mm logs, the net emissions after 50 years are negative. It takes 44 – 61 years to emit as much of CO_2 as was stored in the building in the construction phase (Table 18.1.2). After 50 years the CO_2 content of electricity will be near zero.

However, in the other parts of the world, the CO_2 content of electricity is much higher. The average CO_2 content of the electricity generation of whole world will be about 490 g/kWh in 2020 and 115 g/kWh in 2070. Thus the average CO_2 content of house during years 2020 – 2070 will be about 300 g/kWh or three times the figures in Finland.

Log houses can last for 300 years. Two examples can be found in New Jersey, where Finnish origin brothers Eric and William Mullica built their house in the year 1704 in village called as Mullica Hill after their names. The two houses are the oldest houses in Mullica Hill and still in active use (Figure 18.1.1).

Figure 18.1.1 Mullica House was built by Eric Mullica in 1704 in Mullica Hill, NJ.

The log houses are also suitable for places, where earth quakes and hurricanes can happen. They have rigid structures that do not break down like in brick and concrete buildings. Additionally, the structure is not vulnerable to moisture, because the it is breathing and moisture passes through the log walls.

Today, it is possible to produce all of the electricity needed of the houses during summer time with solar panels and heat needed during winter time with wood. Thus the houses can be as zero emissions even if the electricity from the grid has large CO_2 content.

Multi-family houses and zero energy homes

Zero energy homes can be built also for multi-family houses. In this case the heat consumption will be minimized by building better insulation of walls and windows so that heat consumption drops from average 40 kWh/m^3 to 16 kWh/m^3 (building volume). Thus this amount of heat can be produced by solar collectors in the summer and heat pumps in the winter.

The electricity needed for lighting, heating and cooling devices can be generated with solar panels. Only the electricity needed for individual homes should be bought from the grid.

Zero emission homes

The present standards speak about zero energy homes. They should concentrate the speak about zero emission homes. If the energy comes from the sun, wind or heat pump, it does not matter, how much is consumed. The main thing is that CO_2 emissions will be zero. Thus the coding of homes should be made from the basis of the emissions.

The norms should be made based on the CO_2 emissions per square meter. If the starting heat consumption is 150 kWh/m^2 and the house is warmed by oil, CO_2 emissions are 50 kgCO_2/m^2. Assuming that each member of family has 40 m^2, the emissions are then 2 tons CO_2 per capita.

Next step will be heat pump homes, which will use then 50 kWh electricity per square meter to generate 150 kWh/m^2 heat. If the electricity has CO_2 content of 150 g/kWh, the emissions will be 8 kgCO_2/m^2 or 300 kgCO_2/capita. Third step will be heat pumps which use 100 gCO2/kWh electricity. Then the emissions will be 5 kgCO_2/m^2 or 200 kgCO_2/capita. By lowering the CO_2 content of electricity, finally zero emission homes can be built (Table 18.1.3).

Table 18.1.3 Transition to zero emission heat pump home.

Year		2020	2030	2040	2050	2060	Average
Heat consumption	kWh/m2	150	150	150	150	150	150
Energy factor	kWht/kWhe	3	3	3	3	3	3
Electricity load	kWh/m2	50	50	50	50	50	50
CO2 content	g/kWh	150	100	50	0	0	60
Emissions	kgCO2/m2	8	5	3	0	0	3
Emissions	kgCO2/capita	300	200	100	0	0	120

18.2 Transportation

Zero emission trains

Trains have been using electricity for a long time. An average train is consuming 0.12 kWh/km/passenger of electricity. If the electricity has 200 gCO_2/kWh, the emissions will be 24 gCO_2/km. This is about 80 % lower than average cars, which have about 120 gCO2/km emissions in Europe.

In Finland the electric trains have been using only CO_2 free electricity for a long time. Thus they can be considered to be zero emission already today.

Zero emission busses

Busses are following the trains and will be changed from diesel oil to electricity in the cities, where they have short driving distances a lot of stops and starts. They can be recharged within 1.5 – 3 minutes for the next ride (Figure 18.2.1).

Figure 18.1.1 The first of 12 fast recharging busses in Helsinki have started their drive in 2016 (Courtesy of Linkker Oy).

Several other cities have started to buy electric busses. Also London is starting its first experiments with new electric double deck busses.

The main advantage of electric busses is zero emissions in big cities where the air contains too much particle emissions from diesel busses. Also the noise emissions are much lower. Electric busses consume much less energy in frequent starting and stopping in the city traffic. WHO has made a list of 1600 most difficult cities in air pollution based on PM 2.5 concentration. Half of the 30 most polluted cities can be found in India (Table 18.2.1).

Table 18.2.1 WHO list of 30 most polluted cities on PM 2.5 concentration (µg/m³)

(source: http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/).

	Country	City/station	PM 2.5
1	India	Delhi	153
2	India	Patna	149
3	India	Gwalior	144
4	India	Raipur	134
5	Pakistan	Karachi	117
6	Pakistan	Peshwar	111
7	Pakistan	Rawalpindi	107
8	Iran	Khoramabad	102
9	India	Ahmedabad	100
10	India	Lucknow	96
11	India	Firozabad	96
12	Qatar	Doha	93
13	India	Kanpur	93
14	India	Amritsar	92
15	India	Ludhiana	91
16	Turkey	Igdir	90
17	Bangladesh	Narayonganj	89
18	India	Allahabad	88
19	India	Agra	88
20	India	Khanna	88
21	Bangladesh	Gazipur	87
22	Afghanistan	Kabul - ISAF HQ	86
23	Bangladesh	Dhaka	86
24	India	Jodhpur	86
25	Qatar	Al Wakrah	85
26	Mongolia	Darkhan	80
27	Turkey	Batman	77
28	Bangladesh	Barisal	77
29	India	Dehradun	77
30	Egypt	Delta cities	76

Annual PM 2-.5 concentration should be less than 10 µg/m³. The median figure of 1600 measured cities in 16 µg/m and only 500 of them can meet the annual average standard of 10 µg/m³. This list shows the cities which should change diesel busses and cars to electric to save lives and diseases caused by pollution.

The list includes 5 Finnish and 5 Swedish cities. All of them except one city in Sweden has less than 10 µg/m³ concentration. The list includes 378 US cities and 105 of them have higher than 10 µg/m³ concentration. Most western capitals have higher than 10 µg/m³ concentration (Table 18.2.2).

Table 18.2.2 PM 2.5 concentration in some capital cities (µg/m³).

City	ug/m3	City	ug/m3
Istanbul	32	Copenhagen	17
Budapest	28	London	16
Warszawa	26	Riga	16
Moscow	22	New York	14
Frankfurt	19	Oslo	13
Wien	19	Madrid	11
Brussel	18	Helsinki	8
Amsterdam	18	Tallinn	7
Paris	17	Stockholm	7

In long distance traffic the diesel busses will remain. They are not causing similar health problems in the country side. However, they have CO_2 emissions and can converted to use renewable diesel oil, which has been manufactured from wood or vegetable oil. These can be then considered as near zero emission busses.

Zero emission passenger cars

Road to zero emissions cars has already started. Electric cars will gradually find their market share. Of the 1500 million vehicles on the roads only 0.1 % are electric (Figure 18.2.2). However, the annual growth has been more than 50 %. With this growth 100 million EVs and 5 % market share can be achieved within 12 years.

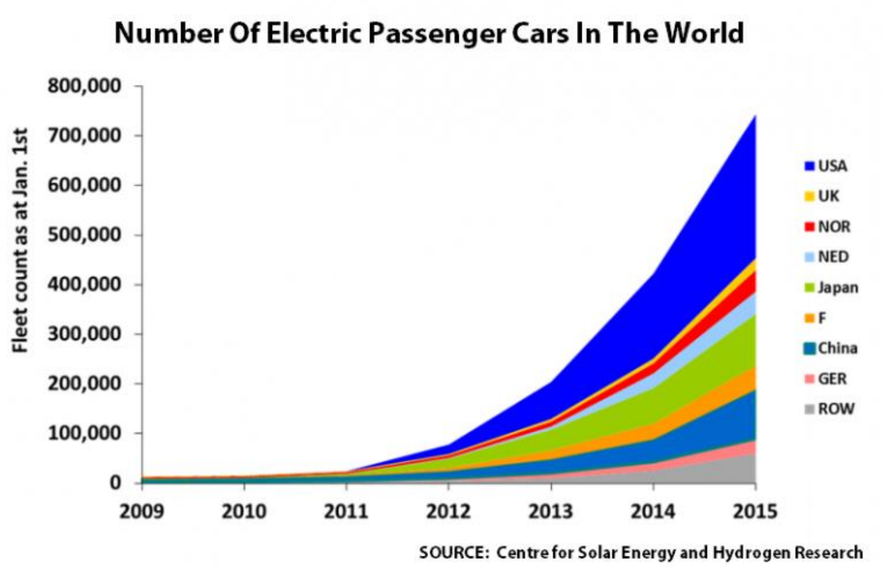


Figure 18.2.2 Number of electric vehicles on the roads.

Norway has been leading the development. In 2015 about 22 % of new cars sold were plug in electric vehicles. Of the all cars on the road now 3 % are EVs. They are all zero emission vehicles, because the almost 100 % of electricity comes from hydro power. Government policy gives EVs tax exemptions from VAT, road taxes, parking fees and toll payments.

Transformation to electric vehicles has already been evaluated in Chapter 9 (Figure 9.2.2). This can happen only, if CO_2 emission standards of vehicles will be tightened gradually until only zero emissions. With the present electric vehicles (EV), which use carbon free electricity, emissions can be zero. If the CO_2 content of electricity is gradually approaching zero by 2060, the emissions will also be zero at the same time (Table 18.2.2).

Table 18.2.2 CO_2 emissions of electric vehicles in the future.

Year		2020	2030	2040	2050	2060	Average
Driving distance	km	20000	20000	20000	20000	20000	20000
Electricity consumption	kWh/km	0.2	0.2	0.2	0.2	0.2	0.2
Electricity consumption	kWh	4000	4000	4000	4000	4000	4000
CO2 content	g/kWh	200	150	100	50	0	100
Emissions	kgCO2	800	600	400	200	0	400
Emissions	kgCO2/capita	400	300	200	100	0	200

Countries are in very different starting points concerning CO_2 content of electricity. Norway is already at zero level. In Finland the CO_2 content of electricity is 150 g/kWh. The average figure of CO_2 content of world electricity is about 500 g/kWh (Figure 18.2.3).

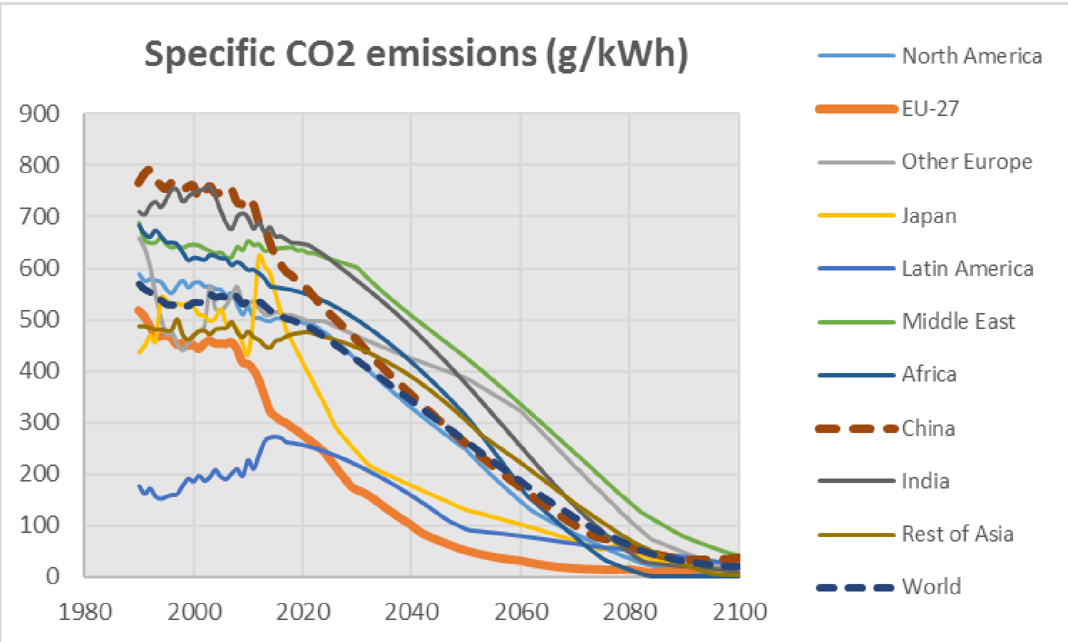


Figure 18.2.3 CO_2 content of electricity.

EU is now approaching 400 g/kWh. China has 700 g/kWh CO_2 emissions factor. Thus it will be long way to go to achieve Finland's todays figure of 150 g/kWh. EU will achieve 150 g/kWh in 2030 and the whole word in the year 2065 or 50 years from now.

18.3 Low carbon food

Greenhouse gas emissions caused by food has been estimated in chapter 16.6 to be 5 – 6 Gt CO_2 eq. This can be divided between food components, where the largest emissions are coming from beef, pork and chicken (Figure 18.3.1).

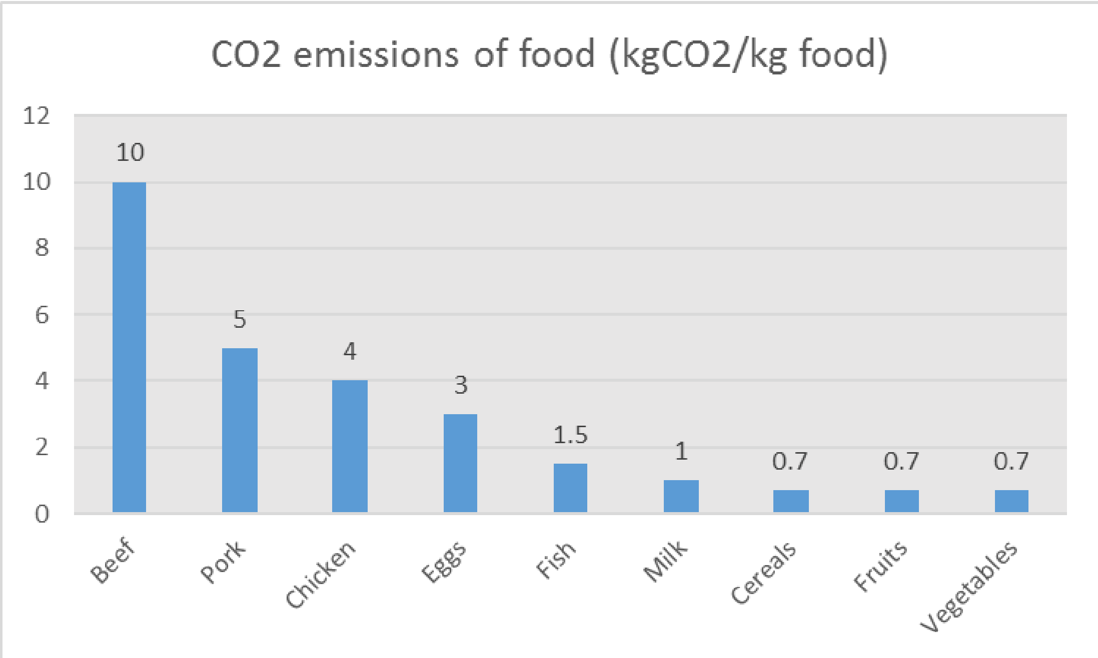


Figure 18.3.1 CO_2 emissions caused by eating 1 kg of food.

If the greenhouse emissions caused by food production are about 5.5 Gt CO_2 eq., with 7.1 inhabitants this corresponds to 780 kgCO_2-eq./capita. About 400 kgCO_2-eq. per capita emissions are caused by CO_2 and the rest of CH_4 and N_2O.

Variations between countries is large. Developing countries consume less meat and more cereals. Thus they cause much smaller emissions. However, their consumption is gradually moving to same level as in the developed world. It is also necessary to change the food habits of developed world to less meat diets.

18.4 Emissions caused by families

There are many calculators of CO_2 emissions available. Table 18.4.1 is given one example of a typical American family living in a heat pump house and driving an electric car. The emissions caused by a three person's family will be 14.5 tons of CO_2 or 4.9 tons per capita. About 25 % of emissions are coming from food and 75 % of electricity. Because of the electricity has CO_2 content of 600 gCO_2/kWh, it will be lowered radically in the future.

The same kind of average zero emission family in the world would have 10 tons of CO_2 emissions or 3.4 tons per capita (Table 18.4.2). An average electricity in the world has 500 g/kWh CO_2 content and an average world will eat less meat than an American family.

The same kind of zero emission family in Finland in 2015 has only 6 tons CO_2 emissions or 2 tons per capita, because the CO_2 content of electricity is only 150 g/kWh (Table 18.4.3). Finally, dropping CO_2 content of electricity to zero of a Finnish family by 2050 could drop CO_2 emissions to about 3.7 tons or 1.2 tons per capita (Table 18.4.4).

It looks that in the future the food will be the biggest source of CO_2 emissions caused by families. If the emission level will remain at 1.2 tons of CO_2 per capita (Figure 18.4.1), the future world CO_2 emissions will remain to about 10 – 12 gigatons with a population of 8 – 10 billion in the year 2100.

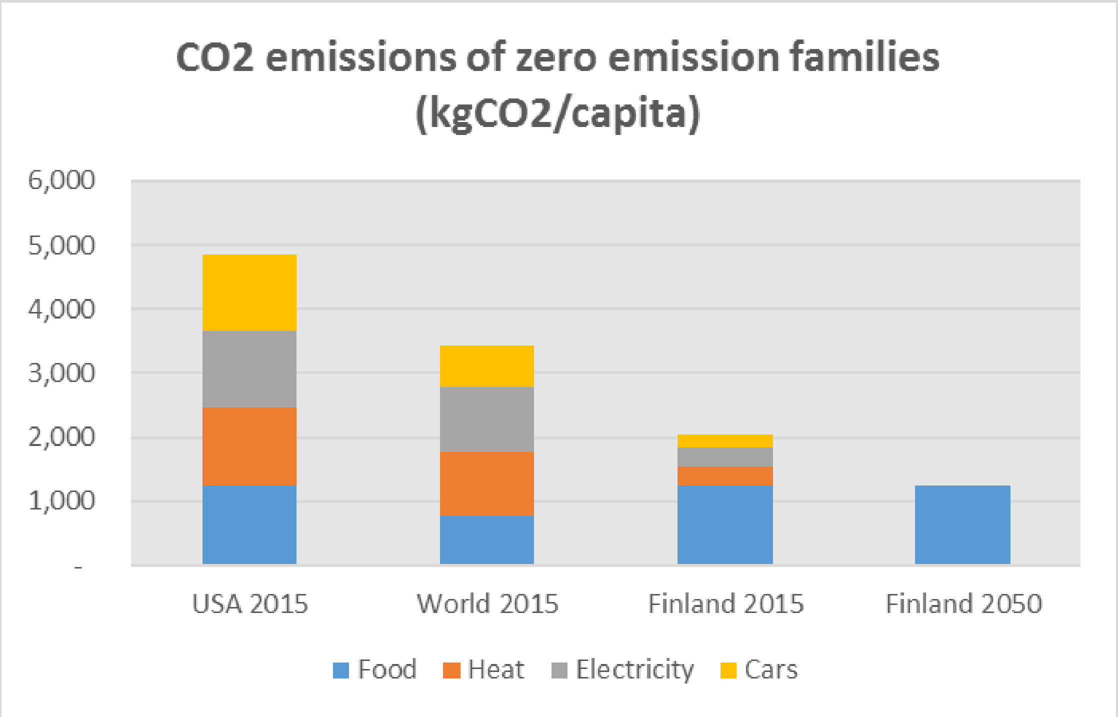


Figure 18.4.1 CO_2 emissions of zero emission families living in a heat pump house and driving an electric car.

Tables

Table 18.4.1 CO_2 emissions caused by an average American family in 2015 driving electric car and living in a heat pump house.

USA 2015	Consumption		Emission factor		CO2 emissions	
Heat consumption						
- area	120	m2				
- heat consumption	150	kWh/m2				
- heat consumption	18,000	kWh				
Gas heating						
- gas boiler efficiency	80%					
- gas consumption	22,500	kWh	200	g/kWh	4,500	kg
Electrical heating						
- electricity consumption	18,000	kWh	600	g/kWh	10,800	kg
Heat pump heating						
- heat pump factor	3					
- electricity consumption	6,000	kWh	600	g/kWh	3,600	kg
Electricity consumption						
- area	120	m2				
- electricity cons.	50	kWh/m2				
- electricity cons.	6,000	kWh	600	g/kWh	3,600	kg
Car driving						
- annual distance	30,000	km				
- electricity cons.	0.20	kWh/km				
- electricity cons.	6,000	kWh	600	g/kWh	3,600	kg
Food per person						
- beef	24	kg/person	10	kgCO2/kg	240	kg
- pork	18	kg/person	5	kgCO2/kg	90	kg
- chicken	24	kg/person	4	kgCO2/kg	96	kg
- eggs	12	kg/person	3	kgCO2/kg	36	kg
- fish	6	kg/person	1.5	kgCO2/kg	9	kg
- milk	240	kg/person	1	kgCO2/kg	240	kg
- cereals	77	kg/person	0.7	kgCO2/kg	54	kg
- fruits	110	kg/person	0.7	kgCO2/kg	77	kg
- vegetables	160	kg/person	0.7	kgCO2/kg	112	kg
- others	300	kg/person	1	kgCO2/kg	300	kg
Total	**971**	kg/person	**0.4**	kgCO2/kg	**1,254**	**kg**
	3	persons	**1254**	kg/person	**3,762**	**kg**
Total					**14,562**	**kg**
Number of persons					3	
Per person					**4,854**	**kg**

Table 18.4.2 CO_2 emissions caused by an average family in the world in 2015 driving electric car and living in a heat pump house.

World average 2015	Consumption		Emission factor		CO2 emissions	
Heat consumption						
- area	120	m2				
- heat consumption	150	kWh/m2				
- heat consumption	18,000	kWh				
Gas heating						
- gas boiler efficiency	80%					
- gas consumption	22,500	kWh	200	g/kWh	4,500	kg
Electrical heating						
- electricity consumption	18,000	kWh	500	g/kWh	9,000	kg
Heat pump heating						
- heat pump factor	3					
- electricity consumption	6,000	kWh	500	g/kWh	3,000	kg
Electricity consumption						
- area	120	m2				
- electricity cons.	50	kWh/m2				
- electricity cons.	6,000	kWh	500	g/kWh	3,000	kg
Car driving						
- annual distance	20,000	km				
- electricity cons.	0.20	kWh/km				
- electricity cons.	4,000	kWh	500	g/kWh	2,000	kg
Food per person						
- beef	10	kg/person	10	kgCO2/kg	97	kg
- pork	17	kg/person	5	kgCO2/kg	85	kg
- chicken	16	kg/person	4	kgCO2/kg	64	kg
- eggs	8	kg/person	3	kgCO2/kg	23	kg
- fish	21	kg/person	1.5	kgCO2/kg	32	kg
- milk	114	kg/person	1	kgCO2/kg	114	kg
- cereals	157	kg/person	0.7	kgCO2/kg	110	kg
- fruits	71	kg/person	0.7	kgCO2/kg	50	kg
- vegetables	4	kg/person	0.7	kgCO2/kg	3	kg
- other	200	kg/person	1	kgCO2/kg	200	kg
	618	kg/person	**0.4**	kgCO2/kg	**777**	**kg**
	3	persons	777	kgCO2	2,332	
Total					**10,332**	**kg**
Number of persons					3	
Per person					**3,444**	**kg**

Table 18.4.3 CO_2 emissions caused by an average Finnish family in 2015 driving electric car and living in a heat pump house.

Finland 2015	Consumption		Emission factor		CO2 emissions	
Heat consumption						
- area	120	m2				
- heat consumption	150	kWh/m2				
- heat consumption	18,000	kWh				
Gas heating						
- gas boiler efficiency	80%					
- gas consumption	22,500	kWh	200	g/kWh	4,500	kg
Electrical heating						
- electricity consumption	18,000	kWh	150	g/kWh	2,700	kg
Heat pump heating						
- heat pump factor	3					
- electricity consumption	6,000	kWh	150	g/kWh	900	kg
Electricity consumption						
- area	120	m2				
- electricity cons.	50	kWh/m2				
- electricity cons.	6,000	kWh	150	g/kWh	900	kg
Car driving						
- annual distance	20,000	km				
- electricity cons.	0.20	kWh/km				
- electricity cons.	4,000	kWh/km	150	g/kWh	600	kg
Food per person						
- beef	18	kg/person	10	kgCO2/kg	180	kg
- pork	36	kg/person	5	kgCO2/kg	180	kg
- chicken	20	kg/person	4	kgCO2/kg	80	kg
- eggs	12	kg/person	3	kgCO2/kg	36	kg
- fish	15	kg/person	1.5	kgCO2/kg	23	kg
- milk	240	kg/person	1	kgCO2/kg	240	kg
- cereals	80	kg/person	0.7	kgCO2/kg	56	kg
- fruits	100	kg/person	0.7	kgCO2/kg	70	kg
- vegetables	116	kg/person	0.7	kgCO2/kg	81	kg
- other	300	kg/person	1	kgCO2/kg	300	kg
Total	**937**	kg/person	**0.4**	kgCO2/kg	**1,246**	**kg**
	3	persons	1,246	kgCO2	3,737	kg
Total					**6,137**	**kg**
Number of persons					3	
Per person					**2,046**	**kg**

Table 18.4.4 CO_2 emissions caused by an average Finnish family in 2050 driving electric car and living in a heat pump house and eating like today.

Finland 2050	Consumption		Emission factor		CO2 emissions	
Heat consumption						
- area	120	m2				
- heat consumption	150	kWh/m2				
- heat consumption	18,000	kWh				
Gas heating						
- gas boiler efficiency	80%					
- gas consumption	22,500	kWh	200	g/kWh	4,500	kg
Electrical heating						
- electricity consumption	18,000	kWh	0	g/kWh	-	kg
Heat pump heating						
- heat pump factor	3					
- electricity consumption	6,000	kWh	0	g/kWh	-	kg
Electricity consumption						
- area	120	m2				
- electricity cons.	50	kWh/m2				
- electricity cons.	6,000	kWh	0	g/kWh	-	kg
Car driving						
- annual distance	20,000	km				
- electricity cons.	0.20	kWh/km				
- electricity cons.	4,000	kWh	0	g/kWh	-	kg
Food per person						
- beef	18	kg/person	10	kgCO2/kg	180	kg
- pork	36	kg/person	5	kgCO2/kg	180	kg
- chicken	20	kg/person	4	kgCO2/kg	80	kg
- eggs	12	kg/person	3	kgCO2/kg	36	kg
- fish	15	kg/person	1.5	kgCO2/kg	23	kg
- milk	240	kg/person	1	kgCO2/kg	240	kg
- cereals	80	kg/person	0.7	kgCO2/kg	56	kg
- fruits	100	kg/person	0.7	kgCO2/kg	70	kg
- vegetables	116	kg/person	0.7	kgCO2/kg	81	kg
- other	300	kg/person	1	kgCO2/kg	300	kg
Total	**937**	kg/person	**0.4**	kgCO2/kg	**1,246**	**kg**
	3	persons	1,246	kgCO2	3,737	kg
Total					**3,737**	**kg**
Number of persons					3	
Per person					**1,246**	**kg**