



## **MECHANISMS AND CONSEQUENCES OF CLIMATE CHANGE**

### **SUMMARY**

#### **Climate change will affect our wellbeing**

The earth suffers from an anthropogenic i.e. human induced disease called climate change. Main cause is the use of fossil fuels, deforestation in the tropics, and industrial processes. These have led to greenhouse gas accumulation in the atmosphere. Signs are an increased average temperature of the earth along with widespread disturbances in ecosystems. Therefore, when the disease advances, it will seriously affect our wellbeing.

This article (I/II) gives a basis for understanding the mechanisms and consequences of climate change and indicates the reality of the current unavoidable climate change. The second article (II/II) "Climate change shaping the future" discusses how climate change will affect industry.

#### **Understanding climate change is prerequisite for coping with it**

Understanding a disease is a pre-requisite for relating to it in a constructive way. Living in the midst of a climate change and not really grasping it, is like being very ill and, despite having a diagnosis, not really knowing what you have, what it will lead to and what you can do about it. A disease of the earth is a disease of ours because it affects us. In this case it is caused by humanity.

I will in this article not only explain the causes, signs and symptoms of climate change, and how it will affect our living conditions, but also its "Status Presens" and prognosis.

#### **Excess of green house gases have consequences on ice, seas, air and land**

The climate is dependent of the earth's average temperature, humidity, precipitation and winds. When global average temperature (GAT) changes over a long period of time, due to natural variability or through human activity, a climate change occurs. The whole ecosystem is affected. This will affect living conditions on earth.

A change in the GAT is related to changes in greenhouse gas concentrations in the atmosphere. Greenhouse gases (GHG) are gases like naturally occurring water vapour, carbon dioxide, methane, nitrous oxide, but also man-made halocarbons like chlorofluorocarbons. GHGs are important because they keep our planet warm. They let solar energy in to the atmosphere but prevent part of the heat from radiating out. The climate will cool down if concentrations of GHGs in the atmosphere decrease. If the concentrations increase, we get a warming of the climate. The more GHGs that are accumulated in the atmosphere, the stronger their heating effect, and the bigger and faster the temperature increase. This is what we are experiencing now.

Increasing emissions from human activities like the use of fossil fuels (oil, coal, gas), industrial processes and deforestation in the tropical area, have caused an accelerating warming of the earth. The reason is nature's very limited capacity to process surplus GHGs and rising temperatures. These have consequences on ice, seas, air and land.

#### **Decreasing glaciers risk important heat regulation and water supply**



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Snow and ice slow down temperature increases by reflecting back to space 80 % of the solar radiation reaching it. When snow and ice melt, the earth will warm up faster because open sea reflects back only 4 % and vegetation 5-20% of the radiation. Melting snow and ice bind heat indeed, but this can't counterbalance the decreasing reflectivity. Millions of people are dependent on mountain glaciers as sources for drinking water, irrigation and electricity. As mountain glaciers melt faster than new ice is formed, water shortage will be a consequence. Furthermore thawing of permafrost on mountains leads to land slides that can be disastrous. Even worse, a collapsing ice sheet could be creating a mega tsunami.

### **Seas suffer as a climate change buffer**

Seas have slowed down earth's temperature increase by taking up a lot of heat that would have warmed the atmosphere. Seas play a major role in the carbon cycle by storing and dissolving a lot of CO<sub>2</sub> from the atmosphere. Until saturation, the more CO<sub>2</sub> that is released in the atmosphere, the more of it will be dissolved in the water. This is also a problem because CO<sub>2</sub> and water form carbonic acid, which contributes to increased acidification of the seas. Increased water temperatures and decreased saltiness due to melting inland glaciers lead to lazier deepwater currents. This disturbs the marine balance and decreases the capacity to store CO<sub>2</sub>. At some stage the CO<sub>2</sub> storage may turn into a CO<sub>2</sub> source. That would accelerate the warming. Coral and plankton are invaluable for marine ecosystems and food chain. Acidification weakens coral and destroys them over time. Increasing temperatures decrease the amount of plankton. As a consequence the amount of fish will decrease.

### **A warming sea will bring coastal erosion, then flooding, inundation and ...**

A warming sea will expand. That contributes to the volume increase caused by melting inland glaciers. As a consequence sea levels will rise, causing coastal flooding and inundation. In the beginning the main problem is not the absolute sea level rise but the variations between extreme low and extreme high sea levels. This causes severe coastal erosion. It includes both salty water sipping into fresh water wells and, seawater causing infertile cultivations. When the average sea level rises, large areas will become impossible to live in.

Over thousands of years microbes have produced huge amounts of methane from organic plankton falling down to the seabed. The methane is stored as methane hydrate. As such they are not dangerous but increasing temperatures may release them. Their eruptions are explosive and vigorous. The methane released will significantly speed up the warming of earth, as methane's heating effect is 25 times CO<sub>2</sub>'s.

### **Clouds may contribute to the warming**

The role of clouds in global warming is not yet clearly defined. Generally clouds, especially clouds in the lower layers of the atmosphere reflect solar radiation and thus help to cool the earth. But, the warmer the air, the smaller is the number of clouds in the lower layers of the atmosphere. Thus less reflection of solar radiation back from earth to space. It is assumed that cloudiness at the poles will increase when the global warming increases. At the poles, clouds in the lower layers of the atmosphere give milder weather. At Arctic, clouds could accelerate the warming speed with 40 % and, speed up the worldwide warming with 30 %. Clouds of pollution (e.g. clouds formed during forest fires) and sand storm clouds tend to dry the clouds. This decreases rainfall with 30 %. That will increase droughts and the number of both forest fires and sandstorms. Winds will also behave differently. Storms will be, if not more numerous then at least more intense than ever experienced before. Horrendous storms may arise in completely new areas.

### **Warm air increases land destruction**

On land, vegetation, mainly forests, are part of the carbon cycle. They absorb a part of excessive CO<sub>2</sub> from the atmosphere. When CO<sub>2</sub> concentrations and temperatures have increased enough, the growth of the plant will suffer and the capacity to process CO<sub>2</sub> will decrease. It may even be reversed. Warm air binds more water leading to more rain at a time, but more seldom. The rain will not be evenly distributed. We will





see extreme droughts - and floods. Heat waves and droughts dry up the soil. If and when the rain comes, it is most likely torrential rain wiping away topsoil. Widespread years of bad crops are expected. This will affect also animals.

Warm air increases evaporation, escalating droughts and, multiplying the amounts of fires. Fires and destroyed forest areas emit CO<sub>2</sub>. This happens e.g. in Amazonas. Attacks by noxious insects and other noxious animals on trees rocket as an effect of the increase in temperatures. It is estimated that a 3°C increase in average winter temperature is enough to destroy 50 % of forests in the northern hemisphere. This equals 1/6 of all the forests in the world. In Siberia and Alaska considerable amounts of CO<sub>2</sub> and methane are stored under the ground in the permafrost areas. They will significantly contribute to the warming when they start to be released.

### **Earth's average temperature has been increasing alarmingly fast**

It may be interesting to note that for thousands of years the climate on earth was stable. Then slowly (very slowly) starting to cool down towards a new ice age, until human activities after 1750 reversed the development. As a consequence, the earth's average temperature has increased approximately 0,8°C, of which 0,4°C during the last 30 years. 0,8°C does not sound as very much. The planet has seen similar increases in temperatures before but, at that time it took thousands of years to reach it, not some hundred.

### **There is more warming in store**

For every day that we continue emitting GHGs into the atmosphere, their concentration will increase and further warm the climate. Once seas have fully warmed up, they will cause additional warming of the atmosphere as well. Today seas have already stored heat corresponding to roughly 0.6°C of extra warming (so called "committed warming") to increase the GAT. Hence, the signs we have seen so far are only the beginning.

### **Consequences of the warming are already visible**

The 0,8°C increase has been enough to magnify the intensity of extreme weather conditions like heat waves (Australia 2008, Europe 2003), droughts (China 2008), storms (Katrina 2005, Catharina 2004) and floods (India 2008, Africa, UK 2007). Permafrost thawing and glacier melting has accelerated (Matterhorn 2003, Larsen B 2002). In Antarctic seas CO<sub>2</sub> sinks have started to turn into sources. Large areas of forests in northern hemisphere (Siberia, Canada) have been destroyed by noxious animals and are turning into CO<sub>2</sub> sources. Climate ranges shift towards north 7 times faster than species can adapt why many species are going towards extinction. Even nations are approaching the end (Tuvalu, Kiribati).

### **Even if emissions were stopped the warming will continue for a long time**

The future climate will be characterized by extreme and erratic weather putting strains on the living conditions. This will accentuate with increasing GAT. The temperature will continue to rise as long as we emit greenhouse gases into the atmosphere. Even if the emissions were stopped abruptly, the warming would continue for several decades or even centuries. This is because of the long lifetime of GHGs and, the delay in warming associated with oceans.

### **Climate models have been too cautious**

Scientists use climate models, actual measurements and findings from historical times to estimate future temperature increases and consequences. Some people doubt the accuracy of the GAT measurements and the models. Indeed, predicting the future climate is connected with a lot of uncertainties. However, the majority of scientists and experts agree that the temperature increase trend is evident. IPCC or the Intergovernmental panel for Climate Change has in their reports since 1990 drawn many scenarios for the future. So far, most of the models seem to have been too cautious. With these results in mind and, looking at





the current concentration of GHGs in the atmosphere, and the rate at which the warming already has proceeded, a GAT increase of min. 2°C by the end of the century can't be avoided anymore.

**A dangerous climate change is inevitable**

Assumed consequences of a +2°C GAT increase are possible extinction of 30 % of the species, increasing droughts, water stress for 1-2 billion, more intense storms and floods, decreasing yields, and increasing deaths due to excessive heat, malnutrition, epidemic diseases and natural catastrophes. Sea levels could rise with almost one meter. This could create 50 to 150 million environmental refugees and increase flood damages with up to 200 %. Furthermore a +2°C GAT increase is considered a limit where natural carbon sinks start turning into CO2 sources. This would further accelerate warming. No wonder EU has defined +2°C as a dangerous climate change.

Findings from the Pliocene time, 3 million years ago, show that the CO2 concentrations which were similar to what we have today, caused a 3°C increase in GAT. Considering the speed at which GHGs currently increase in the atmosphere today and how slow actions to curb emissions proceed, I think we will be very fortunate if we manage to limit the temperature increase to “only” 3°C. What the final temperature increase will be depends on our emissions. It is actually quite simple, the more GHGs in the atmosphere, the higher and faster the temperature increase and the more dramatic the outcome. A list of possible consequences can be found in Table 1.

The disease is severe. It is advancing and is potentially fatal. However, with right medication the disease and its consequences can presumably be kept under control. This will be discussed in my second article “Climate change will affect the industry”.





**Table 1. Foreseen consequences of different GAT increases during 21<sup>st</sup> century**

GAT increase/°C	Threshold	Possible consequences in the 21 <sup>st</sup> century - TRemperature increases compared to pre-industrial levels
0-1 <b>At present</b>	Accelerated arctic warming	Warming in polar regions intensifies, local retreat of ice in Greenland and Antarctica, local deglaciation, drinking water supply decrease, damage from droughts, floods, storms, coral bleaching
1-2	Positive feedback loops (aggravating) get activated	Local deglaciation, water stress 1 billion, most corals bleached, sea level rises, heat waves and forest fire frequency up, vegetation start releasing CO <sub>2</sub> , 50-150 million environmental refugees
2-3	Carbon sinks turning to sources	30% loss of arctic permafrost area, water stress 1-3 billion, sea level rise +1-2m, warm seas release CO <sub>2</sub> , widespread coral mortality, 15 % of vegetation releases CO <sub>2</sub> , extinction 30 % species
3-4	Releases of Siberian methane	West Antarctic glaciers close to collapse, water stress 1-3 billion, sea level +5m, permafrost thawing releases Siberian methane => extra warming +1-3 °C, 30 % loss of coastal wetlands
4-5	Releases of methane hydrates from seas	No glaciers, >3 billion with water stress, sea level rises, methane hydrate releases from seas warms climate and causes tsunamis and underwater landslides, 40 % of vegetation CO <sub>2</sub> source
5-6	Major extinctions	Oxygen free seas produce H <sub>2</sub> S, methane hydrate releases are strong like nuclear bombs, no ozone layer, unstoppable super hurricanes, human life may end, other major extinctions
For every temperature interval	Increasing Intensity	Sea level rises due to thermal expansion and glacier melting Damage from droughts, floods and storms, inundation Morbidity and mortality from heat waves, floods and droughts Burden from malnutrition, diarrhoeal, heart and lung diseases and infectious diseases

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