A TINY BOOK ON CLIMATE

What Can we Do to Prevent the Overheating of the Planet?

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A Brief Introduction: What is Global Warming?

The planet Earth is, at the moment, radiating back to space a little bit less energy than what it receives from the Sun. The result is a small energy imbalance, amounting to roughly 1 watt of heat for every square metre of our planet's surface. This means that the Earth is now like a house which is being heated so efficiently that the production of new heat is more than the amount which escapes through the windows, walls and the roof. Sooner or later a new balance will be found and the amount of escaping heat will again be equal to the production. But until this new equilibrium is reached, the planet will keep on heating.

Where does this approximately 500,000 -gigawatt imbalance in our planet's energy budget come from? One reason are the so called greenhouse gases, water vapour, methane, carbon dioxide, nitrous oxide, tropospheric ozone, the freons (or chlorofluorocarbons or CFCs) and some of the substances which have now largely replaced them (like the HCFCs). The greenhouse gases are able to "catch" infrared or heat radiation before it escapes back to space from the surface of our planet, like an invisible glass of a greenhouse. Human activities are increasing the concentrations of greenhouse gases in the atmosphere, and by doing this we are heating the planet.

Another factor are the so called black aerosols, small soot particles and tar balls which are produced when something is burned. They do not stay in the atmosphere for a very long time, but they absorb sunlight efficiently.

Most scientists think that between 0.1 and 0.2 degrees Celsius of the 0.8 degree warming which has already taken place, this far, has probably happened because the Sun has been a little bit more active than what is its long-term average.

Our home planet is also overheating because of its albedo or reflectivity – its capacity to reflect sunlight directly back to space – is diminishing. Open water surfaces, forests, other vegetation and dark soils absorb most of the sunlight falling on them like a sponge, so when the ice and snow cover retreats in the polar regions the surface of the planet becomes darker.

The condensation trails left on the sky by the jet planes also contribute to the global warming. Their global impact is relatively small when compared with the other factors. However, the heating impact of the condensation trails concentrates on the northern areas. Therefore it is likely to be one of the reasons for the unexpectedly rapid melting of the Arctic.

Why Global Warming is a Very Serious Issue

If the climate heats by a couple of degrees centigrade, the average strength of hurricanes and typhoons should increase by 50 per cent or so, which would make them much more destructive. The annual number of cyclones might also increase. If the warming amounts to 6 degrees or even more, such impacts will be much more intense.

The world's rice crop is very vulnerable to rising temperatures. If temperature rises above 35 degrees Celsius for more than one hour while the rice is flowering, the heat sterilizes the pollen so that no grains will be produced. According to the International Rice Research Institute we might lose 15 per cent of the world's rice crop with every degree of global warming.

Global warming should increase rainfall because more water will evaporate from the oceans. However, the evaporation of water from the soils and from the freshwater lakes and rivers is likely to increase even more. Thus most of the tropical and subtropical regions may become much drier than now. The Intergovernmental Panel on Climate Change has said that up to five billion people might soon suffer from an acute lack of irrigation water, partly because of the global warming.

James Hansen, the leading climate scientist in the USA, has said that sea level rise will most probably become the most important single issue of the 21st century. In the 19th century the sea level was rising by only 0.1 millimetres per year. In 1950's the speed started to accelerate, and was approximately 2 millimetres in the 1990's. The present rate of sea level rise might be 3.7 millimetres per year, even though there is some variation in the results. This rate corresponds to 37 centimetres in a century.

However, the melting of the Greenland and the West Antarctic ice sheets seems to be accelerating. A few years ago glaciologists still thought that even if the climate would become significantly warmer, it would take thousands of years before the extra warmth would reach the bottom of the glaciers. It was thought that two kilometres of ice would act like a two-kilometre thick bed of effective insulation material.

The basis of these old models describing how continental glaciers melt has since then been completely annihilated by empirical observations. The surface melting on the Greenland and West Antarctic ice sheets has achieved unprecedented proportions during warm summers, and whole small rivers of melt-water have started to disappear inside the glaciers through cracks in the ice. Scientists watching the process in awe suddenly realized, more than a little bit shocked, that the heat can actually reach the bottom of a glacier in thirty seconds instead of thousands of years, in the form of waterfalls created by the surface melting. The melt water pooling under the glaciers acts like a lubricant which accelerates the speed by which the glaciers flow towards the ocean.

The destruction of many ice shelves, floating tongues of ice which stretch into the ocean, has accelerated the melting of many glaciers. It seems that the ice shelves are acting like a cork in a bottle, and slowing down the movements of the glaciers. For example the glacier behind the famous Larsen B ice shelf – which suddenly broke to thousands of icebergs and floated away in 2002 – is now streaming towards the sea eight times faster than before. The glaciers on the Antarctic Peninsula are relatively small, and even if they would melt totally they would only raise the sea level by half a metre. But glaciologists are now more than a little bit afraid that Larsen C will be the next to go, and that after that even the massive Ronne ice shelf might be in danger. This would accelerate the melting of the whole West Antarctic ice sheet.

Some scientists have started to fear that the whole complex of glaciers streaming to the Pine Island Bay of the West Antarctic may already be doomed for rapid destruction, unless the climate cools again. Pine Island Bay is the soft underbelly of the West Antarctic. If the two gigantic glaciers, Pine Island Glacier and Thwaites Glacier, streaming to the bay will melt, sea level will rise by two metres. Moreover, the whole West Antarctic ice sheet would in practise be cut into two separate pieces. If this happens, these separate pieces would be attacked by the warming sea waters from all directions at once, and would not be likely to last very long.

James Hansen wrote, in July 2007, that in the light of these recent observations a five-metre-rise in the sea level before the year 2007 is a much more probable scenario than the official, much lower prediction of the Intergovernmental Panel for Climate Change (IPCC). The well-known US glaciologist Richard Alley has noted that we can no longer, after the observations made during the summer of 2005, exclude even the possibility that a large chunk of the Greenland ice sheet might disintegrate in a couple of decades.

14,500 years ago there was a period of 400 years during which the sea levels rose by 20 metres, and it is possible that 13.5 metres of this 20-metre rise took place in a very short period of time, within a few decades, possibly even faster. The only plausible explanation for this is that some large, continental ice sheets which were anchored below the sea level suddenly broke to pieces and just floated away.

Could something similar happen, in our own time? Unfortunately the possibility cannot be excluded. Almost the entire West Antarctic ice sheet is anchored 500-1,000 metres below the sea level. A part of the Greenland ice sheet also lies on ground that has been depressed below the current sea level, as well as some relatively large chunks of the massive East Antarctic ice sheet, especially the Cook and Totten Glaciers and parts of the so called Ingrid Christensen Coast.

One further factor which has not yet been properly tabulated into the models are the small soot particles, tar balls and the dust from Sahara which have been raining on top of the continental glaciers for centuries, and which were then buried under snow and ice.

When the surface melting of a glacier reaches a certain rate, the melting begins to uncover more and more solid particles, especially if a growing proportion of the ice starts to disappear through sublimation, through a process in which ice becomes water vapour without first melting to water. This should make the ice darker and decrease its reflectivity. If the ice will be able to reflect less sunlight back to space its melting will accelerate. This will again reduce the reflectivity because more soot, dust and dead algae will emerge from the melting ice. Thus the combined impact of water and "sand" on the ice might one day lead to the very rapid destruction of some of our continental glaciers.

The melting of the West Antarctic ice sheet would add 5-6 metres and the melting of Greenland 7-8 metres to the sea levels, while heat expansion of the sea water would add a further 4 metres for each 3-degree centigrade rise in global temperatures. Almost three-quarters of the humanity live on the coastal zones which may be in danger. Most of our fertile farmlands and large cities are on the same coastal lowlands.

Large tsunamis triggered by the warming may also become a serious issue. There are at least five different mechanisms through which global warming can cause giant tsunamis. The most immediate problem has to do with the melting of the continental glaciers, especially in Southern Greenland, where the speed of the melting has increased three-fold in ten years.

An ice sheet is so heavy that the Earth's crust below it can be depressed down by almost one kilometre. When the glaciers melt their weight is reduced and the crust starts to bounce back. This causes violent earthquakes which can happen simultaneously on very large areas. The Greenland ice sheet is still losing only 240 cubic kilometres of ice, annually, less than 0.01 per cent of the total, but even this rate of melting has led, in a decade, into a substantial increase in the number of small earthquakes (or, more precisely, ice-quakes) taking place in Greenland.

There are large deposits of loose sediments on Greenland's continental slopes and they can be destabilized by earthquakes. In 1929 Newfoundland was hit by a tsunami which was created when a Richter 7 earthquake triggered a 200-cubic-kilometre underwater landslide. The tsunami was 7 metres high on large stretches of the coastline and 27 metres high at bays which concentrated its energy. The wave did not do any damage in Europe or further South because its power on that direction was broken by shallow waters. But the Southern tip of Greenland is actually relatively close to Europe, and a slightly larger underwater landslide could cause a very dangerous tsunami surging towards Europe with the speed of a jet plane. If the melting accelerates further so that hundreds of thousands or millions of cubic kilometres of ice will melt, there will be much larger rebounce earthquake tsunamis.

It is urgent and of utmost importance to improve the sea defences of the coastal nuclear power plants, nuclear fuel recycling facilities and the cooling ponds storing used nuclear fuel before anything like this happens. The easiest and fastest way to do this is to use large blocks of concrete and pile them on top of each other so that they make a high wall capable of breaking a tsunami. For example the Japanese have often used this method.

What Can we Do to Stop the Warming?

There are hundreds of different things that can and should be done to prevent a "greenhouse catastrophe". However, this tiny book only mentions seven possibilities, which could be especially important.

Some of the solutions presented here aim at reducing our greenhouse gas emissions, others aim at sequestering (taking back) some of the carbon dioxide that has already been released in the air, and storing it safely. Both methods lessen the amount of carbon dioxide remaining in the air.

1. Don't be a BioIndicator – Stop Eating Meat!

According to published figures, meat production is responsible for at least 20 and possibly 40 per cent of all human-made greenhouse gas emissions.

This sounds a lot, but the real figure might be even higher. It now looks possible that meat production might be responsible for approximately one half of our greenhouse gas emissions. In other words, eating meat might constitute one half of the greenhouse problem and everything else – cars, aeroplanes, factories, electricity, plastics, rice farming and innumerable other things – would together make the other half.

But… can it really be so?

According to some often quoted studies cattle-raising could be responsible for 20-30 per cent of the humanity's methane, 70 per cent of the nitrous oxide and 10-20 per cent of the carbon dioxide emissions. This would amount, altogether, to 20-30 per cent of our combined greenhouse gas emissions.

However, in the light of some recent but less well-known studies, the above-mentioned figures have started to look like underestimations. Moreover, cattle-raising probably also plays a role in the production of ozone, a fourth important greenhouse gas.

Let's start with the nitrous oxide. Cattle-raising is producing nitrous oxide by two different ways. First, when manure drops in wet soil, it produces nitrous oxide. Second, most chemical fertilizers are now used to produce fodder for animals that are grown for meat. According to an often-quoted estimate nitrogen fertilizers are responsible for roughly 80 per cent of the humanity's nitrous oxide emissions, which, in turn, make a little bit more than 8 per cent of our combined greenhouse gas emissions.

The Dutch atmospheric scientist Paul Crutzen – the only climate scientist who has ever won a Nobel prize – has now calculated that between 3 and 5 per cent of the nitrogen spread on the soils as chemical fertilizer will finally be converted to nitrous oxide, instead of the 1 or maximum 2 per cent which has been assumed, before. If Crutzen's calculations are correct (and they tend to be), a larger than assumed percentage of the atmospheric nitrous oxide has been produced by human activities, and we can also expect larger future emissions from our agricultural soils. If nitrous oxide emissions will, in the future, constitute more than 20 per cent of our greenhouse gas emissions, the role of meat production also becomes more prominent.

According to the official statistics, between 20 and 25 per cent of the man-made carbon dioxide emissions are produced by tropical deforestation, and the rest released by burning oil, coal, natural gas and peat, or in the manufacturing of steel and cement.

Most of the tropical forests, between two thirds and three quarters, are cleared for pasture, and the rest for field farming. The process typically starts by removing the most valuable individual trees from the forest. This does not destroy the forest, but the roads built by the logging companies also bring immigrants who then clear the remaining trees. Besides the land cleared directly for cattle-raising, much of the land appropriated for field farming will not be able to sustain agriculture for a long time, and will soon be converted to pasture.

We know roughly how much carbon dioxide is annually produced by fossil fuels and we have a relatively precise idea on the amount of carbon in trees that are cleared from the forests. We also know roughly how much carbon is being absorbed by the oceans and how much remains in the atmosphere.

However, according to a growing number of studies the world's forests, especially the forest soils, currently absorb more carbon from the atmosphere than we have thought. To mention just two very important examples, the Amazonas, alone, seems to be absorbing between 300 and 600 million tons of carbon and the world's mangrove forests a roughly similar amount, annually.

If the carbon sinks are larger than we have thought, there must also be additional sources of carbon dioxide emissions, which have not been included in the statistics. Most of this extra carbon dioxide is probably produced by the decomposition of organic matter in fields and pasture lands. When a forest is cleared for pasture or farmland much of the carbon content of the trees will be released into the atmosphere relatively quickly, but the decomposition of the carbon compounds stored in the soil – including the trunks and the roots and the humus layer – should take much longer. In other words, it is likely that the forest lands cleared for pasture or field farming keep on producing carbon dioxide for some time after the trees have been cut. These emissions have mostly not been included in the official statistics, but they could be of the same order of magnitude than the amount of carbon dioxide which is released when the forest is cleared.

Moreover, if all the people living on Earth would suddenly stop eating meat, thousands of millions of hectares of pastureland which are now used for cattle-raising would suddenly be liberated for other purposes. If for example one half of all this land would be converted back to natural forests or managed as multi-storey home gardens or as grasslands growing strong, perennial grasses, a huge amount of carbon dioxide could be absorbed from the air, and the carbon dioxide content of the atmosphere would start to decline, instead of continuing to rise.

The digestive tracts of cattle also produce about 20 per cent of the man-made methane emissions, and another 10 per cent or so comes from the decomposing manure. Besides this a substantial amount of methane is produced by the termites which rapidly conquer the areas cleared for cattle-raising. In tropical areas dense forests are typically dominated by ants, while open savannah forests and pasture lands belong to termites. Ants cannot digest cellulose or lignin and only make carbon dioxide, but termites emit large amounts of methane, which is a much stronger greenhouse gas. A large percentage of the lands now dominated by termites (instead of ants) have been created by cattle-raising, but the methane emissions produced by all these termites have not been taken into account when the cattle's greenhouse gas emissions have been calculated.

Then we have ozone, a strong but short-lived greenhouse gas, which is produced when nitrogen oxides are exposed to intensive sunlight. Nitrogen oxides, on the other hand, are produced when either biomass or fossil fuels is burned in relatively high temperatures.

Nitrogen oxides, however, have both cooling and warming impacts on our climate. They cool the climate by removing methane from the air, and they heat the climate when they become converted to ozone. In the mid-latitudes, like in Europe, the cooling and heating impacts of nitrogen oxides roughly compensate for each other, so the net effect is almost zero. However, in the tropics the intensive sunlight is roughly five times more efficient in converting nitrogen oxides to ozone, and the heating impact dominates.

Because there are still relatively few nitrogen oxide-producing cars in the South – compared to the West – most of the world's ozone emissions are probably produced when forests are cleared by burning or when biomass is burned on the pasturelands and fields in order to destroy weeds.

To sum it up, it now seems that cattle-raising is responsible for a large percentage of all our greenhouse gas emissions. A great majority of the cattle-related emissions are produced because billions of people still insist on eating a lot of animal flesh. The production of milk and cheese also causes some greenhouse gas emissions, but these emissions are far less significant, because the animals that are grown for meat are much more numerous than milk cows, and the young, rapidly growing animals require more food than the adults.

You can also reduce your personal greenhouse gas emissions (and water consumption!) by eating wheat, maize, potatoes and vegetables instead of rice, because the farming of wet paddy rice both consumes a huge amount of water and produces a lot of methane. But avoiding meat is the main thing to do if you want to act in a responsible way, because meat typically contributes about 90 per cent of the food-related greenhouse gas emissions of a non-vegetarian person.

While meat production may be responsible for roughly one half of our greenhouse gas emissions, it is also largely responsible for our present water crises, and might cause approximately one half of all clearly premature human deaths on our planet.

According to numerous different studies made in the West meat-eaters are two times as likely to die prematurely of cardiovascular disease than vegetarians. Meat-eaters also have a much (about 50 per cent) higher cancer mortality than vegetarians. These are highly significant findings, because cardiovascular disease and cancer have now become the most common causes of death also in the South.

Why is vegetarian food so healthy? Plant food contains natural antioxidants, substances which may offer some protection against heart disease, strokes and cancer. Meat typically contains large amounts of unhealthy fats which block our arteries, thus exposing us to coronary heart attacks and strokes.

But there is also a third reason: if we eat a lot of meat and fish, we will become a kind of bio-indicators. We will accumulate to our bodies all kinds of toxins and other environmental poisons that exist in our environment.

As a general thumb rule an animal needs ten kilograms of food to increase its own weight by one kilogram. Therefore, by eating a kilogram of meat we will ourselves acquire ten times more environmental toxins than by eating a kilogram of plant food. If the animals have been partially fed with fish flour or pulverized animal carcasses, the density of toxins can become one hundred times more than the average in plant food.

The so called adult onset diabetes (Diabetes 2) has recently become the world's most rapidly growing major public health problem. Already 180 million people in the world have diabetes, and the number could increase to 400 or 500 million per year by 2030. The epidemics is threatening to overwhelm the health care systems of even the rich, western countries. In the USA, alone, treating diabetes cost about USD 174 billion in the year 2007.

However, the adult onset diabetes is also becoming more common in the South. The global annual diabetes mortality could now be somewhere around three and a half million, and it might triple within a few decades.

It now seems that this massive increase of diabetes 2 mortality is mainly caused by environmental toxins known as POPs, persistent organic pollutants. POPs are a varied group of nasty and long-lasting organic compounds, including DDT, aldrin, dieldrin, chlordane, endrin, mirex, heptachlor, toxophene, hexachlorobenzene, PCBs, dioxins and furans. Many POPs have been used or are still used as pesticides or herbicides, others are created as by-products of different industrial production processes or waste incineration.

According to the studies first conducted by the Korean scientist Duk-Hee Lee and her co-workers, and later confirmed by many other groups, people who have a lot of DDT in their fat tissue are roughly ten times more likely than the average person to get Diabetes 2. A high amount of six different POPs has been shown to increase the risk of diabetes 38-fold (!).

Other researchers have claimed that his could be an illusion, arising because the body of a diabetic person cannot remove POPs as effectively as the body of a healthy person. However, according to already existing studies it seems that diabetes does not lessen the body's ability to remove POPs. In other words: it now seems that persistent organic pollutants could well be the main cause of the whole diabetes 2 epidemic.

This is a strong further reason for not eating meat! You can, of course, also acquire enough POPs to get a diabetes by eating heavily polluted plant food, but the risk is much smaller.

In Finland it has also been shown that heavy doses of dioxins destroy the protective, hard cover of human teeth, exposing them to dental rot. And it is possible that diabetes 2 and dental rot are only an iceberg's tip, and that other health problems will soon emerge and accumulate if we keep on concentrating even larger doses of environmental poisons into our bodies.

In other words: try to convince your children and friends to become (or remain!) vegetarians. This will reduce their personal contribution to global warming, but it also has a more than a 50 per cent chance of prolonging their healthy life-span in a most substantial way.

2. Providing Clean Cooking Energy for Everybody!

Three billion people in the world cook their food by burning wood or other biomass in simple stoves. The small particles released in the burning contribute to the blocking of our arteries, thus exposing us to cardiovascular disease. Smoke also contains a number of toxic compounds which can cause lung, pancreatic and other cancers. Exposure to smoke increases the risk of tuberculosis, pneumonia and bronchitis. And continuous, hard coughing will always finally lead to emphysema, a lethal lung disease which kills slowly and painfully. It has been estimated, that between 2 and 7 million people die prematurely, every year, because of their exposure to small particle pollution, which mostly comes from cooking.

When people can afford it, they almost always shift to non-polluting or less polluting ways of cooking, like liquefied natural gas, kerosene or electricity. Nobody wants to inhale large quantities of smoke and spend much time ill and coughing. However, the poor families cannot afford to use electricity or natural gas.

It would thus be very important to provide the poor families with non-polluting cooking stoves, like solar cookers, free of cost or with a heavily subsidized price, to protect their health and the health of their children.

This would also be a very efficient way to fight global warming.

Most aerosols like sulphur, ash and dust particles as well as the various bioaerosols produced by trees, plankton and other living vegetation have a cooling impact on the climate, because they reflect sunlight back to space and increase cloud formation.

However, black aerosols, small soot particles and tar balls, heat the planet. Even the black aerosols do provide some shading which cools the Earth. But they also heat the atmosphere like the greenhouse gases: because their surface is pitch black they absorb sunlight efficiently.

When soot particles fall on snow or ice, they reduce its reflectivity. Even a few billionths of soot on the snow can reduce its reflectivity by 1 per cent.

Globally the heating impact of soot is, of course, very small compared to the radiative forcing caused by the extra carbon dioxide and other greenhouse gases. But in areas where there is ice even during the summer, when the days are long and the sun powerful, black carbon on snow can be a very important factor. The extreme case is the high Arctic, with several months of continuous sunlight on glaciers and floating sea ice.

According to a recent study by the University of California, soot might already contribute more to the heating of the Arctic than the greenhouse gas emissions. Mark Flanner and Charlie Zender estimate, that soot has been responsible for 33 to 94 per cent of the warming of the Arctic. It now seems that the climate forcing by black carbon on snow is three times more efficient in melting the snow than the climate forcing caused by carbon dioxide.

In the Tibetan Plateau the soot is causing, during springtime, a climate forcing equivalent to 20 watts for each square metre, which is locally 15 times more than the heating impact of the extra carbon dioxide in the air. On the southern slopes of the Himalayas there must be still more soot coming from the innumerable small campfires, polluting factories and other sources. It is almost certain that in the Himalayas soot is the most important factor contributing to the melting of the glaciers. If the melting of the Himalayan glaciers will go on, Indus, Ganges, Huangho and Yangtze could soon become totally dry during the dry season.

In South Asia most of the soot is produced by small, biomass-burning stoves and by the burning of biomass on the fields.

Therefore the most cost-effective way to reduce South Asia’s contribution to global warming and to save the Himalayan glaciers and the dry season flows of Indus and Ganges would be to donate every family two different types of cooking stoves.

One should be a solar cooker, which does not require any fuel when the sun is shining. The other should be a stove that the people can use after the sun has set or when it rains.

An excellent option would be to distribute, to each family, a solar cooker and a so called Anila stove. If produced in very large quantities, such a package of two different stoves would probably cost less than Rs 5,000.

The Anila stove is a cheap biomass cooker, developed in Mysore, India. With an Anila stove it is possible to produce small cakes of fine-grained charcoal from all kinds of biomass, and to use the burning gases released from the biomass to cooking. The stove produces very small soot emissions, because the fire is lit from the top and not from below.

The stove's ability to produce fine-grained charcoal (biochar) is important, because if the biochar is mixed with compost or with chemical fertilizer and spread on the fields, it will both absorb a lot of carbon from the atmosphere and reduce the farmer's need for organic or chemical fertilizer. The next chapter will concentrate on this possibility.

3. Terra Preta do Indio – an Ancient Way to Absorb Carbon out from the Air

Everybody has probably heard that it is impossible to cultivate the tropical rainforests in a sustainable way. All the nutrients are tied in the vegetation. If the trees are removed and the land is cleared for farming or pasture, the rain will soon wash the nutrients into the deeper soil layers where the roots of the plants can no longer reach them.

This has been the generally accepted wisdom endlessly repeated in innumerable authoritative books and articles. However, there is a problem with this view. For example in the Amazonas there are large areas which were successfully cultivated by the Pre-Columbian peoples for at least 2,500 years. The milpas of the mayas in the Central American rainforests also maintained their fertility for prolonged periods of time. All this has been amply documented, and the facts go against the conventional wisdom.

In the Amazonas there are patches of deep, dark, fertile soils which can contain up to two metres of soil rich in nutrients, humus and organic carbon. They are artificial creations known as terra preta do Indio, the black soils of the Indians, or as the Amazonian dark soils. According to Brazilian, German, Japanese and US scientists who have studied the terra preta soils the Amazonian peoples used to mix charcoal and all kind of waste matter into the soil. The nutrients stuck to the small charcoal particles and were not washed away or into the deeper soil layers by the heavy rains. This resulted in enriched bacterial and fungal growth in the soil and into a gradual accumulation of humus which, in turn, increased the soil's moisture-holding capacity.

According to the studies carried out by Wenceslau Teixeira of the Brazilian Agricultural Research Enterprise and by Bruno Glaser, Wolfgang Zech and Christoph Steiner of the University of Bayreuth, Germany, the system is an efficient way to reduce the need for chemical fertilizers. In the trials the plots which received both charcoal and fertilizer yielded nine times larger crops than the patches which were only treated with a similar dose of fertilizer. Such a difference is phenomenal and the result only applies to tropical rainforest conditions in which there is a lavish supply of rainwater and sunlight, and where the lack of nutrients is the main factor inhibiting the growth of the crops. But also in the field trials conducted in China the charcoal reduced the need for fertilizer two or three times. More recent experiments in a number of other countries have produced similar results.

This is a highly significant finding, because the production of chemical fertilizers consumes a lot of energy and causes large carbon dioxide emissions. Above all, nitrogen fertilizers are responsible for 80 per cent of the anthropogenic nitrous oxide emissions. Nitrous oxide is one of the five most important greenhouse gases and it could also be the most important threat to our protective ozone layer.

The terra preta fields gradually accumulate a very large store of organic carbon. According to the studies conducted by Bruno Glaser, the first metre of an Amazonian terra preta patch typically contains from 16 to 120 tons of black carbon (charcoal) per hectare. The total carbon store is still larger, because the humus also contains a lot of carbon. According to one estimate the first metre of terra preta might altogether contain about 250 tons of carbon on one hectare.

Many aspects of terra preta cultivation are still poorly understood, but it seems that the system could easily absorb at least 500 tons of carbon per hectare in the soil, on a long run probably even more than this. Only a fraction of the carbon needs to be charcoal. It could be assumed that the finer the pieces of the charcoal, the less charcoal is needed to prevent the nutrients from escaping.

All these reductions in greenhouse gas emissions and the sequestration of carbon would most probably come with significant negative costs. A small amount of charcoal costs much less than a heavy dose of fertilizer, so the terra preta cultivation can perhaps absorb huge quantities of carbon dioxide from the air in a way that would also save a lot of money for the world's small farmer families.

The method should also help in the efforts to reduce the nutrient loads and other pollution entering the lakes, rivers, seas and groundwater. It might be useful in both small- and large-scale wastewater treatment. It might be able to convert many kinds of waste-water treatment facilities to new carbon sinks. It might even be an important means to improve the quality of water produced by different types of dugwells. Charcoal could be buried in the soil near the wells so that it would sieve the various pathogens and pollutants off the drinking water.

Charcoal is not bio-degradable so it will stay in the soil almost for ever. Also the carbon store of humus seems to be rather permanent in the terra preta soils, because some of the patches of deep dark soils in Amazonas seem to be relatively ancient.

The Earth produces, every year, hundreds of billions of tons of organic biomass – for example hay, grass, leaves, needles, wood, cones, nut-shells and single-celled algae – some of which could be converted to charcoal. Anything biological can be used as a raw material of charcoal (or biochar), wood is only one possibility. For instance in India it has been estimated that between 80 and 250 million tons of biomass is annually just burned on the fields. The global estimate for annual biomass burning is at least 7,000 million tons, much of which is wasted. Why not burn part of this biomass in a less complete way, so that it becomes fine-grained charcoal that can be added to the soil?

This probably is the most promising and important way of absorbing carbon from the atmosphere that has this far been invented. About three billion people, half of the humanity, still live in small farmer families and every farmer would like to increase her/his crops in a way that would reduce her/his costs. If a kilogram of charcoal (which is cheap) can compensate for twenty kilograms of chemical fertilizer (which is expensive), the method might become very popular and spread like wildfire on billions of hectares of farmland, pastures and forests.

If people mix the fine black char produced by the Anila Stove with organic or chemical fertilizer before they spread them on their fields, they can greatly reduce their need of fertilizer, and thus their farming costs. Alternatively, they can get a much better crop with the same amount of fertilizer.

The government and companies could perhaps also pay something for the poor families (which would start to cook and produce charcoal with an Anila Stove) for the carbon they take out from the atmosphere and store in the soil.

4. Protecting and Regenerating the Mangrove Forests

The world still has about 24 million hectares of mangrove forests, but there used to be much more of them. According to one estimate Africa has lost at least 55 per cent and Asia at least 58 per cent of its mangroves. Many of the existing mangroves are seriously threatened. Mangroves are cut for charcoal and cleared for prawn farming. This has had devastating consequences for the fish catches because many commercially valuable fish species spend one or more periods of their life cycles in the mangrove swamps and are thus totally dependent on them.

In Thailand it has been estimated that the clearing of 100,000 hectares of mangrove forests for prawn farming has caused the loss of 800,000 tons of fish. Each hectare of mangrove swamp also directly produces hundreds of kilograms of edible shellfish and crabs. Mangroves form very efficient and cheap natural breakers against tsunamis and against the flood waves (storm surges) caused by typhoons.

Even more important is the fact that mangrove forests are very, very efficient carbon sinks. The remaining mangroves may annually remove around 300 million tons of carbon from the atmosphere and store it on vast mud flats which may finally become coastal peatlands.

According to one estimate each hectare of mangrove forests annually absorbs about 40 tons of carbon from the air. One third of this amount will be quickly released back into the air as carbon dioxide, one third will be more or less permanently stored in the mangrove mudflats and the last one third will be dissolved in the oceans as relatively long-lived organic compounds which will remain in the sea for a couple of decades or for a century.

If this estimate is correct, the regeneration of the perhaps 30 million hectares of mangrove forests which once existed but which have since then been destroyed might annually absorb something like 400 million tons of carbon out from the atmosphere for an indefinite period of time and an equivalent amount for a few decades or for a century. On the other hand, if a mangrove forest is destroyed, it will start releasing large amounts of carbon dioxide back to the atmosphere.

The dominant plant species in many natural mangrove forests of Asia is a strange, ancient palm "tree": the nipa palm (Nypa fruticans). The nipa palm is a very productive biofuel species. It can annually yield 11,000 litres of alcohol per heactare, twice as much as sugar cane. It can be cultivated on regenerated mangrove swamps without changing the habitat in any major way. Cultivation is easy because nipa grows like a weed and because it does not require chemical fertilization. Practically no nutrients are lost with the sap and a mangrove swamp will anyway be richly fertilized by the sea water. Thus a hectare of regenerated mangrove forest could both annually sequester 11 tons of carbon and produce 11 tons of fuel alcohol, which would again prevent 7 tons of new fossil fuel carbon emissions.

Regenerating the mangrove forests is, therefore, a very cost-effective way of mitigating the global warming in a way that will also provide numerous other benefits for the coastal communities.

5. Planting Large, Food-producing Trees

Numerous people have remarked, that one of the easiest and most obvious ways of removing huge amounts of carbon dioxide from the air is to plant more trees or, alternatively, to let the already existing trees to grow larger.

There is absolutely no doubt that carbon dioxide can be taken out from the atmosphere, this way. There are numerous tree species which live for thousands of years and which can attain a gigantic size. However, a number of concerns should be taken very seriously, in this context.

First and foremost, it is imperative that the schemes are strongly supported by the local people. If they are opposed by the people, the carbon in the trees will not be safely stored. The programmes must be beneficial to the local people and they must add to their resource base. Also, the existence of the benefits must be perceived, acknowledged and appreciated by the people. The species have to be chosen so that the people consider the trees useful and that they will have a very strong incentive not to cut their main trunks, ever, for timber or firewood. In practise this means trees that attain a large size and produce large quantities of food and possibly also raw material for bio-energy, as long as they remain standing. And the trees should preferably be species which can not burn in a forest fire.

Farmers and other land-owners can plant such trees on their own lands, and many could also be planted on communal lands or state-owned lands. Wherever the structure of land ownership is very unequal, the planting of carbon-absorbing and food-producing trees could be combined with an agrarian reform, distributing land for the landless families.

There are hundreds of popular, food-producing trees that can attain a large size. For example seed-grown mango trees can become 40 metres tall and three metres in diameter, and the largest trees can produce up to two tons of fruit in a year. The sal trees can attain a height of 55 metres and a diameter of three metres, and they produce large quantities of edible oilseed. Many different nut trees growing higher in the mountains can become very large and produce huge quantities of human food, and they can be grown on rocky hill slopes which have no value for field farming or as pasture.

However, the queen of all the world's carbon storage trees could be the African baobab (Adansonia digitata). The African baobab, the wooden elephant, is no ordinary tree. Baobabs cannot burn in any kind of forest fires, they do not even notice them. Carbon stored in a baobab is, therefore, carbon safely stored. On dry and hot areas baobabs reach a much larger size than any other tree species. They are able to become giants where nothing else grows well.

Young baobabs grow much faster than any other trees that attain a substantial size and have a long life-span. A 70-year-old baobab planted on good soil may already be three metres in diameter. Baobabs grow astonishingly fast for 270 years or so, then the growth slows down, but the trees can already be a bit large, at that time. The largest specimen which has ever been measured had a diameter of 18 metres.

African baobabs are, in many countries, considered the most useful of all trees. The fruits are large and the fruit flesh and seeds highly nutritious. The fruit pulp makes a nice, refreshing drink when mixed with water. The numerous large seeds can be eaten raw or roasted, or processed to flour or oil. The leaves are edible and have a nutritional value comparable to spinach. They contain large concentrations of vitamin A. This is important because it seems that a sufficient amount of vitamin A significantly reduces illness and mortality caused by diarrhoeal diseases, respiratory diseases and malaria among children. It also prevents xerophtalmia, which still blinds hundreds of thousands of children, every year.

The young roots are edible. The bark is an excellent raw material for mats, cloth fibres, water-proof roof tiles, water-proof hats, ropes, nets, baskets, insulation material and paper. The bark grows back quickly. The fruit shells are wooden and water-proof and are often used as containers or to make cups, plates, saucers and other utensils. During colonial times, when giant baobabs were much more common, large trees were often used as offices, restaurants, cafes or bars. They would also make nice schools, libraries and book shops!

African baobabs do not even compete with other land uses to the extent most other trees do. They do not kill the undergrowth under their canopies, their style is relaxed, African, live and let live. Annual food crops, including maize, can be grown very close to giant baobabs, so close that some of the plants touch the main trunk. The partial shade provided by the baobabs and the fertilizing effect of their leaves may even be beneficial for the surrounding crops. Their roots, of course, can destroy the buildings which have been constructed too close of them.

Baobabs could be planted on a vast range covering almost two thirds of Africa, much of Australia and India, Indonesia, tropical South and Central America, the Caribbean and even some parts of the United States (Florida). Lets assume, as a thought experiment, that we would plant 6.5 billion baobabs, one for every woman, man and child on the planet. This would not take long if many people cooperated, because baobabs grow easily from the large seeds. After planting they need some protection against the cattle and against elephants, but they will soon be able to manage by themselves. 6.5 billion surviving baobabs should, in half a century, absorb from the atmosphere at least 100 billion tons of carbon, when also the carbon in the roots, fine roots, litter and humus is taken into account.

The idea of this example is not to say that we should only plant baobabs and that we should plant exactly 6.5 billion of them. There are thousands of other beautiful and magnificent tree species, and many different food-producing trees should definitely be planted. The point of the example is only to show that the often repeated claim that it is not really possible to absorb much carbon dioxide from the atmosphere by planting trees simply does not hold water. If we think in terms of pulp plantations with a short rotating cycle, the possibilities are, admittedly, extremely limited. But if we take a closer look at the various land-use systems and ecosystems and at all the tree species available, the picture changes, in a most dramatic way.

In the most densely populated areas of Nigeria field farming has already been largely replaced with multi-storey home gardens in which annual plants are being grown together with food-producing trees of differing sizes. Such tropical home gardens are typically 5 - 10 times more productive (per hectare) than field farming. When field farming is replaced by multi-storey home gardens a lot of carbon dioxide is always sequestered, because such agroforestry systems have a much larger store of organic carbon on each hectare than the lands used for field farming or pasture.

Specific attention should perhaps be given to trees which attain a large size and which can produce both food and raw materials for biofuels. For example selected varieties of the African marula trees (Sclerocarya spp) could produce an annual hectare yield of 20 tons of fruit flesh, 1-2 tons of highly nutritious, edible kernels and about 20 tons of very, very hard nut shells with an energy value closer to that of coal than that of softwood. Marula shells are so hard that they do not burn well in small stoves, but they could be burned in somewhat larger local power plants. The West African safou (Dacryoides edulis) is a relatively large tree which might become an even more productive oil tree than the oil palms, if some effort were devoted to its selective breeding.

Even in the commercial forests producing raw materials for forest industries the carbon-storing possibilities are more significant than what is often admitted. In Finland the largest standing stocks of wood found in natural reserves or other more or less untouched natural forests are around 800 fast cubic metres of trunk wood per hectare. However, spruce forests planted on good soils can reach a standing stock of 600 fast cubic metres in 70 years. In Punkaharju a planted larch forest reached 1,200 cubic metres in 110 years and the best-growing part of another larch forest in Raivola (which is now on the Russian side of the border) contained 2,000 fast cubic metres of trunk wood when it was 257 years old.

In other words, planted commercial forests may be able to grow even larger carbon storages than the protected, natural forests, if their growing cycles are lengthened so that a little bit less pulp wood and a little bit more timber wood will be grown in them.

The average carbon store on commercial forests in Finland is, of course, very low because the normal growing and cutting cycles are so short. On average there is less than 80 fast cubic metres of standing trunk wood in the Finnish forests, which is a very low figure.

Besides carbon dioxide, trees also absorb nitrous oxide, ozone and black aerosols from the air. According to recent research the six million trees growing in Sacramento County, USA, annually remove 665 tons of ozone, 164 tons of nitrous oxide and 748 tons of small particulate matter from the air. Both nitrous oxide and ozone are strong greenhouse gases. Above all, the trees and other vegetation annually produce about a billion tons of bioaerosols, tiny organic detritus, which reflects sunlight back to space, contributes to cloud formation and increases the reflectivity of clouds by making them whiter. According to the latest estimates 25 per cent of all atmospheric particles might consist of such bioaerosols.

6. Towards Solar Electricity

The people who can afford it, usually want to use some electricity. Electricity is a very convenient form of energy, because it is easy to use in very small packages, and the package can be exactly of the size you need. When for example fuelwood is burned, this is clearly not possible. With electricity you can use all kinds of gadgets like computers, mobile phones, ordinary telephones, televisions and radios. Electricity is also a very efficient way of providing light, and electric motors are much more efficient than the motors that are run by burning something (like diesel oil, gasoline or natural gas).

At present most electricity is produced by very large and complex machines known as steam turbines. Most steam turbines are produced by a small handful of very large companies in Europe and North America. Even many technologically advanced but small or middle-sized European countries (like Finland) cannot produce their own steam turbines.

Above all, steam turbines are the more economical the larger they are. This means that the steam turbine technology is biased for very large power production units, often feeding more than 1,000 megawatts of power into the power grid. To put it differently, the steam turbine technology is heavily biased against small, village-sized units.

When power production concentrates on very large units the result is a highly centralized power grid and a highly centralized market for electricity. In such a situation big players, the large companies whose factories consume enormous amounts of electricity, get their power with a very cheap price, while the small and middle-sized companies and individual households have to pay much more. For example in Finland small and middle-sized companies and individual households pay for their power twice as much as the largest buyers of electricity.

This means, effectively, that individual households and small companies end up subsidizing the giant companies. The giant corporations become more productive because they get cheap power. This leads to extreme concentration of wealth and income into fewer and fewer hands. Unemployment increases, because the small and middle-sized companies are wiped out from the market. The small and middle-sized companies always employ many more people for the same amount of production than the more automatized, big factories.

However, when we shift to a solar economy, many things will change. The most promising fields of solar electricity, the concentrator photovoltaics technology and the thin-film solar cell technology, are both modular by nature.

This means that power can be produced with either large or small units, because a large power producing plant is, essentially, nothing more than very many small plants concentrated on the same area. If power can be produced in small units at the village level small and middle-sized companies become more profitable than giant factories. The large companies lose their subsidies, and the small companies and individual households in villages no longer have to subsidise the energy consumption of the giant corporations.

Moreover, power in the villages can be fed into small local grids as direct current or as alternating current. Thus the village economies do not have to pay high transfer prices for electricity. In a system dominated with a small number of very large power production units, the transfer price can amount to more than half of the actual price of electricity.

Because solar economy would benefit small and middle-sized companies and village economies at the expense of large factories, it would probably create work for one or two billion people which are currently un- or underemployment. It would also lead to a much more equal division of wealth and income Therefore a shift to solar economy might be a way to create a more democratic and equal society, and of revitalize the Gandhian vision of Gram Swaraj, about millions of semi-independent village republics or local economies.

A shift to solar power will also reduce the wealth and income differences between the various continents, because the continents that are now the wealthiest (Europe and North America) have much less solar energy than Asia, Africa and Latin America.

The colonisation of other continents by the European powers was probably the greatest and most destructive crime human beings have ever committed against other human beings. Before the colonial period, the income and wealth differences between the continents were very small. Europe was, most probably, a little bit poorer than the other continents, but the difference was too small to have any real significance. Due to the colonial conquests Asia, Africa and Latin America became the impoverished South, the Third World, the developing countries. The process started gradually, but in Asia and Africa the most destructive underdevelopment programmes of the colonial powers were carried out at the end of the 19th and at the very beginning of the 20th century. Most of Africa and Asia was in serious trouble because of the El Nino famines, and the colonial powers utilised the situation in a most ruthless way to dismantle local production and safety networks. The Southern continents haven't fully recovered from the colonial period, yet, and to correct the evils of the colonial legacy is still one of the most important things to do in the world.

However, when solar electricity becomes cheaper than nuclear or coal power, one of the results is a vast transfer of economic resources and wealth from the North to the South. This would simply happen because the South receives much more sunlight than the North, and because the sunlight is in a more useful form than in the North.

The South receives a lot of direct sunlight, which can be concentrated by reflecting mirrors. Most of the sunlight in the North is diffused sunlight, sunlight scattered by clouds, which cannot be similarly focused. Thus solar economy would give the South a new and very important competitive edge in innumerable different sectors of economic production.

The transfer of wealth into the South through such a shift to a solar economy would probably be at least one thousand times more significant than the whole present volume of international development aid. By shifting to solar economy we could re-create a world in which all the continents are, once again, relatively equal in wealth and well-being.

For these reasons a shift from fossil fuels and nuclear power to solar electricity and to other forms of renewable energy complementing it (wind, geothermal, biomass) is also socially and not only environmentally desirable. It is also, already relatively soon, going to be cheaper than coal or nuclear energy. For example in the USA the price of photovoltaic power is expected to fall to the level of the average price of grid power in 2011 or in 2012.

The most promising new solar technology is known as concentrator or concentrating photovoltaics, or cpv.

Ordinary photovoltaic panels cannot deal with concentrated sunlight, they overheat and experience a brownout, which means that they stop producing electricity. However, if the photovoltaic cells are kept cool, the situation changes and the efficiency of the cells grows when the photon flux (the amount of light falling on them) increases. When the sunlight is concentrated 1,000 times the concentrator photovoltaic cells can produce 2,000 times more electricity, if they do not overheat The US company PhotoVolt Inc has been able to produce 400,000 watts of electricity for one square metre of photovoltaic cells by concentrating the sunlight 2,500 times. IBM has achieved 700,000 watts for square metre with a concentration of 2,300 suns. The Israeli scientists have experimented with even higher concentrations of sunlight amounting to 9,600 suns (!) but these seem to be a little bit too much for the presently available materials and cooling techniques.

Concentrator photovoltaic systems will soon be able to produce electricity with a much lower price than coal-fired or nuclear power plants because they now routinely attain efficiencies of 25, 30 or even 40 per cent, and because they can reduce the need of expensive semi-conductor materials by hundreds or even thousands of times.

In practise semi-conducting materials are replaced by reflecting mirrors or Fresnel lenses which are much cheaper. There are numerous different designs. Ben-Gurion University of the Negev in Israel and the Australian company Solar Systems are using very large parabolic reflectors with a small photovoltaic panel at their focal point. The German Concentrix GmbH and the US Amonix have developed modular panels meant for large-scale power production, in which numerous small Fresnel lenses concentrate the sunlight to small pieces of semi-conducting material. The Japanese Sharp, the Californian SolFocus and the Australian Green and Gold Energy have developed modular panels using a large number of small parabolic reflectors.

The Israeli MST Renewable Energy Company has estimated that it would cost about USD 850 million to construct a 1,000-megawatt concentrator photovoltaic power station, and that a factory annually producing 1,000 megawatts of further power plants would cost about USD 650 million.

The chief executive officer of SolFocus, Gary D. Conley, has said that his company could produce a hundred megawatts of its concentrating photovoltaic panels with less than one dollar per watt, and that the retail price will drop to USD 0.35 when the orders reach the level of 1,000 megawatts. The world’s largest manufacturer of thin-film photovoltaic cells, Moser Baer India Photovoltaics, has bought a part of SolFocus.

We should demand, that our governments stop investing in nuclear power stations (which produce dangerous radioactive waste and employ only a handful of people) or in coal-fired power plants (which produce a lot of carbon dioxide) and that they concentrate on solar, wind and geothermal power, instead.

7. International Travel: Back to Propeller Planes, Airships and Wind-Powered Passenger Ships

Many environmentalists in the West have wanted to portray aeroplanes as the number one icon of climate change, the most blatant form of conspicuous consumption on our planet.

There is a lot of truth in such a view. Air traffic currently produces only two or three per cent of the man-made carbon dioxide emissions, but it is growing with a very rapid speed. Moreover, the condensation trails – the white, straight lines of ice crystals left on the sky by the jet planes – heat the planet at least three and possibly ten times more effectively than the carbon dioxide produced by air traffic.

However, there are complications, as well. International tourism has become a very important livelihood. It now provides 200 million full-time and 300 million part-time jobs, many of them in the South. If international tourism would be run down in a quick and drastic way, many people would suffer and lose their present livelihood.

Large-scale tourism probably reduces serious human rights violations. Because of tourism the various governments have a vested economic interest to avoid atrocities, and a hundred million tourists can see a lot more than a thousand official human rights rapporteurs. Eco-tourism is making a rapidly growing contribution to protecting coral reefs, mangrove swamps, peatland rainforests, other wetlands and ordinary rainforests.

Besides, at least five hundred million people in the world live in the northern latitudes, in areas where the people do not get enough sunlight during the winter-time. According to studies which have compared the health statistics of the Southern and Northern states of the USA, this seems to increase the risk of at least 18 different types of cancer, cardiovascular disease, osteoporosis (a disease in which the bones become fragile) and diabetes. Most people in the North die because of these diseases. In other words, a trip to the South during the midwinter is probably very good for the health of the people living in the North, because it loads the vitamin D stores of their bodies for one or two months when these stores are at their lowest.

With all these complications, how can we decide what is the right thing to do, concerning international travel? Can we say to the people in the North that they should not do any flying, even when we know that by asking this we are asking them to endanger their own health?

The answer should perhaps be some kind of a compromise. We cannot allow the air traffic to grow with the present speed, indefinitely. It is utterly immoral for anybody to keep on making several or numerous long flights per year. However, we should allow a certain amount of flying for everybody who can afford it, for various health, recreational and occupational reasons, and in order to protect the livelihoods of the people who are now dependent on international tourism.

However, we should also demand a global return to propeller planes. Jet planes are a little bit faster than propeller planes, 900 or 1,000 kilometres per hour instead of 700 kilometres per hour, which is the speed of the modern propeller planes like the Canadian Bombardier Q400. However, propeller planes only produce one half of the carbon dioxide emissions of the jet planes. Above all, they do not produce condensation trails because they fly at a lower altitude. Thus their combined global warming impact would probably amount to only 5 per cent of the impact of the jet planes.

The people who want to fly must be able stand a few hours more in the aeroplane, if they really need to go somewhere. There are no acceptable reasons for why all the rest of the world's people would have to suffer for a tiny reduction in flying times! There should be a strong international campaign for banning the jet planes and for replacing them with propeller planes.

Besides the propeller planes, we could also use modern airships and wind-powered passenger ships. They would be, from the viewpoint of the environment, an even better choice than the propeller planes.