

## Threat to the planet: implications for energy policy and intergenerational justice

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Thank you very much for the invitation to deliver a speech at this conference. I am very glad to come back to the Netherlands. I have fond memories of my time as a postdoctoral student at the Leiden University, quite a few years ago.

I would like to emphasize the implications of climate change for energy policy and for intergenerational justice. The situation with regard to global warming is that there continues to be a large gap between what is understood by the relevant scientific community and what is known by the people who need to know, the public and the policy makers. It is hard for people to understand that we have actually reached a crisis point. Weather fluctuations are much larger than global warming, but yet global warming is very important. What has become clear scientifically, is that we have reached a crisis point, partly because of the inertia of the climate system. And that comes especially from the ocean, which is four kilometers deep on average, so it takes (it) a long time to respond to changes in forcing, human made forcing, or natural made forces. The system can reach tipping points, the climate does have tipping points, you can push it beyond the point where the dynamics of the system begins to take over and move forward under its own inertia without any additional forcing. The bad news is that it has become clear that we are already into the dangerous range of atmospheric composition. The good news is that we can still take steps to solve the problem providing we act quickly. And there would be other benefits if we did that.

Here is picture of my newest grandchild. It's my son's first child, Jake. Jake has not done very much to cause global warming. He can't even walk yet, he can crawl pretty fast, but Jake is going to feel the brunt of what we have done. My parents lived to be about 90 years old, so he will probably be around for most of the century. As I mentioned, you don't notice global warming in day to day weather, but if you average the temperature over the first seven years of this century, the temperature anomaly - that is the deviation relative to the average temperature in a period of 1951 to 1980 -leaves a clear pattern, where yellows and reds are warmer than that long term average. You can see that most places are warmer if you average over time; you can see the warming is larger over land than it is over the oceans, because the oceans respond slowly; it's larger at high latitudes than at low latitudes, because of amplifying feedbacks that occur at higher latitudes. As ice and snow melts, it exposes a darker surface that absorbs more sunlight and causes more warming. And it's larger in the northern hemisphere than in the southern hemisphere, because there is more ocean in the southern hemisphere.

These are my daughter's children, and Sophie is explaining to Connor how the green house effect works. The net effect of human changes to the atmosphere is to increase of heating of the surface of the earth by a couple of watts per square meters. So it is like you have two of these little light bulbs over every square meter of the earth's surface. This seems like a small effect, it's about 1 percent of the amount of energy that is absorbed from the sun. So you might ask: should we really be concerned about warming? There have been huge climate changes in the earth's history, and how do we really know enough to say that today's climate is necessarily the best one for the planet, for humans? Intelligent, well-educated people can ask that question. These questions were asked by the NASA administrator, my bosses bosses boss on national public radio. We should indicate scientists haven't done a very good job at explaining what the situation is. Our understanding is based especially on the history of the earth, how the earth responded in the past, when there were changes in the boundary conditions, such as the composition of the atmosphere. Also, now we can observe globally what is happening with the changes that we have made in the last century.

We have increased CO<sub>2</sub> from 280 parts per million to 385 parts per million and we can begin to see effects of this already. Climate models help us also, but they are not the primary basis for our understanding. As you probably know, the earth's climate oscillates in recent times between glacial periods and warm interglacial periods. On the picture you see the temperature near the South Pole over the last 400.000 years. The Holocene, the last 10 to 12 thousand years, was a relatively warm period. About 20 thousand years ago, during the last Ice Age, the global temperature was about 5 degrees Celsius colder than now, and there was an ice sheet that covered Canada and parts of the United States, and another ice sheet over northern Europe. There was so much water locked in those ice sheets that the water level was 110 meters lower than it is now.

These oscillations from the warm periods to the ice ages and back are associated with changes in the earth's orbit. The earth's orbit is slightly perturbed by the planets Jupiter and Saturn because they are heavy, and by Venus, because the Earth comes close to it at times. Those perturbations will effect the distribution of sunlight on the planet. The tilt of the planet's spin axes wobbles by plus or minus one degree and when it's tilted more, there is more sunlight on the high latitudes. That can melt ice and snow. As you get some melting, it makes the surface darker and a little bit warmer, and as the climate gets a little warmer, the ocean can give up some CO<sub>2</sub>, just as your coca cola will give up some more CO<sub>2</sub> when it gets warmer. There is a solubility effect and there are other effects that cause the ocean to give up some CO<sub>2</sub>. CO<sub>2</sub> is a green house gas, so things get warmer then. But the orbit continues to oscillate and therefore we get natural oscillations of the climate.

During warm periods there is more methane and more carbon dioxide in the atmosphere. What we find is that, although the changes of climate are instigated by the orbital changes, the mechanism that actually drives the large temperature changes is about half due the green house gasses and about half due to changes in the surface reflectivity of the planet. Now both these green house gasses and the surface albedo are now under the control of humans. You can see how much methane and CO<sub>2</sub> have increased and you can see that ice is melting all over the planet. So humans are now in control of future climate. In a time period of the last few 100.000 years the changes in carbon dioxide were a feedback with the instigation of the changes being the changes in the Earth's orbit. Then the temperature changed because of the albedo changes and that causing gas changes.

If you want to see an example of where the gasses change first and the climate is strictly a response to that, you can look at longer time scales. Over the last 65 Million years, which is the Cenozoic Era, there have been large changes in the Earth's atmosphere. 50M years ago there was about 1000 parts per million of CO<sub>2</sub> in the atmosphere. As I said we humans have increased it from 280 to 385. Well, at earlier times, when CO<sub>2</sub> was a thousand parts per million, the earth was so warm that there was no ice on the planet and sea level was about 75 meters higher. During the glacial and interglacial times CO<sub>2</sub> in the atmosphere changes because it is moving between the atmosphere and the ocean. But on longer time scales you can increase the total amount in the surface reservoirs because the amount of CO<sub>2</sub> is determined by the balance between the sources of CO<sub>2</sub>, which are volcanoes, and the sinks which are principally weathering. As rivers carry sediments to the ocean and deposit them on the ocean floor, the chemical reactions associated with that, draw CO<sub>2</sub> out of the atmosphere and deposit it as carbonated sediments on the ocean floor. Those two processes, the volcanoes and the weathering, do not have to be in balance at any given time. So if you look back 65M years ago, when India was still south of the equator and was moving north at a rapid rate of about 20 centimeters per year, it was plowing through the Indian Ocean, which had long been the depot centre for the major sediments of the major rivers of the world. So it's a very carbonate rich ocean floor, and as the ocean crossed the subducted underneath the moving continent, the metamorphoses of these carbonated sediments into salt and other rocks releases CO<sub>2</sub> which comes out in volcanoes and salacious springs. As India was moving through the ocean, it released CO<sub>2</sub> to the atmosphere and the planet steadily got warmer and warmer, until India crashed into Asia. And then India is pushing up the Himalaya Mountains and the Tibetan plateau and the weathering associated with that began to draw down the CO<sub>2</sub> in the atmosphere and the planet began to cool off. By the time it got to 30M years ago it was

cool enough for ice beginning to form on Antarctica and it rather quickly covered the whole continent. Ever since then we've had ice on the planet, for the last 34M years.

There are two lessons worth noting. The first is that there can be an imbalance between the sources and sinks of CO<sub>2</sub>, but it is of the order of one 10.000<sup>th</sup> of a part per million per year. Over a million years that's a lot: 100 ppm of CO<sub>2</sub>, which is a huge change. But that rate is actually very slow compared to what humans are doing. We are increasing CO<sub>2</sub> at 2ppm per year, so we are now 10.000 times more powerful than the natural forcing. The NASA administrator was right: there have been large climate changes in the past, but obviously we don't want to go back to the time when there was no ice on the planet. The sea level would be 75 meters higher.

The question is: what was the level of CO<sub>2</sub> when ice began to form on Antarctica? That was about 450 parts per million plus or minus a 100. So that means: we can not burn all fossil fuels; we would increase the level of CO<sub>2</sub> to 700 or 800 parts per million. It means we would be initiating the change back to an ice free planet. We simply cannot do that, we would produce a different planet. All 170 countries have agreed that we should stabilize the atmospheric composition at a level that avoids dangerous human made effects. The problem is that nobody has defined what a dangerous change is. I think that the two metrics important in defining dangerous are first of all the extermination of species. There have been a global warmings 5 or 6 times during the history of the Earth, and in each of these cases more than half of the species were driven to extinction. And new species came into being, but it took 100.000nds of years. So we can imagine we would be leaving a much more desolate planet for our descendants if we allow global warming to be so large as to begin to effect the number of species on the planet. We are in danger of doing that, because now at a given temperature line is moving polewards at a rate of about 60 kilometers per decade. Species can attempt to migrate to stay within their climate zone, but there are limitations. If we push it too far, many species would not be able to migrate and because there is an interdependency of one species upon another, ecosystems can begin to collapse.

If we get to the point where ice sheets begin to disintegrate, so that the ice sheet dynamics begin to take over, we could reach a point where it's out of our control. Even decreasing the amount of CO<sub>2</sub> in the atmosphere won't stop the dynamics from carrying forward the disintegration of the ice sheet and the sea level could rise with meters or even tens of meters. We have to avoid that. Here is an example of a tipping point which we have already passed. That is the sea ice in the Arctic at the end of the summer. That fluctuates from year to year depending upon the weather, but it has decreased by almost half from what it was at the late 1970s, when we began to make satellite measurements. The last two years there has been much less sea ice.

Because the planet is now out of energy balance, as Sophie was explaining to Connor, it is clear we are going to lose all of this Arctic sea ice over the next few decades. But it is an irreversible tipping point. If we wanted to stop the sea ice from melting, we would need to restore the planet's energy balance. This means we would need to decrease the amount of CO<sub>2</sub> in the atmosphere to something between 300 and 350 ppm. The tipping point we have to avoid is the instability of the ice sheets. We notice that the area on Greenland that has melting in the summer fluctuates from year to year, depending on the weather that summer, but it has generally been increasing with time.

Last year we have had the maximum area of ice melt on Greenland. The melt water tends to find a low spot on the ice sheet, where it burrows a hole all the way to the base of the ice sheet. The melt water then lubricates the base of the ice sheet and speeds up the discharge of these giant ice bergs to the ocean. We wondered what the net effect of warming on the size of the ice sheets is. Some people argue that with global warming there will be more water vapor in the atmosphere or therefore more snowfall and the ice sheets will get bigger. Of course common sense tells you that as a planet gets warmer, the ice is probably going to melt. We now have a good way of quantifying what is happening and that's with this spectacular gravity satellite, which measures the gravitational field of the Earth with such a high precision that you can determine the mass of the Greenland ice sheet and the Antarctic

ice sheet. What we see is that during the winter the ice sheet gets heavier and during the melting season it loses mass, but overall it's now losing mass at a rate of about 200 cubic kilometers per year and Antarctica at a rate of about a 100 cubic kilometers per year.

So if we wanted to stabilize the ice sheets we can see that at 385 ppm they are clearly not stable; eventually they are going to be much smaller if we stay at 385 ppm. Paleoclimate records tell us that, if we wanted ice sheets comparable to the size of the current ones, we would probably need CO<sub>2</sub> to be closer to 300 ppm. Another criterion is the fact that the overturning circulation, the rising in motion in the tropics and the subsiding motion in the subtropics, that circulation cell expands as the planet gets warmer. We observe empirically that it has expanded by about 4 degrees of latitude, which is beginning to effect the southern part of the United States and the Mediterranean region and Australia and parts of Africa. This is causing these places to be hotter and dryer, so lakes like Lake Powell are only half full. Fires are increasing in the southern and western part of the United States and in the Mediterranean region as a consequence of this shift of climate zones. Another major impact is on recession of mountain glaciers all around the world. They are receding at such rate that they will be gone within 50 years if we continue on business as usual. As they are beginning to melt now they give extra fresh water, but once they are gone, there will be a big flush of fresh water in the spring as the snow melts. But in the summer and fall these rivers will run much drier. There are hundreds of millions of people who depend upon rivers that originate in the Himalayas, the Rocky Mountains and other mountain ranges.

The coral reefs are under stress for a number of reasons, but the two big ones are both a direct and indirect effect of the increase of carbon dioxide in the atmosphere. The direct effect is the increase in acidification of the ocean. As the ocean takes up more CO<sub>2</sub> it becomes more acid. That has an effect on those life forms that have carbonate shells or carbonate skeletons, because as the ocean becomes more acid it can dissolve the carbonate and also the increasing the temperature. The coral reefs are the place for between one quarter and one third of the species in the ocean. So this is a big deal.

All of these things tell us that the target atmospheric CO<sub>2</sub> that we should be aiming for is no more than 350ppm and is probably less than that. But just the realization that it is less than 385 is enough to tell us what we need to know with regard to policies. Once we get it back to 350 we can worry about whether we should be 300 or some other number. We should be aiming for an amount of CO<sub>2</sub> less than what is in the atmosphere now if we want to preserve a planet that looks like one that we inherited from our parents. The problem is that the CO<sub>2</sub> that is put into the atmosphere by burning fossil fuels, that pulse of CO<sub>2</sub> initially begins to disappear quite rapidly. After 25 years about half of it is gone, mostly into the ocean. But then the ocean begins to resist taking up the rest of it, because the CO<sub>2</sub> can come back out of the ocean. And until the CO<sub>2</sub> that has been taken up is deposited on the ocean floor as carbonate sediments, it will not take up all of the CO<sub>2</sub> from the atmosphere. And after a thousand years about a fifth of it is still in the atmosphere, that's the problem.

The implications become quite clear if you look at the size of the fossil fuel reservoirs. There is oil, gas and coal, and the purple portions in the picture are the fractions that we've already used, that we've burned and put into the atmosphere. You have to recognize that it is practically impossible to stop putting the oil into the atmosphere, because it is used in vehicles, it comes out of tail pipes, you can not capture it. And we are not going to be able to tell Russia and Saudi Arabia not to sell their oil. So the implication is that we decide to either leave the remaining coal in the ground or else use it in power plants where you capture the CO<sub>2</sub> and put it back into the ground. If we did that, depending upon the different estimates of how much oil there is still to be discovered and likewise with gas, but depending on who is right.

If we decided to phase out the coal between now and 2030, CO<sub>2</sub> would peak at about 400 and 425 ppm. It would be possible to get below 350, especially if we imposed improved forestry and agricultural practices. So it's technically feasible to get back to 350 ppm, but the key requirement is to phase out coal use unless you capture the CO<sub>2</sub>. That means we should have a moratorium on any new coal fired power plants unless they capture the CO<sub>2</sub>. You can

not say they are capture-ready, that's a euphemism. You have to actually capture the CO<sub>2</sub>, otherwise you shouldn't be allowed to build them. So we have a basic conflict between the fossil fuels special interest and the young people and nature in my opinion. The problem is that the fossil fuel interests have a lot of sway in Washington and other capitals around the world, and young people and nature don't have much voice. Animals don't even vote and they don't talk. The point is that we have to figure out how we get beyond this addiction on fossil fuels anyhow, so why don't do it sooner before we have made irreversible changes to the climate?

In my opinion, the two things that are going to be required are phasing-out coal and, in order to make changes in our lifestyles, we need to put a price on carbon emission. We need political leaders that have the courage to stand up and say that we are going to have a price on carbon emissions. I think the way to do that and to have the public accept it, is to give back 100% of the tax to the public on a per capita basis, so the person who does better than average in reducing his carbon footprint will actually make money in the process. The person who has a few large vehicles and a large house will pay much more tax than he gets back in the dividend. People have to recognize that the tax rate is going to increase with time, but those people who make the changes will not suffer from that at all because the dividend will at least cover and possibly more than cover the costs. The essential thing is to not give the money to the government and let them decide how to use the money, because then the public is going to object to the tax and it will simply be not large enough to have an effect. You need to let the market place do its work, because this would drive innovations. If you have a carbon price then people will try to invent things that don't use carbon and the dividend will give them the money to buy those things that don't produce carbon. We just had a workshop two weeks ago in which we brought in the experts in energy efficiency and renewable energies and electric grid. Many people hope that those three things can cover most of our energy needs in the future. Others think we do need additional energy and I do think we should have rapid research and development on both fourth generation nuclear power and carbon capture and sequestration. The fourth generation of nuclear power burns all of the nuclear fuel. Presently nuclear power plants burn less than 1% of the energy in the uranium. The other 99% plus ends up in a waste pile that has a half life of more than 10.000 years, so you have a tremendous problem with nuclear waste. But it is possible to burn practically all of that energy and by doing so we would not need to mine uranium for a thousand years. There is enough uranium and thorium that you could use.

The United States and Europe should get together with China and India and developing countries in the next year or two and agree on some very rapid research and developments. Those countries who need more energy and have very polluted atmospheres are eager to have sources of energy that don't produce air and water pollution that coal is presently producing. Presently the emission from China and India are polluting the entire oceans with mercury and other pollutants, so we need some technological solutions to that. It is possible, but it is not likely to be developed within the United States or within Europe who would just move too slowly. But if you get China to agree that we need something and technologically help them, we could move rapidly.

Finally I would like to emphasize the intergenerational issue of justice and equity. Our parents had the excuse that they did not know the consequences of what they were doing by starting an industrial revolution. But now we know and this raises questions of ethical and legal liability. I think we are going to have, if we don't address this problem very promptly, more and more protest by young people and I frankly think they are justified in doing so. I testified on behalf of Greenpeace activists who blocked the Kings North power plant. These were Greenpeace people who knew what they were doing. In this case, the jury of peers of twelve people from the Count area found these people innocent, because they were protecting property of greater value, namely the planet. Unfortunately, I was also prepared to testify on behalf of eleven young people who blocked construction of a coal fired power plant in Virginia in the United States, but ironically they were charged with obstruction of justice, which is really double speak. They were threatened with 14 years in prison and the lawyers decided that the jury pool was very unfavorable, because it's coal country. So they had to accept a

plea bargain. The young people are beginning to chomp it a bit if the new politicians do not make actual changes. And it can't be just goals. The Kyoto approach, which will have goals for such and such emission reduction and carbon caps, that will not work. You will have to actually identify what is the carbon we're not going to put in the atmosphere and that, it seems crystal clear, has got to be coal and unconventional fossil fuels. If there are actual constructions of conventional coal fires power plants then you know you are not going to meet those goals.