Climate Change: global solutions for an international problem

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Chair: Professor David Held

Professor Held
Good evening. Thank you very much, audience for coming, it's been a very difficult day in London and they say that the weather was so appalling in the last 24 hours that transportation has more or less ceased in some parts of London so for all those of who have travelled a long way thank you for your efforts.

Tonight's lecture is Climate Change: global solutions for an international problem. It's the second in the Ralph Miliband series on global risks in the 21st century. I started this series off about 2 weeks ago with a rather pessimistic account of where we are today and facing a number of key challenges and set forth something of a paradox that the problems we face are increasingly global and yet the means we have for addressing them are local, national, weak and have been damaged over the last few years but we need to move on from that rather sober view and rather pessimistic view and as I said 2 weeks ago look at the key global challenges one by one and there cannot be any more pressing issue than climate change and it's hard to imagine a more suitable and more significant and better informed speaker than out speaker this evening.

Professor Sir David King is chief scientific adviser to the UK government, the head of the Office of Science and Innovation. If that is not enough he is also an active professor of chemistry at Cambridge university and he combines being chief scientific adviser and being a professor of chemistry, something which I think is quite unique but as I understand it he didn't take on the role of chief scientific adviser without saying my condition is that I stay active as a scientist and he certainly has done. He has had a long and distinguished career, and it will go on of course for a long time, marked by many prestigious posts including mastership of Downing College and he has received numerous prizes and recognitions for his work. He has published over 450 papers in scientific journals including 20 in the past year. When I read that I checked it two or three times to look for the date. This surely was when he was a full time academic, this must have been about 10 years ago or so but no, in the last year, 20 papers. I mean it's extraordinary. It's extraordinary if you were a full time academic. It's even more extraordinary if you are doing that in combination with being the UK chief scientific adviser. On top of that as chief scientific adviser to government he's not only done the daily work that requires but has given over 300 lectures related to science and government in various venues throughout the world. So it's an extraordinary contribution. He says in private that he's energised by this and he clearly must be or he's on something we don't know yet very much about! We are very fortunate that he's here this evening so please join with me in giving him a very warm LSE welcome.

Professor King
David, thank you very much for that. I'm going to start by saying this is actually the first time I have been back here since I was a PhD student based at Imperial College and I came over here and attended all of Karl Popper's lecture course here and what a wonderful period that was for me, especially when I stood up and disagreed with him and ended up having a row that lasted a good 45 minutes which was a very interesting challenge for me at that time.

What I am going to be talking to you about is what David has described as the major challenge. I certainly believe it's not the only biggest challenge facing us a society today, it's probably the biggest and most testing challenge that our civilisation has yet had to face up to and let me try and then put that statement in context and see if I can get you to agree with me.

If we look at the 21st century as distinct from the 20th century. The 20th century was really a century in which science and technology, engineering, medicine, all of those advances, led to a very big change in life span. Around the world we now see life span, anticipated life expectancy well over 70 for most of the world and that is all because of the focus and pull through of those areas of research that have come through to society. The 21st century we're in a very, very different place and just to introduce the subject let me take you through why I make that statement. First of all in terms of population growth we know that the 21st century is going to see us from today's 6.4 billion to 8 billion in 2028 and probably about 9 billion in 2050. We may well plateau off at about 9½ billion just after mid-century. So there's another 50% growth left in the population system. That raises questions about resources on a single planet. It raises very big questions about the environment, infectious diseases within a globalised economic system. We are currently faced with a pandemic flu possible outbreak and that is actually pre-occupying me at the moment and amongst all of these I am saying that climate change is the biggest challenge. So let me take you through why I make that statement and in order to do that I am going to start with the science so that we can all if you like start from the same point and I am going to hopefully not make any assumptions about your scientific background in making these statements.

So what I have here is a very simple picture of the earth's surface. Earth heated up by sunlight, earth cooled down by radiation. A great French mathematician, Fourier 1827, looked at this picture and said well, I should be able to calculate the surface temperature of the earth, the average surface temperature of the earth because I know that if the radiation from the sun was overwhelming the radiation going out back into space the earth's temperature would keep heating up but it's been approximately constant for many hundred's of years so it must mean that the radiated energy going out is exactly balanced by the sunlight coming in. He also knew that the radiated energy leaving a body is very sensitively dependent on its temperature so what he concluded was the surface temperature of the earth would heat up in the presence of the sunlight until it gets to that point where radiated energy going out into space exactly balances sunlight coming in. So he calculates the average temperature of the earth and he reaches an answer of minus 15 degrees centigrade which even for that time, 1827, he thought he wouldn't be good enough to get published and he also realised there was another little problem that his calculation couldn't cope with. So what if I should switch off the sunlight. We think of the sunlight streaming in at quite a rate, switch it off, we'll leave the radiation going back out into space, how far would the earth cool down and he calculated that over 10 hours the earth would cool down another 20 degrees centigrade.

So in other words he was saying because the sunlight is switched off as the earth rotates he was saying daytime temperatures should be minus 15 and night time temperature minus 35. What he had done was calculate the properties of the moon, in other words a system which has no atmospheric environment. So he then puts back the blue stuff into his equations but at this point he doesn't have the information that he needs. The information he needed was to know how much of that radiated energy going out into space is absorbed en route by the atmosphere, the atmosphere then acting as a blanket at night and keeping the earth warmer and also keeping the earth warmer during the day. That was the greenhouse effect 1827, fully understood the greenhouse effect and what he did then and this got published, he didn't know

the measurements so he put in a factor alpha which was the amount of the radiated energy absorbed by the atmosphere and he needless to say with one variable he managed to get 15 degrees centigrade instead of minus 15 as the average temperature of the earth.

Then we get a British scientist, Tyndall, who comes along and is not satisfied with this variable parameter that Fourier used and he said well, we can measure the amount of heat radiated out that is absorbed by an atmosphere and he took a great tube of atmosphere and he put radiated energy in one end and measured how much came out the other end and being a very careful British scientist he first of all cleaned up the atmosphere that he measured on and he found Fourier's coefficient was zero and of course what he had discovered was that in cleaning up his atmosphere he had removed what we now call greenhouse gases. What Tyndall discovered when he redid the experiment with the air as it is he got Fourier's coefficient very precisely. So what he had discovered was that it was the minority gases, not the oxygen and the nitrogen that is the majority of the atmosphere, that provides the greenhouse effect. Today we understand in fine detail why oxygen and nitrogen don't absorb any of that infra red radiation energy going out and why the bigger molecules absorb it very effectively. So we have Tyndall to thank for picking up on greenhouse gases and understanding that carbon dioxide and water vapour were the key greenhouse gases.

Going forward very quickly in time to 1896 we arrive at the important point where a Swedish scientist, Svante Arrhenius, said well we are burning fossil fuels and if we are burning fossil fuels we may change the balance of carbon dioxide in the atmosphere. What would that do to the average temperature of the earth? Using Fourier's equations he then calculated should we double the amount of carbon dioxide in the atmosphere, he published in 1896, the temperature would rise on average by 5 degrees centigrade. So his conclusion using Fourier's coefficient as measured by Tyndall and nothing else, these simple equations, he concluded the earth's temperature would rise by roughly 5 degrees centigrade.

Now let me tell you that when I was in Japan in 5 years ago I organised for the British scientific community to use the largest computer in the world, the earth simulator in Japan to prepare a model to mimic all of this throwing in absolutely everything, volcanic activity, green matter, the whole lot. It's an enormous computer programme and the answer for doubling of carbon dioxide in the atmosphere that emerges from that programme is 5 plus and minus 2 degrees centigrade.

So the answer is that effectively by 1896 the physics of the problem had been understood. It is not to say there aren't important parameters that are being still debated and looked out. One of them is this little white thing here because most of you know that if we have a cloudy day clouds can do one of two things, if they are nice and white and quite high flying they can reflect a lot of that sunlight straight back out into space and so they can cool the earth surface down or at night they will keep that radiated energy back in and they will act as an added blanket to the greenhouse effects so clouds are a complication. Dark clouds, white clouds, we need to know what's forming and as we emit more carbon dioxide through fossil fuel burning temperature of the oceans also rise and that means water vapour goes up and so one of the tests of these models is the feedback of water vapour pressure going up, it's a positive feedback term that means that global warming goes faster because of more water vapour coming up but if that water vapour forms more clouds and there is more rain you have another complication.

We have also been putting a lot of aerosols up into space, into our atmosphere, and aerosols tend to play the effect of reflecting sunlight back out into space. They tend to cool the atmosphere. So there was a volcanic eruption in the 19th century which actually removed a summer in the United States completely so there was an entire crop failure throughout the United States. So this is aerosols scattering sunlight straight back up into space and causing significant cooling.

The next thing is does 5 degrees centigrade temperature rise matter? Well, the answer is that in terms of the planetary climate system that is an enormous change. If we look at the difference between an ice age and a warm period the temperature difference is around 5 to 6 to 7 degrees centigrade. So we are talking about that sort of significance of change.

I've just got to explain one more little piece of science so bear with me and that is the carbon cycle. Where does this carbon dioxide come from but a bigger question is the following – we know now that for millions of years the amount of carbon dioxide in the atmosphere has been remarkably constant. To give you some numbers it's been roughly between 200 and 270 parts per million for many millions of years as I'm going to show you in a moment. Why has it been so constant? I believe the answer is to do with a complex aspect of evolution, that evolution has taken place in ecological niches, evolution has taken place in all different parts of the planet in different ways and it's taken place in different forms. For example the green matter on the right of this photograph here and also the living matter that is represented in this room, two legged, four legged or three legged, we behave totally differently from green matter in the sense that we give out carbon dioxide, green matter takes it in. That atmosphere acts a connector within which the evolutionary system took place and that connectivity means that if you have a period when there is too much green matter it will consume the carbon dioxide in the atmosphere so it itself will run out of carbon dioxide. The reverse is true for us, we can't have too much carbon dioxide in the atmosphere. So there's a kind of symbiosis in the evolutionary process but at the same time during evolution something very important happened which is geological evolution, that a good bit of this matter that is formed, that all living matter contains carbon, was sequested naturally in a form of oil, coal and gas reserves. That natural sequestration process got rid of excess carbon from the atmosphere to keep it at a level that was suitable for all types of living systems and of course what we then did, very industriously, is dig that up as fast as we can and burn it back into the atmosphere and we've caused a massive change in the carbon dioxide level in our atmosphere for the first time in that many millions of years.

Now let me just come to, what is absolutely amazing in this field is the number of top quality scientists that have moved into it. Every week new papers are being published that move on the level of understanding. I used to talk about, 5 years ago, about what the level of carbon dioxide was in our atmosphere going back 200,000 years. I can now tell you that from a very recent paper and the top of the slide we have information going back 60 million years. Now you could ask where do we get this information from? Well, if you go to the Antarctic for example, snow has been falling every winter in the Antarctic. It comes down in layers, you can count the layers if you take an ice core and it's like counting rings on trees and so you can count the years from the layers and the net result is you can count back, from icicles in the Antarctic you can count back quite accurately about 850,000 years now. The longest ice core that has been measured is 3km long. It's taken quite a bit of time to measure it all up. Contained in that then right at the bottom of the ice core is a snowfall that fell 800,000 years ago and it contains little bubbles of gas that represent the atmosphere that existed at that period of time. Another way to do it is from ocean sediments. So you can take cores of

sediments or you can take cores of ice. Whichever you take the agreement between the data sets is absolutely remarkable. What I am showing you here is this stunning set going back 60 million years. What you see is, it's actually the ice tub of eighteen oxygen in the water which gives us a proxy of the temperature and I won't take you through that you'll be pleased to know but all I want you to know is that temperature goes up on this axis, time across and I've put time on a semi-logarithmic scale.

So if we go back 50 million years you'll see that the planetary temperature went through a maximum at that point. At that point in time there was no ice left on the planet and if you were thinking of buying real estate you would have wanted it in Antarctica because that was a tropical forest and the rest of the planet was unbearably hot. So no ice left on the planet, that means that sea levels had to rise because all of the ice that accumulates on land has to end up in the oceans so the sea level goes up and the ocean warms and expands and so sea levels were about 150 metres higher at that point than they are now. The map of the world was very different and at the same time there in Antarctica you find large beasts and their remnants are down there underneath the ice.

We move from that period, that is the Eocene/Pliocene interface, we move forward and you see that it took about 45/50 million years for the planetary surface to recover from that very high temperature, very high carbon dioxide level at that point. When the temperature drops there are blips and bumps and we don't know the details of what was happening and then we move to the present period and you see that we come to the period of mankind. So the evolution of mankind is the last bit of that graph and by the time we get there those oscillations are not noise in the data, those oscillations we have come to call the ice age/warm period oscillations. So when we hit that period the earth has moved into a period of instability in its temperature and that instability means that we have this phasing of warm periods and ice ages.

At the bottom here I'm just expanding the last bit, they're showing the last 400,000 years and now I'm showing in blue the temperature and in red the carbon dioxide levels. What you see, peak here is a warm period, at the top here is the ice age, warm period and every time we have a warm period we see carbon dioxide levels are high so this is the Fourier effect coming through. We see that when carbon dioxide levels are high we go into a warm period. Sea levels are changing as the water percolates on to land during an ice age or off from the land into the oceans. Sea levels change about a hundred metres between an ice age and a warm period. Sea levels are very important precisely because during our period of civilisation we've been building 80% of our cities on coastlines thinking that coastlines were pretty stable.

Now I come to the last 12,000 years, that is the period here of our current warm period, so that's the period, it's the longest lasting warm period and at the same time it's the period of our civilisation, that's 12,000 years. It began to come out about 18,000 years ago. So for 12,000 years we have had a relatively constant temperature period but that's unusual if you look back over this period. Now the top curve you see that sudden steep rise in red on the right hand side. Zero is today, the sudden steep rise, carbon dioxide going out, remember I said carbon dioxide levels were between 200 and 260 parts per million for the last many millions of years and now suddenly we are, just to give you dramatically today's figure, 383 parts per million. So we are at 383 parts per million today and that figure is rising at 2 part per million per annum. So that's the nature of the problem. If you want to ask how far do I have to go back in time before I get to that level of carbon dioxide is roughly where that

purple line is, 3 million years, and you can see that already the planetary temperature was quite a bit higher than today.

So what we're saying is we've effectively done enough to our atmosphere to switch off the cycle of ice age to warm period and we are heading into the first hot period for probably about 45 million years. That's what these graphs are telling us and the big question is what is the impact going to be on us as we move through the coming centuries and that's where I am now going to take you.

If we look at impacts, I want to explain that actually we're already experiencing these impacts. We had a hot summer in central Europe in 2003. It's the hottest summer on record which probably isn't saying very much and you will see in a moment that it was a severely hot summer but the important thing is it's not only the hottest summer it's the biggest single natural disaster in central Europe on record measured by the number of fatalities. Also the biggest natural disaster that's gone unrecorded as a natural disaster because it played out over a period of about 6 weeks. 32,000 people lost their lives during the summer of 2003 in central Europe. Now if we analyse that summer we can do it a non-timescale form and here I'm just doing it by representing a vertical line for every average summer temperature in central Europe going back to 1863 and the summer of 2003 is clearly unusual. There is a gaussian curve drawn through the data without including the 2003 summer.

What does that mean? It means, for those of you who understand statistics, it's 5.2 standard deviations from the mean. That means it is a one in a thousand year event. Now most of us would say that's therefore an event that isn't going to happen. Now the alternative way to look at this is to take a time line through it and the time line demonstrates that actually over that period of the last 50 years the temperature rise we've experienced has been around .7 degrees centigrade in central Europe and that base line temperature increase, the average temperature increase means that when we get a hot summer it's sitting on an already higher baseline and another way of saying that is that the present average temperature in the 21st century in central Europe, and this century is only 6 years old, is now roughly the same as the hottest summer of the 20th century, that summer of 1947 that you see on the right hand side in blue there. So let me repeat that, the average central European summer temperature is now the same as the hottest summer of 1947. So that means when we get a hot summer now on top of that 1947 hot summer we experience a lot of pain. This means it is no longer possible for climatoligists to talk about an event as a one in a thousand year event because of that time line change. So the analysis indicates that half of the severity of that summer in terms of the temperature rise can be attributed to the global warming that's already occurred but most are the fatalities, because it's that excess heat that has produced the fatalities.

So what is the modelling say that we have ahead of us? So we now stretch forward in time and I am now taking the models that I was discussing before running on the earth simulator, these are massive pieces of work, extrapolating forwards I've got a pale blue curve and I've got a dark blue curve, of course what we've got to know what is the global behaviour going to be about carbon dioxide emissions? So as we go forward in time we could either say business as usual, we keep burning all of that coal and gas and oil that we need to energise our societies and then we stay on the pale blue curve or we get some global agreement to reduce emissions over the coming years and manage to terminate with an atmosphere containing about 550 parts per million. Now if you remember I said 270 parts per million was the normal warm period level so this means we are actually going to have to bust a gut to be at something like twice the normal level for a warm period. That is what that blue curve is

showing and that blue curve is indicating a 4 degree centigrade temperature rise, average planetary temperature rise.

The interesting here is the carbon dioxide level has increased so quickly in our atmosphere over the last 50 to 100 years and particularly in the last 50 years that it is going to take another 30 years for the climate system to catch up so the next 30 years of temperature rise which would take us to somewhere around here, the next 30 years of temperature rise are in the pipeline anyway. So whatever we do in terms of global action is actually going to only phase through into these graphs in the later part of this century. That's one of the big political challenges I'm referring to. Is it possible for us to make a political decision to act on something now when the change that we are trying to engineer will only happen in 40 or 50 years in the future? That's the first of the big challenges. You'll see that the temperature rise around the planets is not anticipated to be even and as a matter of fact these models are extremely impressive, they give you a temperature rise down to a 60 x 60 kilometre pixel scale. So we've got the whole planet predicted down to a 60 x 60 kilometre scale.

Now this is one run of one model with one set of parameters fed into it and your next question would be so how reliable is that? So now we go back to a probabilistic analysis, and I promise after this it all gets a bit easier, a probabilistic analysis which just says what is the probability if the ultimate carbon dioxide level in the atmosphere, for example the one curved in blue, was to be at 450 parts per million, what will the average temperature rise of our planet be? You take that 450 million, you can see that the most probable increase is about 2.2 degrees centigrade. I've said we've already had .7 degrees so there is still a significant temperature rise ahead of us even if 450 parts per million but the probabilistic analysis then shows on a 5% to 95% basis. So here's the 5% and the 95% we are talking about 1½ to almost 4 degrees centigrade on a 450 parts per million level and then as we increase the amount of carbon dioxide in the atmosphere up to the orange curve, 750 parts per million, the most probable temperature rise is heading towards 5 degrees centigrade. Now 750 parts per million isn't randomly chosen. Here by the end of the century business as usual we will pass 750 parts per million. There is enough coal for us to burn to take carbon dioxide levels probably up to about 2000 parts per million so if we really try hard we can push the planetary temperature up very substantially.

What are the consequences of all of this? Well, as we move these models forward to the 2080s we can first of all see what happens in terms of sea level rise so these curves are just showing what happens in terms of sea level rise and you'll see that parts of our planet where the effect is greatest are very much around India and Asia and the African continent as well and the number of people displaced from their normal place of abode because it would no longer be possible to live there is roughly indicated here but certainly by that time hundreds of millions of people will have had to move from their normal place of abode. Now I would suggest that would be a massive geo-political destabilisation and economic destabilisation because those people would be moving to other areas which are more habitable but which would already be occupied and I don't think any one of us would be free of the consequences of that process.

I would also just at this point interject and say that I do believe that Darfur is arguably a climate change conflict. The changes that are happening in northern Africa in particular but it's beginning to happen in southern Africa we are seeing increased desertification which is again predicted by these detailed models and that desertification means that crop failure

becomes routine and people start to clamouring to move and as they start moving they're moving to already occupied areas.

What is the point at which most of us feel we should not test the climate change models and we have come up with a single icon and that is ice on Greenland? So if we forget everything else and just concentrate on ice on Greenland why is that important? Well again Greenland has been accumulating ice for thousands of years and if all of the Greenland ice were to melt and regarding nothing else, just the melting of Greenland ice going into the ocean, the sea level rise around the world would be 6½ metres. Of course at 6½ metres sea level rise we would certainly not only lose London but we would lose all of the major coastline cities around the world. They would become indefensible at that level. People tend to think of sea level rise and then measure where that would mean but don't forget it's actually storms at sea that determine how close you can live to the actual sea level.

So what will it take to avoid melting Greenland ice in terms of carbon dioxide level increases? This is a massive problem for scientists to try and work out but it does seem that in the models if you exceed 550 parts per million of carbon dioxide irreversible melting of Greenland ice follows. The problem is that it may even follow at a lower level of carbon dioxide than that. The models that were conducted are rather like taking a great block of ice and calculating what would start it to melt and how long it would take to melt. The good news is the models say 3000 years to melt all of the Greenland ice sheet with lots of trouble before that time because of the warming of the oceans and all the other ice that is currently melting. By the way if you take Kilimanjaro for example, again the ice cap on Kilimanjaro goes back to the last ice age and further, Kilimanjaro in about 8 to 9 years time will no longer have summer ice for the first time since the last ice age. So we are losing glaciers around the planet at quite a rate.

So staying with Greenland we now have the most sophisticated measurements being returned to us from satellites. Satellites are now measuring by altimetry, height measurements, what is the loss of ice from Greenland, mapping out the height of the ice year on year and from those measurements we are finding it's around 200 cubic kilometres of summer ice being lost from Greenland per annum and that's at the current level of carbon dioxide in the atmosphere, 383 parts per million. It's much faster than the modelling was predicting. The most beautiful piece of science, and you must forgive me for telling you this, is the latest satellite data which has just been published is from gravitational field measurements. So if you have a satellite going over at a fixed height it can measure the gravitational field change as the height of the ice falls and from that measurement again we are coming out with around 200 cubic kilometres. Think of a 200 kilometres side cube of ice being lost from Greenland each year.

Now the puzzle is why is it going faster than the models were saying and I'll give you a photograph that tells you…ah, sorry this is the satellite data but let's move on…this photograph tells you what's actually happening. So you start getting summer melt and the summer melt speeds up and the summer melt creates these Moulins. The Moulins being a river, eats into the ice below it and creates a waterfall. As it creates a waterfall it speeds up until it gets to the land base and once it's at the land base it can lubricate underneath the ice and the net result is you get large chunks of ice carving that can enter the ocean from the land. So instead of just the normal carving occurring from ocean based ice you can carve off chunks of ice in this way. So very difficult to model. The modellers are back to work with all of the data that they now have and we hope to see that in the next year or two emerge in a better way. So there's the science now we move on to the policy bit.

What is the message of all of this? What do we have to do? Well the first thing is I've said the next 30 years of change is with us anyway so the first thing we must do is adapt. We have to prepare for the changes that are ahead of us. The number of fatalities in central Europe I would suggest was that large because we were not prepared for a very hot summer of that kind. So first of all we must adapt but secondly for the longer term, if we are concerned about the future welfare of the planet, if we wish to avoid long term catastrophe for our civilisation we must mitigate. So we've got to reduce our emissions now with an eye to the future and we have to adapt now with an eye to the present and the near future.

Adaptation is a measure that requires action country by country and therefore I suggest that adaptation is not a big challenge. It's also something that governments will realise is in the best interests of their people even during their period in government and so they are more likely to take that action. Mitigation is the difficult challenge because the response comes over 30 to 100 year period time and at the same time it requires global action. We all need to act on that.

Now there is only one country that has actively gone into adaptation mode so far and that is the United Kingdom. Some years ago I started a government foresight programme and I started it with a programme looking at the impacts of climate change on the United Kingdom and you will see in the moment the small pixel scale that we were studying, the future changes to the United Kingdom over the next 80 to 100 years. The important point here is before I show these maps that we were looking at this with a view to managing risk to a constant level to our population to the year 2000. So here are the maps. I said that because I got into trouble in the House of Commons when I showed these maps because people felt they could see where there constituents houses were and might be a little worried about the state of play. Red is bad and yellow is good so in the pixels marked red we are anticipating very severe flooding as we move forward through the century and interestingly the analysis which took a hundred scientists, engineers, economists, social scientists, about two and a half years to produce with the modellers, the analysis indicates not only that it's our coastlines that are at risk but also our major cities and the reason is that our cities were designed for a different kind of rainfall pattern that we can anticipate into the future. Already we are seeing more and more flash floods in this country and our drainage system and indeed our sewerage system were designed by the Victorians extremely well but for a different kind of rainfall pattern. So what happens in our cities now is that if we have a flash flood our drains can't cope and the net result is we get major city flooding. So if you look at these maps you can see major conurbations as well as coastline area are problems at risk.

We had to work again on different scenarios. The left hand one is the scenario where internationally we get best behaviour and on the right hand one is where we get business as usual. So you can see very simply that this was one argument that was used, that I used freely with the Cabinet to say we need global action to mitigate because there is no question which scenario you'd rather be defending the country against, it's the left hand one. So the cost of trying to manage the risk in the right hand so the whole map looks yellow really becomes rather prohibitive whereas to manage this one so that it is all yellow is okay. So an outcome of this programme is that the United Kingdom back in 98 was spending 200 million pounds a year on flood and coastal defence management and we are now spending 500 million pounds a year and our programme said we've got to keep increasing that as we move forward in time to keep this map yellow. So bottom line we are keeping the map yellow but as long as we can persuade all the other countries to stay on this scenario and not move on to that one.

During that process we developed a large scale computer programme to enable planning to proceed and this computer programme is available in the form of a game because we see it as an educational programme and I am pleased to say that many departments of engineering are now using it. The game is called *Floodranger* and it is based on the computer game *Sim City* and you are given a piece of coastline and you have to defend it against future flooding and it's a properly worked out process in which you build your defences but you have to pay for it. So you have to balance your budget so it's really useful for city councillors and county councillors. You have to build your defences, you have to change your drainage system and then we run the programme forward in time to see how well you've managed and with this programme we have actually provided a means of taking planning into the stage of using the capabilities of computational exercises rather than simply a wet finger in the air.

Now perhaps the sad information to give you is that we received an order for this programme in the United States, about month after the New Orleans disaster, and the order came from the US Army Corps of Engineers and they bought a thousand copies of this programme at this point. I have to tell you if you run the programme as we had done on the city of New Orleans we knew that the levies would break in the city of New Orleans. As a matter of fact those levies were designed for a one in a hundred year event. In Europe all of our flood defences are based in a one in a thousand year minimum and in the UK one in two thousand years so one in a hundred years is really asking for trouble. I wrote an article back in 2002 predicting that New Orleans would be one of the first cities to suffer from this.

Now what do we mean by flood defences? Well, I've got one very good example which you are all very familiar with and it just so happens to be an example where we have a bit of foresight without quite realising it at the time. In 1926 there was a massive flood in London with a large number of people dying and the government of the time decided we should try and design barriers to prevent flooding of London. Now I've talked about the inertia of the climate system, the inertia of the political system may be even greater because it was 1980 by the time the Thames Barrier was up and constructed and it was thought to be quite an expensive exercise but let me tell you the Thames Barrier was designed to prevent flooding in London and it was anticipated that the flooding would occur roughly once every three years and therefore the Thames Barrier would be used once every three years. Today the Thames Barrier is used six times a year so this is already the impact of climate change on what is happening here in the UK. So this is my figure of the potential usage of the Thames Barrier if it had been built in 1930. So this is counting every flood in London and you'll see once every three years. Then you come to 1980, for the first period, ten year, it was only used three times and now we are up to an average of six times a year. We are only showing the usage here for those cases where it has prevented a flood. One of those floods breaking through the barrier we now estimate would cause direct damage minimum of 30 billion pounds to London, indirect damage would be massive. We are looking at the potential flooding of underground, flooding of power stations and so on. So the utility of the Thames Barrier is a massively good example of a piece of foresight planning to prevent the impact of climate change events.

We can manage those processes because we have the economic capability to do it and I've talked about the level of investment required to manage that as we move forward in time. Africa can not so not only are the impacts of climate change probably going to be more severe in Africa than in other continents but the process of adapting to climate change is going to be more challenging because the finances are not there and the skills are not there. So as we move forward and see a global position on adaptation I have to correct what I said

that it has to be done country by country, we really have to have international exercises so those countries that can't manage the process are assisted by those countries that can afford the process.

During our presidency of the G8 the British government put two items on the agenda up at Gleneagles. The first was climate change and the second was Africa and most people missed the point that the two are closely related. Africa will not manage this process unless we can get economic growth of a kind that hasn't occurred, in fact just the reverse has occurred in Africa for a hundred years. So what we need to see is economic growth, a growth in sustainability of the African system and then assistance in managing the climate change impact.

Here's the big problem that we are faced with. If we look around country by country at the level of emissions of carbon dioxide you will see there is a dramatic difference. Here I am representing this as per capita emissions per annum, as tons of carbon per person per annum. I think most people are a little bit surprised to see how much carbon is emitted to sustain them through a given year of normal living but the amount required to sustain an American is around 5½ tons of carbon per person per annum whereas the amount required to sustain an Indian is about .2 tons of carbon per person per annum.

Now the point I am going to emphasise with this disparity is really, well there are two major points, one is that the rectangle represents that area in the rectangle is the amount of carbon dioxide emitted per country so of course the population of China is much larger than that of the United States but as China's population continues to grow so one axis will extend and as they continue to grow their economy the vertical axis will extend and so the area in the Chinese box will soon overtake the area in the American box and of course the same is happening with India and all of the emerging economies. At the same time there is a very big difference between the average in western Europe at about 2.2 tons of carbon per person per annum and the United States. There's an interesting fact that if you take it per person per annum then in the United States and in the United Kingdom there hasn't been an increase in this number, in the UK virtually no change, since 1950. So once your economy reaches a certain level then the amount of carbon dioxide emitted per person remains approximately constant. However there are different speed limits apparently for different countries.

The second point I want to emphasise here is that this underlines the problem of reaching an equitable international solution because what we have is some countries that have been gaily emitting carbon dioxide and putting much of this in the atmosphere that is creating the potential problem and the existing problems whereas the other countries that are suffering greatly, such as Africa, are not putting it up there and are therefore pointing a finger at the developed world and the developed world is saying but look at the rate of expansion of China and India, they will soon overtake us so they ought to do something before we will take action. I think that's the nature of the challenge. You'll see if we look at emissions of carbon dioxide from fossil fuels alone and by the way carbon dioxide levels have also been going up because of land use changes but really it is the fossil fuel burning that's the major factor. Then you'll see there has been a very rapid rise since 1950. It's slowing down, OPEC brought about a significant slowing down of the carbon dioxide increase but nevertheless it's projected to continue increasing very substantially because of the rapidly emerging economies and their contribution to increased emissions.

So if we look at future world energy demand out to 2030, these are the figures from the International Energy Agency, you'll see that we are still in for a substantial increase and therefore we must anticipate that the rate of carbon dioxide increase, which I told you was two parts per million per annum, will therefore increase as the rate of emissions goes up as indicated here. Now of course that will only happen if we don't find some other way of energising, providing the energy for our societies and the alternative is to look for emission paths to stabilisation and what is shown here in blue is that curve of increased energy usage where it's all related to fossil fuels, going up in blue business as usual, 550 parts per million we would need to be on that trajectory so this is the rate of emission and the year, we need to be on the yellow trajectory and 450 parts per million on the red.

Now I believe that to be below 450 parts per million is a piece of wishful thinking at this point in time. We should have been discussing this properly back in 1980 if we wanted to really keep this below 400 parts per million for example. So 450 is probably the best we could possibly achieve, 550, beyond that the models are all showing us that heads towards catastrophe. So what we need is to see if we can get policy that hits us somewhere in between the yellow and the red curves and at the same time we would rather be closer to the red than the yellow. I've been vastly misquoted and misrepresented in the media but I am getting used to this now because it's been stated that I believe that 450 is perfectly okay. Believe me I would rather we were at 270 parts per million. I am talking about the real world. If we were to go for a 400 parts per million, we are going to pass that in less than ten years, if we were going to go for 400 parts per million we would actually have to turn off all of the coal fired power stations around the world and I just don't see that that is a manageable proposition. So we also have to live within a manageable situation.

So here we have the nature of the problem, remember I mentioned 9 billion people by mid-century. We've got an expanding population, we've got expanding expectations and therefore greater and greater energy demands. If we don't do something about this we are going to see that by 2030 we'll be at 50% higher than we are now.

If we look at the energy policy of the United Kingdom, which I have now been working on very closely for the last three and half years, it's based on this Venn diagram. We need a secure supply of energy. We don't want a winter to come along when we find we can't heat our homes and buildings. We need energy cost to maintain our competitiveness industrially and with all of our near neighbours in particular and we need emission reduction. So we want to find a policy that sits right in the middle there and meets all three of these demands. I don't happen to think it's impossible and nor is it going to be tremendously expensive. In fact I don't think it will be for us expensive at all.

There's a range of processes we are going through. The government produced an energy White Paper in 2003, that is being revisited because as a matter of fact it needed more flesh on the bones particularly in terms of economic and fiscal process to drive through what is required to meet the challenges. The energy review published in the summer of 2006 indicates the way forward. There will be a White Paper, a new White Paper in Easter, I'm told never say a month when you are in government, in Easter 2007 and that energy White Paper I believe will for the first time set out a hard track which can be torn apart by economists, a hard track to demonstrate how we can follow the government's intended policy to reduce our emissions by 60% by 2050.

Now why are we saying we'll reduce emissions by 60% by 2050? The answer is because it undoes a negotiating block. When we sit in international negotiations others are saying we are going to wait for you to move first and Britain just decided all right, we will move first, we will declare unilaterally our intention to take the action that we think all other developed countries ought to be taking and that undoubtedly has put the United Kingdom into a lead role in the international negotiations on this position. We are finding it considerably easier in bi-lateral and multilateral dialogue precisely because we are declaring ourselves in that position. There is an unexpected outcome of that. I was invited to head up the Governor's Conference on Climate Change in California and I announced that the British were going to reduce their emissions by 60% by 2050 and Schwarzenegger announced that California would reduce its emissions by 80% by 2050! Last month Chirac announced that France would reduce its emissions by 75% by 2050 so there is if you like an unexpected outcome, there is almost a competition to show that we are going to be good players on this which is precisely where we want to be.

Now how do we achieve it? This is precisely where we are now. I set up an energy research partnership which was a public/private dialogue to discuss this a couple of years ago. The Research Council's spending on energy research has increased quite substantially into our universities and we are now setting up a new energy technologies institute which is a 1 billion investment into new energy technologies which is all renewable. It is non-nuclear I should stress, new technologies, and this is a public/private partnership with half of the money coming from government and half from the private sector and we hope to announce soon that we've got all of the private sector money that we need for that process. So what we need is the whole range of new energy technologies to be brought on stream and what I want to stress here is the old arguments that there is no silver bullet. Actually we need everything we can get our hands on. We need every tool in the bag and in that process we therefore will need to look at every possibility and push that possibility as hard as we can to get it to delivery.

When we look at that ambition to reduce our emissions by 60% by 2050 I'm not going to give away what's going to be in the White Paper but I will just demonstrate the thinking that currently underlies that White Paper with the so called Socolow wedges. So here's where we are in emissions in 2006, because our population isn't expanding significantly and our emissions per annum is not growing, I can say that's roughly a straight line across. It's all very schematic. We want to be down at 40% of that value by 2050. How do we get there? We introduce renewables obligation on the grid. That is already there and then we extrapolate that forward by continually upgrading the renewables obligation and we get the first wedge and we are on our way but we are certainly still a long way from the 40% figure. We introduce energy efficiency gains, by the way what's the constraint on renewables, we have 1.4 gigawatts of energy on the grid at the moment from wind farms, there's another 9.5 gigawatts caught up in planning permission. So we do have a population that is very keen that we deal with climate change but not in my backyard or perhaps I'd be kinder to say not on my favourite piece of landscape please. So we know that we can't push renewables too far but in any case because the wind doesn't always blow we can't rely on too much wind turbine energy.

Energy efficiency gains, big win, win. 50% of our carbon dioxide emissions in the UK come from the built environment. The built environment in the UK is rather badly designed which is good news because that means there's a lot of headroom for emission saving and as we move forward we are going to see new building regulations rolled out and we will see a 21st century building design emerge. This will have to look not only at existing buildings, we

must do, but also of course [end of side] …efficiency, economic win, carbon dioxide win, so that's what everybody wants.

Perhaps the one that not quite everybody wants is nuclear and here let me tell you that a few years ago we had 30% of our electricity on the grid from nuclear. We were the first country in the world to build a nuclear power station and because we were the first country in the world we've got Model T Fords all around the country. These are old aging power stations, not very efficient, and they are being decommissioned now. Today we are at 19% through decommissioning old power stations, by 2020 we will be at 5% of electricity from nuclear on the grid. If we don't build new more efficient power stations we don't get a negative wedge as I've got here we get a positive wedge as we take those power stations off the grid. So put new power stations in place of the old ones that produce more electricity, they don't produce carbon dioxide and we get a negative wedge which is what we want. Without that it's going to be very tough because the upward wedge would actually wipe out the gains I have already indicated there.

Carbon capture and storage, we will soon roll out the first demonstration of carbon capture and storage that is taking a coal fired power station, capturing the carbon dioxide that emerges from the top and burying it in one way or another. The first example of that is going to emerge from the UK but interestingly it may well be on a Chinese power station. When I was in China last December I signed an agreement on behalf of the British government with the Chinese government to take our technology out to China and to install it on to a Chinese power station. We are working with the Chinese on where the saline aquifers are so that we can choose a good power station to start as a demonstration. Why are we doing that in China? China is building a new coal fired power station every week at the moment and unless we manage carbon capture and storage and unless the Chinese introduce it then everything we do is to no purpose at all. Incidentally we are also taking our programme on flood and coastal defence management to China and we have our team out there right now working with the Chinese in the area of the Yangtze basin where Shanghai, this wonderful growing city, but a city that is more at risk from flooding than London. So it's at risk from flooding from the Yangtze river and from the ocean just as London is and the lessons they are learning from that exercise I'm sure are already indicating to us that the Chinese are determined to manage the process and all we're looking for is an equitable solution to the political problem.

We need to put a transport wedge on. Transport is the one sector where carbon dioxide emissions are growing in the United Kingdom. We have to turn that positive wedge into a negative wedge so the Department for Transport is involved, the Department that deals with Energy (DTI), the department that deals with planning, DCLG, DEFRA, the department that deals with renewables, you'll see that all of these are being asked to produce their bit of wedge that brings this down.

We haven't got much micro-generation of energy in the UK and finally combined heat and power. We only have 5% of our electricity being produced in a way in which we use the heat that is produced as we produce that electricity otherwise most of it is in those energy exchanges where you see steam rising up into the sky. We are warming the planet with the heat instead of warming our houses. So we've got a lot of head room for using combined heat and power systems as well. That requires a lot of infrastructure.

I got you down to 40% there and I am leaving further developments to bring us further down because I believe that by the middle of this period at least, 2025, that pressure for us to reduce

our emissions even more will be greater. So there's no new technologies included in what I've set out in the first set of wedges but as new technologies come on board we can use them to lower the emissions of carbon dioxide still further.

Carbon capture and storage I won't actually take you through that because I think time is moving on. Let me just say this foresight programme that I've set up within government, we are now running a detailed programme on sustainable energy and the built environment. So we are now using again about a hundred scientists, engineers, architects, builders, to sit down and design what the optimal built environment for the UK would look like and that is suitable for the 21st century instead of that built environment that we all love so much, that the Victorians left for us. So how do we transfer the existing built environment to a more sustainable environment but perhaps more excitingly what about the new environments? We could move towards a building which is essentially wireless, where it generates its own heat and electricity from its immediate environment and where it might also deal with its own waste internally. So moving towards a building where we are using all of our current technological capabilities.

On the global front as I have already indicated our 60% target has played I think an important role in raising the profile of this but perhaps more importantly was that G8 plus 5 meeting at Gleneagles during our presidency where the Prime Minister invited the Heads of States, not only of the G8, but also of the 5 big emerging economies, China, India, Brazil, Mexico and South Africa. The Heads of States all came and discussed this issue. I was at Mexico for the follow up just a month ago and that was a very promising meeting. So we have started now a Gleneagles dialogue and the Germans have promised to take this on to a meeting next year and what this means is that within this grouping of the thirteen leading economic powers, including the developed and the emerging, we are trying to work out an equitable solution and in that process in Mexico, a month ago, we actually took the step forward beyond arguing about the science. Nick Stern was there to present his economic analysis and we had a long discussion on his presentation. That was then accepted. The International Energy Agency was there, the World Bank was there, all telling us the Stern analysis was pretty good and that tells us that it's not actually going to cost us much if we deal with the problem but it is going to cost us a large amount if we don't deal with it.

So I think that was the big breakthrough and now we're challenged, I think it was the Japanese minister who said, let's see if we can find an equitable solution. That's the challenge and that's where we ought to be at this point in time. So the Mexico meeting I think was a major step forward but it also means that the more complex process, the United Nations Framework Convention on Climate Change, which has 183 nations, you can't say sitting around a table, 183 nations represented each of them with 6 or 7 people but that process needs leadership from a smaller core and I do think that the G8 plus 5 grouping is going to provide that leadership.

The Stern Review I've already mentioned. I think that the important point here is that when he runs his economic models forward he's saying that without dealing with climate change we are headed for the kind of economic downturn that was experienced in the first part of the 200th century, two World Wars and the Great Depression, but if you look at his models please remember that that downturn is only going to occur towards the end of this century. So once again we are up against this political problem that he's talking about, paying up front now to avoid an economic cost at some point in the future. By the way this question of 1% cost on GDP by 2050, that's an integrated cost so that's quite a small number.

For those countries first up to the plate actually you can see an economic gain. If you get into new energy technologies early and begin to export them, as Denmark has with wind turbines, there is a real benefit in getting and investing in those new technologies. There's another factor which is that over the next 20 years, because around the world we are looking at old energy resource, there's going to be an investment of about 20 trillion dollars in new energy providing devices, power stations. 20 trillion dollars worth of investment is an opportunity for new technologies to be brought through. So I think there's a very good window of opportunity as we move forward in time which is why, and I come back to David's first points, I am actually an optimist on this. I think we can manage the problem.

We do need both national and global solutions. We need a strategy worked out with key partners that we can take to the entire global community. We need to work out new technologies and to get there early and if possible first and in particular I'm going to leave you with the Energy Technologies Institute. The Institute is really the brainchild of myself and Paul Golby, who is the Chief Executive of EON UK. You in London buy your electricity from EDF. EDF have also joined us in this exercise, that's a French based utility, EON is a German based utility, BP and Shell are on board and we are calling for new partners until we reach a total of 10 and we are rapidly closing in on that number. So I can tell you that Rolls Royce and Scottish and Southern Electricity have already joined and this means that I can anticipate that in three years time we'll have a new investment in new technologies in the United Kingdom which will amount to that 1 billion pound aspiration over a ten year period. We are hoping to ramp it up very quickly. It should be up and running to its full operational scale in about 3 years, that is 100 million pounds a year.

So I think as we move forward because science is telling us what the programmes are and technology can provide the solution and it is not going to be at too great an expense but my bottom line is I think we can manage it and it is all a question of political aspirations. Thank you.

[Applause]

Professor Held
I think that was an extraordinary lecture, one of the most informative lectures I think I have ever heard. I liken it, I was thinking what kind of a lecture is this? I've sort of watched it before in the cinemas, it's a classic horror film, not the contemporary variety which always has a gruesome end but actually gothic horror which is elegant, sophisticated and resolved at the end in a most positive spirit. So I feel I've watched this story before but now here it is clearly presented in one of the most formidable challenges of our time. It seems that the problem is politics but before I ask some questions about that I am sure there are many in the audience.

Question
Thank you very much for the lecture. You said in the lecture, Professor King, that to a certain extent the next 30-50 years are already set and I wanted to ask a question particularly on Africa given that you said that Africa is specifically at risk and the Darfur war could be attributed in part to desertification and the need for economic developments in that area so that they can address it in the way the Thames Barrier has addressed the potential risk here but if they need economic growth, given the very interesting presentation you put on US carbon emissions per head and where China and India are now and where they'll be going,

and the fact that with Africa with their population at the moment, for them to get significant economic growth to enable them to be able to put technology in place to address this, they will need to have an enormous ramp up in their carbon emissions per head. They haven't even started yet and look at China with their new one a week coal facilities. I wanted to ask whether or not the factors that you've put in and the figures you've put in for carbon emission has taken into account Africa experiencing that kind of economic growth and if not are we just saying that essentially, we are saying that Africa is going to experience severe impact from the global warming that is going to be experienced in the next 30 years?

Question
I arrived late for your lecture so I don't know if you talked about the topic of deforestation at the beginning and I would be interested to hear your views on the role that a global reforestation programme could play in this overall mix of policies to tackle climate change?

Question
I was just wondering if you think that the Brazilian proposal of opportunity, historically proportional targets to countries, could be a feasible solution in terms of blocking the policy and results?

Question
As we know inter-governmental negotiations are notoriously difficult and slow. It seems that the recent UN conference in Nairobi has made rather little progress. Do you think there is scope for there being an international expert working group of maybe no more than about 20 nominees, say two from the European Union and two for the African Union, whereby you could get a small group to come up with some more detailed proposals, much more rapidly hopefully to sort of lead governments and public opinion to reach an earlier settlement than otherwise?

Question
I was just wondering if there was any other way that you know of, of sequestering carbon other than through photosynthesis and if there isn't any other way isn't a substantial part of what we ought to be doing, reforesting the tropics where photosynthesis is most effective and operating within the clean development mechanism towards that end.

Professor King
The first question was about Africa and economic growth, the simple answer to your question and I've got to be brief is that we need to see Africa leapfrog into modern technologies. In other words those technologies that I was talking about, that we're going to push through on over the next 30 years, are also technologies that we need to see transferred into Africa and if that sounds impossible to you please remember what's happened to telephony in Africa. Mobile phones are now used throughout Africa and have really transformed markets in Africa because people are informing each other in a way that hasn't happened before. So leap frogging of technology in an appropriate fashion happens and I believe there is no reason at all why it shouldn't happen in Africa. The key point here is what the cost will be and who will bear the cost and of course I'm suggesting that whatever that equitable process is that we negotiate has to take into account the need for the advanced nations that can afford it to cover that cost and to be involved in that technology transfer but let me also say you mentioned over the next 30 years, the next 30 years the impacts climate change are going to be there whether we take these actions or not and so that will have to be managed with Africa as well so there is another issue which is adaptation. The work that is being done by the British

government on Africa has increased enormously. Since the G8 meeting we are now spending £1.2 billion a year in Africa and it's a good part of the programme.

The second question was land use and deforestation and I can relate that to the fifth question which was on sequestering carbon other than through photosynthesis. The important thing is, just want to say the modern period where, I said we were moving into a hot period, the climatologists refer to periods in terms of cenes, the Eocene and the Pliocene, we are in the first Anthropocene and I would say the first Anthropocene means two things, our change of land use and it is quite arguable that the lengthy warm period we are already in is related to our land use changes, our civilisation developed, and so the loss of forests in Britain as in elsewhere as we've developed our civilisation over the past 5000 years or so has already contributed to that process. So yes reforestation is potentially useful but of course you have to then put value into reforestation so we need to work out an economic incentive to reforestation and also to maintaining forests and of course that's what the Brazilian government has been working on, I believe quite successfully, despite the criticism of putting value into forests. The Mexican government are also doing that and those value elements are all external to those countries. I think we need to build that into international agreement, to clean development mechanisms which is the Kyoto term for this, need to include how we value maintaining forests but I do not think that reforestation is anything like the solution and I won't go into it now but basically that 9 billion people that we are talking about, those people have an enormous footprint on our planet and that footprint requires that we can't have all of the forestation that would be required to return us to a decent amount of carbon dioxide.

Are there other ways of removing carbon dioxide? The answer is yes. It's already been done and I have passed over that slide quickly with old oil wells. If you have a disused oil well you can pump carbon dioxide back into it. Wherever there is oil there is often gas and perhaps I should explain that this means that the local geology produces a rock cap and within that cap is contained the oil and gas its trapped otherwise it would have bubbled out over the last millions of years. That means it's also a perfect place to store carbon dioxide. So you pump the carbon dioxide back in, seal it off and it's going to be good for a long time. There are not enough oil reservoirs around so you also need to use saline aquifers, that is underground water pools and pump the carbon dioxide in there so there are many ways of doing this and that's what is being pursued for example in that project that I mentioned in China.

The inter-governmental negotiations are slow and the question of Nairobi. What I first of all want to say yes, it's slow but actually the meaningful process is happening at head of government level so what I saw from John Howard's speech on Monday evening this week where John Howard, the Australian Prime Minister, has done a complete 180 degree about turn and announced that we need to introduce some form of carbon trading to deal with global warming. That is a critically important factor that has recently occurred and so I come to the United States. If we had a similar statement from the White House, for example George Bush may well be making a speech on this in January and we will be watching with great interest, then I think we can begin to make rapid progress in those international negotiations. In other words if we are left to lead on these on our own or with a smaller group of nations we are going to have a tough time but if the United States should switch its position into leadership I believe this would transform the situation but nevertheless your idea is a critically important one and all I can is, I can't say too much on it, but after the Mexican meeting we are doing something that sounds a little bit like what you are suggesting and what we have to be absolutely careful of that we in the developed world don't come up with a

mechanism ourselves. As you said it is critically important that we have the under developed nations, the emerging economies and the developed economies around that small table you were referring to.

Question
Generally you take a very positive approach towards this problem and if the science is so compelling how do you answer these sceptics who believe that climate change doesn't exist or is negligible.

Question
I would like to push you a little bit on the equitable solution that was proposed in Mexico a month ago by the Japanese and I wonder whether you think, just as a supplementary, whether Gordon Brown will act any faster on this than our present Prime Minister?

Question
Professor, you spent the first half of the lecture certainly scaring the living daylights out of me and you said a couple of times that any action needed required action now but in favour of people 30 years from now. You then went on, as did the Stern Report, to present solutions which actually sounded as if there was very little sacrifice needed and it may even be benign economically. Now I hope that's right but you've also mentioned carbon trading which would push up prices and so on. I don't think we've ever had an example in western capitalism of people voting or accepting against their own immediate self interests in favour of the future. Have you seen any evidence that maybe this time the turkeys will vote for Christmas?

Question
[inaudible]

Question
You said nothing at all in your lecture about cycling on bicycles and for all the bad publicity that we've heard over many years about private cars and diesel engines it seems that they produce more carbon emissions than you suggested in one of your graphs in your lecture. In the graph of the different wedges you seem to have suggested that the contributions from transport is just one factor among several others but all the bad publicity we've heard over many years suggest that it's a lot worse than that so why don't you give some more encouragement for people to go cycling?

Professor Held
Well that's happened before and politicians have done that famously, get on your bike.

Question
I would just like to hear your view on the problem of aviation, whether it is a big problem and how big it's likely to come to be and also we can achieve an equitable solution to that problem?

Professor King
Well they're getting tougher! All right, the question of sceptics, there are various categories of sceptics, some of whom I'm afraid are politically driven and some of them even financed by a lobby group in the United States which has been remarkably effective, the American Enterprise Institute. I say this with some feeling because a man with the impossible name of Myron Ebell used to appear at every lecture I gave and his question at the end was you've

given a very biased account. He never picked on anything I said but simply stated I had given a biased account and then he went on to the Today programme and said that I was a disgrace to the United Kingdom, a disgrace to the knighthood etc. He has never done anything except vilify me. He has never attacked any of the science. We discovered that he was receiving very large sums of money from the American Enterprise Institute to follow me around.

So there's one kind of sceptic and then on the other end of the spectrum and I won't refer to any in the middle, let me say David Bellamy still seems to believe that nitrogen and oxygen absorb infra-red radiation. Now that is simply incorrect and demonstrably so but at the other end of the spectrum you've got a really outstanding American scientist who for some time has raised challenges to the majority view amongst climate scientists, Richard Lindzen, and both of his major challenges have now been the subject of further research and in both cases the Lindzen ideas have proved to be wrong. They have been checked with satellite measurements. So the current state of play is that amongst the intelligent science community, that is the engaged science community, you don't find sceptics. There are lots of armchair critics out there but those people who are actually working in the field, they've moved on from being sceptical about is this anthropologically driven to now being engaged in arguing about what the impacts are going to be and I think that's where the current state of the science is.

The question of the equitable solution, it is the big challenge, and in a way I realise now I didn't answer the question about the Brazilian proportional idea, essentially the Brazilian idea is that we should all calculate how much carbon dioxide each nation has already put into the atmosphere and as we move forward in time we should use an integrated value as an equitable way forward so each country would be required to reduce its omissions based on the amount it's already put up and I personally think that is a substantially important contribution to the discussion. As we move forward in time any solution we have is going to and this ties back to the question raised about Africa again, is going to allow the developing countries to increase their emissions with time but they must be on a curve which begins to go down in time and if we were to look at African countries the allowance should be bigger and if we were to look at Brazil it wouldn't be that big. So we would vary this from nation to nation and this would be fairly close to the Brazilian equitable solution but I think that the answer to the question is we are actually looking at a whole range and bunch of scenarios so that we can discuss them sensibly around that negotiating table with 20 people and take them to the next COP meeting to see if we can make progress and I believe that we are getting enough buy in to that at the moment, to be reasonably optimistic about it.

Then I come to the turkeys vote for Christmas and I've just said I'm optimistic so it's the right moment to come to that question, carbon trading sounds like prices and why would western capitalists introduce carbon trading? Well, let me tell you one of the big surprises for me is the number of times I've been invited into the Square Mile to talk about this subject because those people in the Square Mile are investing in carbon dioxide in the European trading scheme. There's certainly been billions of pounds changing hands because there's money to be made in any commodity and if you declare carbon dioxide is a commodity there will be people making money out of it and that of course is the whole point of the exercise. The point is to reduce it but to get the private sector fully engaged in the process otherwise it doesn't work. One of the problems though is that the European trading scheme has not indicated what happens after 2012 and as a result the market has collapsed. So it started at 6 euros per ton when it was first introduced of carbon dioxide, it rose to 28 euros per ton with a lot of interest in it and we are now back, I think today's price is about 12 euros per ton but if

we can announce a post-2012 process and take it global, include an international trading process, I'm going to make a little prediction, that in about 10 years time we will see a new form of gold pricing. In other words we will see currencies being valued against carbon dioxide prices. It will be the one thing that we are all trading around the planet. So I think we can get western capitalism interest. I think we can create that self interest by putting a fiscal process in place which creates a market and turkeys will vote for Christmas.

All right, flooding and adaptation – I only talked about flooding because that is the biggest risk to the United Kingdom and in Africa the biggest risks are desertification, changes in rainfall. The total change in rainfall across Africa is not predicted to change but the Equatorial Africa scene will become wetter and north and south drier and so there is a massive problem here. As we move forward to a planet with 9 billion people even with climate change it is likely that we will be able to produce enough food for everybody and that there would be possibly enough fresh water for everyone, that's a bigger challenge actually, fresh water. The biggest problem is distribution. I come back to capitalism. Is the economic system that we have in place capable of the redistribution that would be implied to meet the problems that you've talked about? But certainly country by country the impacts of climate change are different. I mentioned the loss of ice on Kilimanjaro, the Chinese and the Indians are now very worried about the loss of ice from the Himalayas because melting summer ice in the Himalayas provides a means for crop growing in both of those nations and they have massive programmes keeping an eye on what is happening there. It is for example true, not only for this reason, but because of desertification in China, that the Yellow River only flows to the ocean three months in the year now. It only reaches the ocean three months in a year. So there are massive problems but you need to analyse that country by country.

I rather liked the one about cycling on bicycles because that allows me to talk about something I didn't mention altogether, a big category not just cycling, which is the cultural adaptation that all of this implies. See I think we could say on the one hand let's just leave it to government and introduce regulation and fiscal process and manage it that way and I think that's required but at the same time we all know there is a massive inelasticity in demand so people who want to drive SUV's, some people call them Chelsea tractors, if we want to drive SUV's apparently we drive them anyway even though they are much more expensive, they use more fuel etc., and so sometimes we need other than fiscal processes. Well I think social pressures are quite important and I don't think there is any harm in advertising to you that I ride a bicycle whenever I can, that when I go around by car it is in a vehicle that produces a large number of miles per gallon. It happens to be a Toyota Prius. You mentioned diesels, now with the new carbon trap that has been developed by a British company, diesels are probably the best way forward at the moment in terms of miles per gallon provided you don't go for a Chelsea tractor. So I think whatever we do, we need to adapt to change by a cultural change as well and I think that is probably not difficult. Now I have never quite understood why people go to gymnasiums to keep fit when they could just as well cycle to work and keep fit and save all that problem on the underground or whatever. So I think absolutely right.

Then I've got the last point which is on aviation and also your other point which is the contribution of transport generally – I said that 50% of the carbon dioxide emissions is from the built environment in the UK. 25% of the carbon dioxide emissions in the UK, you'll see I am using approximate figures, from the industrial sector and 25% from transport. So transport is a big sector but it's not the biggest and within transport by far the biggest sector producing carbon dioxide is road transport. Air transport is currently a relatively small amount but it gets the most publicity. Now that doesn't mean that air transport isn't a

problem that we have to deal with because as we extrapolate our current projections forward for the next White Paper, this is what we're busy doing, we can find that we can bring road transport down with various fiscal processes and air transport is the most difficult and if we leave air transport unattacked if you like by fiscal process then it becomes the single biggest transport producer in about 30 years. So we will have to manage that process as well. Currently the British government has the position that we would like to see tax on air fuel and we would very much like to see carbon dioxide produced from planes included in carbon dioxide emission trading and I believe that we are making a lot of headway and hopefully next year Brussels will announce that we have move forward on that. So creating a level playing field so that it isn't cheaper to fly to your destination around Europe than to go by train for example is a relatively simple matter of fiscal process and I hope we can work on it. The only last point I would want to make on aviation, it is not possible to work without some sort of international agreement. We can work in Europe but we can't work without international agreements otherwise we are going to see the Isle of Man turning into a landing base where planes will be refuelled. There will be places where planes will go to refuel. So it is a tough one because again it requires collective action.

Professor Held
Well, to say that was a tour de force is an understatement. I found that extremely informative and extremely engaging and somehow also profoundly optimistic, something that is very rare these days. One thing to me that is absolutely clear is that David King could go on all night. That's a great thing and we need to you go on day and night. The rest of us probably have to sometimes go home, certainly the LSE staff, who have been very generous by being longer here than they usually are already, have to go home. So on that note thank you enormously and thank you to the staff for staying on longer.

[Applause]