

The Challenge of Climate Change

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Speaker: Sir David King

Chair: Professor David Held

Chair

...this year on the theme of sustainability, social justice and the global order. This is the first of about 10 lectures we'll have throughout the year and if you look under LSE events you will see quite an impressive array of speakers coming over the next two to three terms.

I am particularly pleased however this evening to introduce Sir David King who will be speaking not just really on the challenge of climate change but to the broad issues addressed by the Miliband theme, sustainability, social justice and global politics. He says the title is a bit too bland, not enough crisis in it, so he will inject some drama into the title.

Let me just say briefly about Sir David's background just to fill you in on some of his remarkable journeys. Sir David King is currently the director of the Smith School of Enterprise and Environment at the University of Oxford. He was the UK's Chief Scientific Adviser and Head of the Government Office of Science from October 2000 to December 2007. In that time, among many things, he raised the profile, the need of government to act on climate change and was instrumental in creating a billion pound fund for the Energy Technologies Institute. In 2008, in January this year, he co-authored *The Hot Topic*, published by Bloomsbury on the subject of tonight's lecture. As the director of the foresight programme he advised government on a wide range of long term issues not just climate change from flooding to obesity. He also chaired the government's global and science innovation forum right from its inception.

He was born in South Africa in 1939 and after an early career at a number of universities became the Professor of Physical Chemistry at the University of Liverpool in 1974. A decade plus a bit more later he was appointed Professor of Physical Chemistry at the University of Cambridge and subsequently became Master of Downing College from 1995 to 2000. he has published, wait for it for all of us, you know, budding academics and those of you who wish to become academics, he has published over 450 scientific papers and has received numerous awards, prizes, fellowships and honorary degrees. He continues among many of his day jobs as Director of Research in the Department of Chemistry shuttling between Oxford and Cambridge, I don't know how you do it, and is also at the moment president of the British Association for the Advancement of Science.

There is no one, in my view, no one, who can speak with more authority, more clarity, and a more compelling way on tonight's subject than David King. Thanks very much for joining us this evening David.

[Applause]

David King

I want to start with a very simple idea that we have an enormous knowledge base. It was developing rapidly over the previous 200 years and then the computer revolution comes along and we have a sudden capability of moving from understanding fairly simple

phenomena to very complex phenomena and maintaining in many cases the same degree of understanding.

Now I want to use that as a starting point because my thesis is going to be that having this knowledge capability very largely cocooned into our universities there is a rather poor system around of moving that understanding into policy decision making. You will have heard that I had 8 years in government to become aware of this. I find in principle that in the private sector there is often a better understanding, take as a good example the insurance industry, of managing risks or if you take companies which require innovation to be competitive. There is a better understanding of the state of knowledge relevant to what they are doing than you often find in governments around the world.

So my first example is an admittedly dramatic one but it's one that I was involved in and that is the tsunami of December 26th 2004. So that tsunami happens and it happens to be in a part of the world where there is no early warning system in place and as a result those of us watching it on television sets were aware that the tsunami was moving across parts of the planet and 8 hours later the tsunami killed a bunch of people off the Kenyan coast. So no warning system, no mechanism in place, to see that the risk was managed and when I, I knew I had to make a report to the Prime Minister on this, that was the end of my Christmas break, when I went to the United Nations and asked why wasn't there an early warning system in place I was told this was a random and unexpected event because tsunamis happen in the Pacific Ocean.

So this awful event, which occurred just off the coast of Banda Aceh, so the Sumatran trench runs along here, just off that coast, this part of the planet nobody could have been rescued, it happened far too quickly, but what about in Sri Lanka, what about in India as that tsunami made its way across the ocean? 230,000 people died, I'm estimating that 150,000 lives would have been saved with an early warning system in place. Now what about this being a random event? The seismologists who study where volcanoes are, who study how plate tectonics work, how the plates carry the great continents around, are fully aware of the fact that when two plates are in collision there can be a section that gets stuck. The collision rate is slow, the plates move at about the rate of growth of your fingernails but nevertheless quite a big mass behind it so when a section gets stuck we know that it is going to go and the longer you wait the more pressure builds up the bigger the event is going to be. So as a matter of fact the seismological community had predicted a tsunami would occur along the Sumatran trench and said it would create a tsunami of Force 9. That was the prediction by the scientists and in even the summer of 2004 one Oxford scientist and one Californian scientist went on a trip to Sri Lanka, Indonesia and India to try and persuade the governments they needed an early warning system. They couldn't find a mechanism for talking to somebody powerful enough to take on the idea of spending \$30 million, that is all it would have cost, on an early warning system.

Now the point I want to make is there is now an early warning system going in place. We have learnt nothing in moving the state of knowledge to the decision making process since 1985 when the previous big tsunami occurred off the Peruvian coast and in 1979 the seismologists said the next big tsunami is going to occur off the Peruvian coast and the early warning system that went into the Pacific therefore went in after the event. So my point is very simple, the knowledge is now there, we understand enough, not to be able to predict what day it would occur or what year it would occur but where it would occur and with what force.

Now I am just going to come back to my theme about knowledge and how well we use it and I suspect many of you are feeling that economic modelling on a purely linear basis which doesn't include the possibility of catastrophes is hardly worth the computer time that is spent on it. We know enough to include feedback terms, non-linear terms, in the modelling and we really need to think hard about causality and impacts that lead into catastrophic events, that are building up over a period of time in the way I'm describing this tsunami.

Right, now it's not all going to be doom and gloom and I want to start by saying that through the 19th and 20th centuries we had a remarkable series of improvements in human wellbeing resulting from probably, we could go back to the Enlightenment, we could go back to the Reformation, we can go back to the Industrial Revolution, all of those things, this amazing transformation which I am going to measure in terms of life expectancy. Life expectancy at the beginning of the 20th century around 40-45 in most parts of the world and as you can see on this map here greater than 70 is the dark blue, in many parts of the world now, and life expectancy in many parts of the world simply increasing linearly with time. That is already quite a puzzle. In this country it's around 80 but increasing quite rapidly. I am going to attribute that to all of our infrastructure, to our cultural systems, to the revolutions that have occurred in science, agriculture, civil engineering, the cleaning up of water provision, medicine and so on, these coming through, and I am also going to suggest at the time of the British Empire enabling a lot of those developments in Europe to spread rapidly around the world and we see the benefits then still playing through.

So there's the upside of the 20th century, a massive transformation in wellbeing, and as we move into the 21st however we find that we are building up another sort of catastrophe resulting from this very good picture and that of course arises from the fact that there is a necessary follow through that if you increase lifespan and you do it particularly over a short period, like a hundred years, the follow through is going to be population explosion. So nation by nation you find that as wellbeing improves female fecundity, which in this country and many countries would be about 7 or 8, in South America 20 years ago would be that sort of figure, female fecundity determines population growth only by reaching a dynamic equilibrium with the mortality rate and typically during the Middle Ages in this country, out of the 7 or 8 per woman, only 2 would survive into maturity and 2 is what's needed for a stable population but if you have a sudden improvement in wellbeing all 7 or 8 survive into maturity and that's what's been happening and because they survive into maturity, excuse the scientific term, they form breeding pairs and so we get the explosion in population. It's not just people living longer but we've got many more people having children that causes the explosion.

What then happens in the population dynamics as female education and empowerment improves so female fecundity comes down and so we drop back down towards two and we hit a stable population which is roughly where Europe is today but that population explosion is occurring country by country at different times. South America, I just said, was 7 or 8, it's now...the whole continent of South America is down at 2.3 so rapidly approaching that equilibrium level. So population growth is the issue I want to raise and I want to look at the follow through from that for the 21st century.

We start the century at 1.5 billion. We end the century, after adding another billion every 12 years, we end at 6 billion and we are now at 6.8 billion. By 2028 we'll be at 8 billion and the best current population forecast, as indicated here, and we see that the median indicates

actually a decline towards the end of the century, this may well happen, and on that median you see by mid-century 9 billion. That's the challenge. The 9 billion people are also all of course aspiring to live to the sort of standard of living I see in this room so we not only have another 50% added to the population as we move forward in time but we also have increased demand for resources per head of population in the planet.

So my suggestion is that this contains the seeds of a whole series of necessary changes that if we use that knowledge base we could manage and if we don't it will lead to a series of potential catastrophes. I am going to suggest that we can focus on a few of these challenges so population the driver. I want to say at once that population containment is only a very small part of the solution because the dynamics of the population growth provided you have female education and empowerment follows through it contains itself. That's the driver and then we need to look around here and I just want to focus first of all on the fact that we can't approach these problems linearly as if they are not interrelated. Each one of them is strongly related to another. So we do have to treat this as a complex problem.

So if you take water resource, the state of Victoria in Australia, because of increased desertification in the state, they've had 7 successive years of drought, one of the bread baskets of Australia, the farmers are now packing their bags, and within 2 years one third of the fresh water provision to manage the human population in the state will be provided from desalination. So you immediately say well there's a technological solution. Desalination comes through, solves the problem. However desalination is an energy intensive process so we move round to energy security and supply and it feeds straight into that problem. Ah, but Australia has lots of coal and therefore they can burn coal to produce the desalinated water and I am taking you back across here to climate change which is the cause of the desertification and so we have a positive feedback. So we need to be very, very careful as we tackle these problems that we don't get into positive feedback loops because it's these positive feedback loops that lead to the kind of catastrophe that we should be trying to avoid.

If we look at food production we could say quite a lot about food production but the obvious thing is as human population increases and the demand for fresh water therefore increases but with an increasing human population we contaminate water. So given a stable fresh water supply around the planet, decreasing fresh water supply after contamination, crosses over with increasing demand from the increased population. Where's the crossover point? About 2040/2045, it's approaching mid century. But that's a global crossover point, right, locally people run out of water much sooner. So in other words the presence of water doesn't any longer match local population dynamics. We get high populations in areas where they won't be enough water so we go back to that desalination and technology solution route.

Food production – just increase the amount of land you put under food production and make sure you have a political system for transporting the food to areas where people need it but of course then we threaten the bio-diverse systems. Unless we manage use properly, and I am going to suggest that intensive agriculture is needed for the food production that we require, and if we do that we can set aside land to manage bio-diverse systems. Solutions can be there, whether they are socially acceptable of course is another question. So linkage between all of these and I am going to come back to conflict and terrorism.

As we move forward into a planet where there's limited resources available given the demands there is a potential for increased conflict. The more powerful you are the more likely you are to secure resources wherever they may be for the purposes of your own

population. We for many years have been mining in Africa for the mineral resources that we need and now we're seeing these remarks about the Chinese appearing in Africa. China doesn't have platinum, China doesn't have copper, and of course they want to get in there as a population that needs the mineral products. Potential for conflict I think enormous.

And then you come back to land and climate change. Rising sea levels means less land available and rising sea levels will flood the cities that are based on the coastlines and of course that's a lot of the major cities around the planet. Bangladesh very much at risk from flooding, I can't believe that this wouldn't cause anything but a massive flow of people seeking higher ground, more fertile ground as we move forward in time.

All of these problems imply that either we leave it to power struggles or we manage the problem as we move forward. That is a very big transition and that's really what the message I want to get across, a big transition required.

I am going to just focus on two of these problems and David you will be pleased I will be talking about climate change for most of the time. Of all of these problems climate change is the biggest problem and the reason I'm saying that is because that problem requires global agreement. We might manage other problems locally but because the atmosphere is a shared resource we need global agreement with all major parties on board. So we need a common solution that is accepted by all major nations and that's why I think that is the biggest, the granddaddy of all the challenges we have around here.

Just very quickly I haven't mentioned health and education. As the planet's resources are stretched with growing population within a globalised economic system we know that disease now travels very fast and I give you the example of avian flu which first appeared in birds in 1995. The big fear, of course, is that H5N1 is a virus that no human being has previously been exposed to. We know what happened to the Hawaiian population when Christian missionaries arrived there bringing a flu virus that none of the Hawaiian's had been exposed to so we are all at risk from H5N1 if it transforms itself from an avian flu virus to a human flu virus, that's the worry. It's taken from 1995 to the present day and still avian flu hasn't reached the Americas so the slowness of that process is to do with bird migration patterns.

Human migration patterns are totally different. We move around in aeroplanes and while I was in government we modelled what would happen if a virus appeared somewhere on the planet, how long would it take before it arrived in the British Isles? Well it turns out the model demonstrated would take 3 months to be in every country and much of that movement would have happened during the so called silence spread period of an epidemic, the period that epidemiologists hate because during that period people haven't yet become apparently ill and are therefore freely travelling about and the disease after this incubation period becomes infectious. Right, so hundreds of people would be put at risk with a disease like that being transported so efficiently by our global means of travel. All of this requires a new focus, a new attempt, to manage the problems. I believe we've got potential solutions and if we haven't got the potential solutions we know how to invest brains and money into funding.

Right, I am going to go over to food and I just point to the big hike in food prices that occurred earlier this year. There was a sudden rise around March to May this year and interesting to evaluate the causes. I believe there are two major causes. The first is an issue of unintended consequence, at least I am going to be generous and suggest it was unintended, of the American policy of subsidising grain farmers by subsidising the bio-fuel generation from

food grain and of course what that meant was that surplus food supplies that had previously been used as food aid to other parts of the world suddenly diminished very substantially. So using food as a resource for fuel, it's the energy security in the United States, been tackled from a food security global problem is at the root of the big part of that hike.

Another part of that hike, a significant part, is crop failures. Now of course we've had a couple of series of amazing green revolutions in India, in China, in south-east Asia, where there has been a seven fold increase in crop productivity, food productivity per hectare, as a result of applying agricultural technology in a totally sensible way which has meant that those burgeoning populations have managed to feed their people but there is one particular form of crisis which is that every year rice crops, for example, are lost through flooding. Now a rice plant that is marketable can sustain itself under totally flooded conditions for about 3 days, maybe 4 days, and after that the plant dies. Now we all know that rice needs a lot of water so you are always planting in a region which is susceptible to flood risk and so in this year there was a large loss due to flooding.

Now back in 1992 looking for flood resistant rice was recognised to be a problem and seeking a solution and the International Rice Research Unit in the Philippines gathering bits of information found that there was a variety of wild rice in India that can live right through flooding. In fact it survives 3 or 4 weeks of total flooding. Now this is wild rice and it's not a commercial product that is formed, it doesn't even taste very nice, but the key thing was using genetic markers, moving in, finding out which were the genes responsible in the wild rice for creating the flood resistance. The gene is called FR, flood resistant, 13A. Why 13A I don't know. So having established this, using genetic markers, they could then have snipped the gene from the wild rice into commercial varieties and generated flood resistant rice. Something that could have been brought to the market in a couple of years, this is in 1992, but there is a sensitive opposition to GM that was generated in Europe and so the researchers and the farming communities have been rather resistant to going down the route of using a GM product.

So the alternative has been followed by the International Rice Research Institute which is to go into the business of normal plant breeding but they are using genetic markers so they just pick out the products which carry the right genes but normal genetic breeding you have to follow growth cycles, you have to get into the paddy's up to your knees in mud and up to your arms in mud, you are no longer in the laboratory snipping genes, you are doing something that is painfully slow and in 2010 we now expect the flood resistant rice, commercial rice, will hit the market. That's an 18 year period against 2 years if we could have used the alternative.

So we have the knowledge, we establish ourselves then as a, in western Europe let me say, as a society very comfortable with our level of food available and then we create scares about products such as GM products. Somebody will have to explain to me why you shouldn't genetically snip from a wild rice to a commercial rice product to shorten that process. There is no known and certainly there is no example of a human being suffering from consuming the products of that process. So the solution could have been there.

As we move forward in time however what we need is more food per drop of water. So considerably more research needs to be done all through this particular graph. Now of course those of us who are meat eaters need to just think about this a bit. There's certainly more water required for non...those of us who are meat eaters, but for the developing world this is

an issue because people are eating more meat as they become better off. So we are creating a problem by sliding down this curve into the food provision that we are getting used to.

If you look at the question of water scarcity and where it's happening already, so I am suggesting that by mid-century we will have a global problem but already we are experiencing areas where there is an absolute water scarcity and areas where there is already a water scarcity which is moving towards absolute water scarcity. Water scarcity being defined by population growth creates water scarcity, climate change also creates water scarcity in some areas. So you've got two factors driving the future.

Let me just come to...here's my persuasive photograph about the rice, that it has been developed, so this is a paddy field that has been planted right across on the left hand side with the normal commercial rice, it's been under water for 7 days, and you'll see that the new rice on the right hand side is happily growing. It's a solved technical problem but it could have been in the market place considerably sooner. Now of course drought resistant crops have also been developed but they've been developed by GM techniques. We still haven't got to the point of developing good drought resistant crops, having learnt how to do it by GM, using the painstakingly slow plant breeding process.

I am going to move on to this big problem and let me say at once that I think the nature of the climate change problem is now well understood and I therefore just want to say that we need to take on board the nature of the challenge under the heading of climate change that is now recognised at G8 level. So when I was in government I was struggling to get some foothold on this problem and when we were in the presidency, the UK, of the G8 in 2005, we managed to get the Prime Minister to put climate change on the agenda and it was just climate change and African development, two closely related problems, and now this year successive governments have maintained climate change on the agenda of the G8 meetings and this year in Japan, for the first time, we got an agreement which said we now have a target and the G8 leaders said we are going to reduce our emissions of carbon dioxide globally by 50% by 2050.

Our media by the way picked it up as some kind of further failure to agree. They pointed out that the starting point of the 50% reduction wasn't stated, was it 2000, was it 2009, they pointed out there was no staging between now and 2050, but I believe that's carping because managing to get through the heads of states and agreement saying halve our emissions by mid-century was a tremendous step forward and then think through the challenge of decarbonising our economies. For the developed world a halving of emissions globally is a considerably greater amount of reduction which means, for example for this country, a reduction by around 80%. Now at this moment we emit 11 tonnes of carbon dioxide per person per annum and in India that number is about 2 tonnes per person per annum. 20% of 11 is 2.2 tonnes per person per annum. So by mid-century we need to be where India is today in terms of carbon dioxide emissions per person, that's the nature of the challenge, and the officials of those heads of states of the G8 countries have taken that away and they are beavering behind the scenes to see how to produce a global resolution that actually moves us in that direction. That is going to be the biggest transformation that our economy has seen since we had a global economy, to decarbonise our economy. Our energy, of course, is produced very largely from fossil fuels and let me just underline this by showing you, and I am going to give you some science data which I happen to be very excited about.

When I, this is my excuse for showing you this, when I started talking about climate change in government 8 years ago I was able to show people data from paleoclimatology going back 250,000 years and the data was obtained from icicles taken in the Antarctic. Imagine taking an ice core, at the bottom of the ice core you're looking at ice compacted from a snowfall that fell 250,000 years ago and at the top of the icicle you've got last year's snowfall and collected in the ice core is bubbles of air and you therefore have a sampling of what the atmosphere was like 250,000 years ago at the bottom of your ice core and from the water isotope ratio in the ice you also have the temperature so we know global temperatures and global atmospheric composition is going back a long way.

Now I am showing you data that goes back much further than that. You can take the longest ice core that has been analysed, it's 3km long from the Antarctic, and it goes back 852,000 years with a remarkable resolution, you can pick up year on year, but the ocean sedimentologists began to think well we can do the same so they took cores from the ocean sediment and sure enough the comparison in the 850,000 year cycle is remarkably good. So what I'm showing you here is the last 60 million year record of our climate in terms of the temperature on this axis here. The 850,000 years you get remarkably good agreement between icicles and sediment but you can't use icicles going further back, this is all from ocean sediment base and you see that the planet temperature went through a maximum of about 55 million years ago, the Eocene transition point, and at this point up here no ice left on the planet. The Antarctic was a sub-tropical forest with very large mammals. If you go beyond your last bit of the ice core you find the remnants of all these species there and the temperature is about 10 degrees higher than they were in the pre-industrial period, the recent pre-industrial period.

[SPEAKER MOVES AWAY FROM MICROPHONE]

So we move forward in time. Carbon dioxide levels up but that point we have to estimate, ice cores are needed to know what the atmosphere was like, so we have to estimate and it was probably a couple of thousand parts per million. I am going to give you some numbers and you can compare them. Carbon dioxide levels fall, the temperature falls and we come down to a temperature where we, human beings feel and other large mammals feel relatively comfortable with, about 2 million years ago. This is the point at which $\sim 37.43^\circ\text{C}$ begin to appear. So this is quite an interesting period. This by the way isn't noise. We have a biphasic system, it's unstable, the climate system goes unstable. Biphasic meaning it's either low temperature or high temperature. We call, in common parlance, we call them the ice ages and the warm periods.

So they begin about 2 million years ago and then if I just expand, this is the present day and this little spike at the top here is our current warm period. Now we come back here. Again in blue I've got the temperature but now I've got from icicles the carbon dioxide levels. So we come through a series of ice ages, warm period, ice ages, warm period, and each warm period carbon dioxide levels are 270 parts per million and each ice age carbon dioxide levels are about 200 parts per million. There is a coupling which Fourier understood, the great mathematician in 1827, and we can go into that in the discussion. There's a coupling, it's not a direct linear relationship, a coupling between the two.

We come to the end of the last ice age, 18,000 years ago, we rise out of that, 12,000 years ago, present warm period remarkably stable temperature. That's been good for us. Not only remarkably stable temperature, if you come out of an ice age into a warm period then sea levels have got to go up because ice that's on land is melting and going into the ocean and

pushing up sea levels so the sea level goes up about a hundred metres. So the map of the world changes and then we have a very stable map of the world over this period, so stable we've been building our major cities around the coastline. Of course it's not a case <?? – 39.48> this is the period of our civilisation.

Why is this warm period longer than the others? That is point of some live discussion at the moment. If you look at the carbon dioxide signature you'll see its creeping up whereas it should have started coming down. So there is a discussion about whether this is the first anthropocene, the climate period produced by our behaviour, where during the development of our civilisation we start developing agriculture and taking trees out, taking forests out, removing forests means removing material that removes carbon dioxide from the atmosphere. So maintaining the stability of the atmosphere in terms of carbon dioxide is a dynamic interplay between green matter and us and we've been upsetting that by developing <?? – 40.45>. This of course isn't the mistake.

Then of course we come to that wonderful period I described, the beginning of the Industrial Revolution, and we start providing energy for our requirements by going underground and finding naturally sequestered carbon that is in the form of coal, gas and oil and burning it to provide all of our requirements and the net result of that is that we are now at 387 parts per million and rising at 2 parts per million per annum and then if you ask the question well, how far do I have to go back in time before I get to that sort of level of carbon dioxide and I can only give a rough answer but it is represented by that red line. You could say well the temperature rise so far is only .7 of a degree centigrade but it should have been higher. Well, the reason is we have a lot of inertia in the earth's climate system mainly because of the oceans, the oceans take a long time to catch up, and so because of that inertia we've got another 30 years of climate change ahead of us whatever we do even if we stop at 387 parts per million, which we're not going to do.

Right, so there's the nature of the problem, just one more point. What would happen if we burnt all of our fossil fuels, in particular all of the coal? Can we get the temperature back up there? My research is basically theoretical and experimental but this is one experiment I'm going to suggest we don't try because I believe we could. I think there is enough coal there to produce a carbon dioxide level of about 1500 parts per million if we burnt all of the coal and we are 387 now so we could manage it in a 150 years or so. The future would be a pretty bleak one for a population of 9 billion because the managing, the remaining liveable part of the planet would not actually be an easy exercise so it's quite obvious this is a problem that we have to manage and we have to avoid as we move forward in time.

What is the likely rise in temperature as we move forward under different global agreements? So here the question is coming at me from a prime minister, so, David what is the level of carbon dioxide we have to stay below to avoid a 2 degree temperature rise? Well, I'm afraid the answer has to be given in terms of probability distribution functions. I can only answer in terms of a probability distribution function. This represents the best state of current science today from around the world and it says that in blue that is the PDF for an ultimate carbon dioxide level of 450 parts per million and this is carbon dioxide equivalent, I am including other greenhouse gases now, that peaks at 2.2 degrees, it's an asymmetric curve and that's the most worrying feature. So it says yes, I've got a low probability of only a one a half degree temperature rise, we've already got a .7 degree so double what we've got already, very low probability of that happening, but I've got also a low probability of 4 degrees rise and here's the problem. I said we keep using linear curves, there is a lot of non-linear feedbacks left out

of these calculations, so what is not included here is sudden evolution of methane hydrates from regions of the planet such as around the Arctic Circle. As that melts we may get sudden emission of methane hydrates. Methane is a very strong greenhouse gas. It doesn't include tropical forests dying off. Scientists are very conservative, they can't model these things well so they are just not included in the model. None of us trust the figures above about 3½ degrees on these curves because we think that's teasing these big non-linear feedbacks that might give runaway climate change a chance.

Right, so what is the probability of exceeding 3½ degrees? It's about 20% even on the best possible curve in terms of good behaviour by the international community, in other words if we stay below 450 parts per million. It will take a hundred years for the temperature to rise to these levels but nevertheless, and I said to the Prime Minister, if you get in a plane tonight to Camp David and you ask the pilot what are the chances of landing this plane safely and he says 80% I suggest you get off the plane and yet that is the best way forward for the planet at the moment, an 80% chance of avoiding, teasing above 3½ degrees centigrade and obviously the more greenhouse gases you put in the atmosphere these probability distribution functions shift to the right and to be avoided. So we need a global agreement that keeps us down at that sort of level and of course the question is going to be whether we can deliver that and of course that is the big challenge.

I am going to suggest that as we move towards Copenhagen in, towards the end of next year, 2009, that's not a long way away, we will barely have got a new president into the White House, not an irrelevant factor. This is what is needed out of Copenhagen, the successor to Kyoto. Kyoto has produced virtually nothing except, and it is one great success, the European Emissions Trading Scheme and I will take you through that. What we need now is a totally fresh view, better sciences available, better understanding of what we need to do. These are my de minimus requirements for a decent global agreement. One, that we agree where we're going. Let's stay below X parts per million of greenhouse gases as we move forward in time. I would like X to be even lower than 450 but I am also a realist. Agreed national targets – if that's our global target then we have to have national targets so that when you add up all the figures from every nation it comes to the global target and these targets are trajectories into the future so that by let's say mid-century we're all emitting about 2 tonnes per person per annum, then we're managing the problem.

Once we've agreed national targets we move on to how do we manage that agreement and I'm totally in favour of a trading scheme because once you have a trading scheme in place it's very difficult to stop it so creating a carbon dioxide market, and today the market in Europe is worth about £55 billion, if it goes global – let me rephrase that I am an optimist – when it goes global I believe we will see a trading in the region of a trillion dollars. So a very large investment is already taking place in Europe to sustain the trading process and as we move forward in time and it goes global we will simply have this commodity. I even think the currencies will be valued against carbon dioxide as the major tradable commodity.

We need to move on from carbon trading though to dealing with the demands of those parts of the planet where lifespan is not high. On that map I showed you at the beginning Africa has missed out on all of the developments of the 20th century, the lifespan there is still 40-45, and Africa will not manage to adapt against the impacts of climate change that will happen. This country has an adaptation plan. I'm proud of it because I put it in place, which is costing us about £300-400 million a year and that will be ramped up as we move forward in time, but countries in Africa couldn't possibly afford anything like that so we need an adaptation

strategy for developing countries and technology transfer means, low carbon energy futures being transferred to those countries. We need to create a financial flow to back that up and I believe that this isn't a requirement, I simply believe the way to do it is to auction the permits for the carbon dioxide trading, generate a large sum of funds from the auction and use that in terms of the last requirement. This is in Kyoto terms called the clean development mechanism in part but the adaptation strategy has not yet been discussed and put in place.

What do we need in terms of managing this problem, decarbonise our system? Well this map is just to show you that we have been a bit blinkered in our approach towards energy production. Why? Quite simply because we didn't need to develop alternatives to carbon as an energy source. Coal was cheaply available and we were not inspired to generate alternative large scale energy sources. So what I'm showing is if you ask the question how much sunlight arriving on the surface of the planet would we need to convert into usable energy to provide all of our energies sources out to the middle of the century for 9 billion people, the answer is the amount of sunlight landing on these six small squares. So we have about ten thousand times as much sunlight, solar energy, reaching the planet that we would need if we just converted it efficiently into electricity and transport energy and so on.

We've done very little on this so we need to refocus our attention. Technology innovation, private sector innovations need to refocus on this. I can see massive changes here. It's not only that, I believe it's very short sighted to have solar panels which are made of silicone. This is a kind of scientific laziness. Semiconductors have been very successful in chips and microchips and most of these are silicone based. Semiconductor physics is all built around silicone so now you're asking the same people to develop photovoltaics and they come up with silicone, no surprise. I want to see photovoltaics that are made of ceramics, plastics and paint so that architects can use these on the outside of every building and every building just generates whatever energy it can from sunlight. You then need of course a means of storing the energy. These are solvable problems if we just focus on them.

But there's another, what about large scale energy conversion? I can see using the desertified areas, for example, of Africa, as sources of electricity which just can be piped across into Africa. Spain is becoming desertified as we move forward and Spain using that as an economic resource to invest in solar energy, large scale solar energy, the Spanish government is already moving in that direction. I think these, in other words, are problems that are there because we haven't had to solve them before but as soon as it becomes a necessity I believe solutions will emerge. This is just to indicate where solar possibilities are greatest. These are the areas where solar energy conversion is really ripe for production and I'm afraid as we move up with global warming through the century the red part of this curve moves up towards the Arctic.

I am going to shorten this a bit. I want to say that it in order to meet this challenge but also to meet the current financial crisis we need new thinking. In fact going back to my curve we need to be thinking very hard about how we manage globally to reach solutions. I mean the first thing is by national perceptions versus global priorities. If we move forward in time and still continue to have dysfunctional global bodies, and I'm suggesting the United Nations is no longer in its present form fit for purpose, it's not ready to meet the challenges I'm talking about, unless we rethink these global bodies to meet these challenges we're going to struggle to go forward because national priorities will dominate, national perceptions of what is required. By the way that food crisis I referred to, I was really talking about the initial causes of those prices going up but actually what pushed them up was the secondary effect of

governments stepping in and stopping food crossing their borders. In other words trading will stop because there was a perception that they would be able to feed their own people better from the food that they were themselves growing and that actually caused the crisis to magnify enormously.

So global priorities need to be worked through and worked through in this multidimensional way with intelligent knowledge based communities. Now at the end of the Second World War we did have an American president who saw the need to move on from the old League of Nations to a much stronger global body, the United Nations, and I think we are back into that position now where we need leadership at the very top and today I think it would be asking a bit too much of an American president alone to carry this vision forward. It does require, perhaps Hu Jintao, perhaps Manmohan Singh, to stand with the American president and with the European Union president and push for a stronger globalised system where we can begin to move forward and meet these challenges.

I am going to suggest also there are other challenges. Economism – the idea that consumerism can drive all of our market, through market processes all of our needs, is clearly surely now, at least, something that we all understand has faults to it, a consumerism driven by creating funds out of the value of your house by remortgaging and then off you go on another consumer spin and it turns out the money wasn't there so we have a large amount, trillions of dollars of bad money generated in the system through this consumer driven boom. As we emerge from this, and I'm not suggesting it's going to be easy, I hope we will see it as an opportunity to move forward into a system which manages all of this complexity in our global system and that we move away from a simple market approach. We need market approaches, consumerism is a good idea, but we need all sorts of regulatory systems in place.

Nostalgic romanticism is my reference to the notion that the solutions were in the past. I am not a tree hugger, you might have noticed. I believe that the solutions lie with science, engineering technology, good economics, good behavioural sciences, the solutions are there in the advanced knowledge base.

Then finally, and this is a challenge to scientific people, re-gearing science and technology to meet the global challenge but also economists. I am going to suggest that we know a little bit more about landing a craft on Mars or the functions of a Higgs Boson, which is certainly topical, than we do about managing malaria, managing HIV AIDS, managing alternative technologies for a low carbon technologies and by the way also managing global economies. So we have put a lot of brain power into the first two of those things I mentioned. We need to re-gear the brain power into the real challenges around the 21st century. We need brilliant people to come forward with very clever solutions at this point in time.

I am going to stop because I think I've got to leave a little time for discussion but I just want to say in terms of the market, the free market system, I was recently in South Africa giving a lecture and as I stood up it was 5 o'clock in the afternoon, summers day, I looked outside, I was in Pretoria, I could see across to Johannesburg and I could see on the skyline those amazing skyscrapers in this city in Africa and as a matter of fact all I could actually see were the tips of the skyscrapers, there was this great pool of pollution below the tops of the skyscrapers. I had two ministers in front of me and I have to say I took a bit of pleasure in then starting my lecture by saying that until I stood up I didn't realise that South Africa had not introduced car exhaust regulations and afterwards this red faced minister asked how I

knew that? I said as you travel into any city in the world you instantly know whether you have car exhaust regulations in that city.

There has been a massive clean up through car exhaust regulations being introduced back in the 1970s, initially in California, in Europe we picked it up quite quickly. This is a progressive regulation, progressive in the sense that each time it is announced, in 3 years time no new car can be purchased in Europe it is now unless it meets the following regulatory requirements: nox gases, carbon monoxide, particulate matter from diesel engines and so on to the point now for next years requirement in Europe, if we had let's say a BMW diesel engine car in this room with the car exhaust catalyst on the end of it, it would actually clean up the air in the room. That's what we've managed through a remarkable piece of technology in the back end of cars driven, not by individuals saying I want to clean up through my car, but driven by governments realising this is a problem that can only be managed by regulatory systems.

I am labouring this point because I think that for years now the Chicago School of Economists have been pushing against any form of regulation, that good behaviour will emerge. Good behaviour can't emerge to manage this problem and we've seen how all of these problems signified here have actually been managed. So at the very top we have hydrocarbons, HFCs, that started chewing up the ozone hole, we all know about the ozone hole, and global agreement, Montreal, the ozone hole is going to take a little while to repair itself but the good news is that by mid century that ozone hole will be fully back in place. So we know the problem, the science taxied, we introduced regulatory systems and we can manage it.

On the car exhaust catalyst systems I want to tell you that every time a new announcement emerges from Europe every car manufacturer complains. They say impossible, we can't possibly meet that. They have never failed to meet it, all of them, knowing that their competitors are likely to so they need to as well. It's a driver for innovation. So I think the notion that we can manage this is there and I just want to say, because I am not an economist but I do nevertheless do follow a bit of economic development, that if we are going to move forward sustainably and there's the Brundtland definition up there, we need to use economic tools that allow us to measure how well we are moving forward in time. I just use here Dasgupta's analysis, there maybe better ones about, and Dasgupta says let's take the wealth of a nation as a measure of how well we're doing. Is the wealth of our nation improving or not improving? This is very different from GDP. The wealth of the nation is manufactured capital, human capital, natural and environmental capital, and of course institutions, culture, etc.

If we take a country like Nigeria, which produces oil, the oil under the ground, not mined, with a global value gives me a high wealth for my nation but as soon as I take it out of the ground and sell it I've got a potential for diminishing wealth unless I reinvest in these two. So it's a very good measure for a developing country that's got oil to make sure that they manage their wealth as an upward movement but of course what I've been talking about is the importance of the atmosphere and its contribution to our potential wealth creation capability as we move through this century because as sea levels rise, as temperatures rise, we are going to see all of those challenges around population, as the driver that I began with, mounting up with the impacts of climate change.

I am just going to, if I may, end with a few words about what I'm trying to do now in Oxford. Why start up a new school in an ancient university? Well of course the first idea is that the ancient university is quite a useful branding. The second is that the school is designed to bring together academics, the private sector, and governments to seek solutions around these problems, to create a hub, a global hub, where we can gather people together from each of these sectors to find solutions to these problems and these are going to be multidisciplinary teams so we are going to have economists, social scientists, behavioural scientists, and physicists, engineers and so on. As a matter of fact we now have 60 associates appointed from around Oxford University. We have 25 people in the school, which started on 1st January, and we are already then beginning this process of solution seeking. It's not the usual sort of process for a university department. This is taking the knowledge base into the market place, into governments, for better regulation and for innovations that will take us forward to meet these challenges. I am setting up a futures laboratory and this futures laboratory will set up a series of programmes in which we can corral the knowledge base to begin to take these solutions forward. I'll leave you with that. Thank you very much.

[Applause]

Chair

I said at the beginning you are unlikely to hear a lecture more authoritative, compelling and clear on these issues and I think that's certainly what you delivered, David. Of course it's a very clear narrative, I think it's impressively integrated. The diagram that shows the interconnections of problems with each other is very compelling and it leaves a very clear impression and picture about what we need to do, how we need to do it, although there are lots of uncertainties and listening to the words you emphasised at the end, re-regulation or changing regulation, reframing markets, redistribution, re-gearing, I thought to myself this is the right lecture for an institution founded by the Fabians. In a sense what you're saying is that knowledge empowers, that knowledge creates the capacity for producing the right solutions but we don't yet have a cultural framework and a political will or leadership that can deliver what the knowledge potentially promises in forms of public goods, social goods and so on. A powerful narrative around which no doubt there are questions.

Question

I'd like to ask a question about carbon trading. You said that in relation to carbon trading at Copenhagen you saw carbon trading as a global essential, I think, in view of the current turmoil in the money markets how can we ensure that carbon trading systems do not suffer from similar flaws?

Question

I wondered what you thought the role would be of the various technical fixtures that had been proposed for reducing the actual temperature change because it seems to me that the Americans in particular will find it much easier to agree to invest in technical fixes that would support business as usual rather than to have to change their wicked ways?

Question

[Name, Oxford University] What do you think about this new cohesion policy or <?? – 1.09.50> strategy in Europe? How will it integrate on this issue here? What should be done?

Question

[Katrin from New Scientist] I was wondering we take our natural resources and eco systems services for granted and I am wondering how long do you think it will be before we ascribe economic value to them which corresponds to the services that they actually provide for our society and just as another half question, if I may, about the G8 agreement of this year. I'm afraid I was one of those in the media who criticised it perhaps and I was just wondering on the timing, how was it that that agreement came about without there being a base year set which did strike us as slightly surprising?

Question

[Leslie Dighton, Chairman's Club and governor of the School] Could you tell me just a little bit about the global machinery that you see either in the process of being built or necessary in the future for overcoming national competitive conflict?

Question

What is the role in the feasibility of carbon capture and storage technology for the mitigation of climate change and its effect in your opinion?

Chair

Yeah, and how far are we from having an effective system, so important for developing countries?

David King

That's a nice range of questions. I start with carbon trading. The question was can we anticipate managing to continue with carbon trading given the turmoil in the current market place and I think it is at risk. I think, however, that we have a whole series of risks in the shorter term. I think one of the risks, for example, is that as governments respond by printing money that we might run into hyper inflation so I can see a liquidity crisis becoming an inflationary crisis on a global scale. So my response to this is that we need to set out a global plan to create the liquidity required, to remove this distrust in money, which is the big problem at the moment, who's going to keep my money, and at the same time this is an opportunity to create a plan in which we include a value for eco systems in which we include carbon dioxide trading on a global scale. I actually think there is an opportunity here to generate a solution provided the G8 leaders remember the problem that they've put at the head of their table for the last 4 years while they are dealing with this crisis. I say that because there is a tendency, always, to marginalise problems as long as the next problem comes into view and carbon capture and trading is not something that can be marginalised, we can't possibly do it, so I've been saying for some time we need to manage economic growth, we need to contain inflation as we do that, and we need to reduce our dependence on carbon. All of these things have to be managed together and we can't separate one from the other.

Technical fixes – a very important question and an interesting one. I think, you know, the Americans are looking for technical fixes. What is being referred to here is the talk about, let me give it an extreme example, we put a whole bunch of mirrors up in space and we reflect sunlight back into space and say we cool the planet down. The unintended consequences from any one of these potential geo-engineering exercises are enormous and I rather turn this around and say we need a global agreement that we can stop people attempting geo-engineering fixes. One of them is to toss a lot of iron into the oceans to create algae, the algae uses up the carbon dioxide, it's then supposed to sink harmlessly to the bottom of the ocean.

We have no idea on a large scale what this would do to the ocean bio-system and we know that the ocean bio-system is part of the initial feedstock on which we all depend, the beginning of the food chain.

But Americans looking for that...let me just say, because I need this opportunity to say it, when I went into the White House in 2001, trying to persuade them for the first time that Kyoto wasn't dead and they needed to take action, I was told that the damage to the American economy was worth...it would create more trouble than letting this problem rip if it was a real problem. Now instead when America felt, and I believe this sincerely, that they had passed the peak oil production for the United States, they felt there was a real risk of securing supplies of oil to their nation, the first response, before getting farmers to make bio-fuel, the first response was to look around the world, find an area of significant oil reserves and move into it. Saddam Hussein had created the pretext. They were already talking about it before 9/11 and then 9/11 triggered the response.

The cost, this is a single nation trying to, in my view, secure supplies, the cost according to Stiglitz \$3 trillion, let suppose he's wrong and it's only a trillion dollars, I don't think that has solved any problems for America in terms of security of oil supply. It's created massive problems and probably a big dent to their own economic development whereas if that trillion dollars had been expended on alternatives to fossil fuels they would have created the energy security they needed. So it's a question of moving your thinking away from just saying my god, we're running out of oil therefore we need more oil.

European policy – I'll try and be briefer. European policy and how to integrate. I'm not sure that I quite picked up the point here but we're 27 nations in Europe, yes, and even when we were 15, having 15 different voices around the table with more than 15 simultaneous translators working away behind, was massively challenging, as I'm sure you know, on every issue. What is quite remarkable, in my view, is that Baroso has shown the strength to act on this climate change issue for example. So in the first round of emissions trading in Europe it was a failure and the reason it was a failure was because each nation started playing games and they offered a cap for next year's carbon dioxide emission which wasn't a cap at all, it was really business as usual, and the result is that the markets devalued carbon dioxide and the price going up to 20 Euros flattened at about 2 Euros a tonne. Baroso in the second round then took the initial offers from each country and reduced them by a very significant percentage and that was the first major move towards and ETS that was actually working. So it turns out that a bit of strength is required from within the Commission itself to carry these policies through and then it can be done.

I've mentioned economic value of eco systems and I think this is such an important point. In a way, of course, I'm saying carbon dioxide needs a negative value. So I am putting a value on not admitting carbon dioxide but the more complex problem, for example, is avoid deforestation. About one fifth of the problem is from annual rates of deforestation. So how do we move on avoiding deforestation? One way is to say that we need to put a value on the bio-diverse systems in those forests. As we move out of this super consumerism that has driven us into this crisis I think we need to start valuing good behaviour in this way in terms of how we treat that planetary system in moving forward but you are putting forward a very big challenge because we might all agree on carbon dioxide pricing but it's going to be a great deal more difficult to agree on a general eco system pricing. Lets follow that up. I mean there's a lot of work to be done in that area.

The other thing was your point about the G8 and the base year. 50% decrease on the level of emissions 1990 or 2009 is a massive drop when you compare it with business as usual rising to mid century. So business as usual rising to mid century makes that more like a 75% global decrease. So what I'm saying is, this is the first major signal we've had from all the G8 heads of states that we really must decarbonise our economies. Yeah, we can quibble about what that means in actual percentage terms but as a clear statement for action I honestly couldn't have expected more after the battles, the red line battles in Gleneagles, the United States presidency had officials who put red lines through every single statement of this kind, so finally we did manage to get it through in Japan. I suppose it's the scars on my back that makes it feel like a real victory.

Global machine, this is a such big question, but I just want to say I think it's got something to do with the G8 plus 5 that the G8 grouping is only part of the important equation at the moment but certainly when we were leading up to Gleneagles I was one of those voices in government arguing it's no good just having the G8 countries there, we need China, we need Brazil, we need India there, and we need Mexico and South Africa, we need to have Africa represented. If you imagine an agreement on climate change involving the G8 plus 5 grouping, it's G8 plus 5 plus 1 because Barroso is also there, and they reach agreement so that Japan, Europe, China, India, Brazil have all reached agreement on what to do about climate change and then take it to the United Nations framework convention on climate change with a 190 countries represented I believe you've got a solution that would be just carried through by a vast majority vote. So in other words I think it's something to do with focussing down on to the ability of the larger emerging powers working with the developed nations in a smaller grouping. Now that's not the whole solution, you've then got to have the second round, not the G90, you know, but the second round of countries, but I think we then need to move from this bigger hub to creating smaller hubs that feed into that.

Carbon capture and storage – carbon capture and storage is something that we actually need to invest in. One of my biggest disappointments from a British government point of view was that I thought we had agreed to have a demonstration project on carbon capture and storage. Let me say it once, carbon capture and storage comes in two parts: capture - imagine a coal fired power station, separate out the carbon dioxide coming out of the top of it, that's the capture part, then bury it, safely bury it. The capture part is a done piece of technology, that's the easy bit. The storage part and the transfer, if your power station is a long way from where you're going to store it, you've got a lot of transfer problems, transport, but the storage is a very real problem if we go beyond oil wells that are depleted in oil. Now the very nature of oil is that it's contained geologically. Imagine a large slab of granite containing oil and gas, it's safely capped by this large cap of granite, and so it lasts for millions of years, that's why when we drill through the cap we get a spout of oil out and we get gas out. All you've got to do is push the carbon dioxide back in and seal it and you know it's going to be good but we haven't got enough space in the depleted oil wells to manage the problem so we need to prove that we can do it in a saline aquifer. In other words a rocky deposit of sea water underground where we simply displace the sea water with the carbon dioxide, that is an experiment that still has to be done. It's a half billion pound experiment. I signed an agreement when I was in government with the Chinese government that we would transfer the technology as we developed it but we are not developing. By the way an awful lot of coal left, awful temptation to continue using it, it's so important that we demonstrate whether or not we can do carbon capture and storage.

Question

[Howard Roberts, Trek UK] I believe that concentrated solar power coupled with long distance HVDC transmission represents something of a silver bullet in the fight against climate change, do you agree? I think it's cheaper than CCS as well, it will be.

Question

I am from India and I am here at the <?? – 1.25.42> leadership programme. As you already have presented an answer to part of the question already, which I'm going to ask you, China and India are critical actors in this whole global negotiation on climate change. As we move towards Copenhagen do you really find that a concrete international regime will emerge that will be sustainable or are you going to find a realignment of forces on climate change? After all it's going to become geopolitical rather than the science of it. I'd like your comments on that.

David King

Is solar power a silver bullet? I don't actually think there is a silver bullet as such. I believe as I indicated that we need considerably more research into solar power, energy generation, of all kinds whether it's direct solar heating of your water system, which is easy, focussing with large scale mirrors, which is no new technology, or as I suggested solar photovoltaics spreading into cheap easily available architecturally acceptable materials, but we don't have enough capability at the moment and so for example I was certainly pushing in all my time in government for nuclear new build in this country not because it's a silver bullet but because I think we need one more generation of nuclear power stations to see us through the period until these new technologies emerge.

Nuclear, if I can just sell it to you very simply. If you travel on Eurostar, as I occasionally do, it's my favourite form of travel, it's comfortable, it's fast, it gets you there quickly and it gets you to the centre of the city you're going to and at the same time if you're in France you're not emitting carbon dioxide because the electricity on the railway line is coming from nuclear power stations. So we can generate a comfortable lifestyle if we exploit the capability from nuclear. We can have a long nuclear discussion but that wasn't the point of your question.

I just want to say we need every tool in the bag, we need to examine every possible resource, because this is a massive challenge and it's going to require money. I did set up that Energy Technologies Institute and the Energy Technologies Institute is a £1 billion investment in the UK, half the money coming from the private sector so that it's market facing. £1 billion might sound like a lot of money, the energy industry is a multi-trillion dollar industry and they invest very little in research. I saw that as simply pump priming for the research that needs to be done. We need to be spending billions on research into all of these potential solutions and we can do it.

Concrete regime emerging or a realignment – what is interesting is not only what I said about the G8 countries but it's what's happening in China and in India. So public opinion in India has transformed itself. There is a real understanding, perhaps even a better understanding in India, if you read the media, than there is Britain today of the challenges of climate change. When I first went out to India 6 years ago, during the time of the BNJP, there was no audience whatsoever so there's a real transformation and it's just happened in the last year or so and I see Manmohan Singh making a very clear statement, Deepak [Syble] making a very clear statement, India is moving in towards a leadership position on this whole issue. Why? Because India's coastline is massively under threat as you move forward in time through this century from increased flooding and that understanding has come through.

In China, equally, the biggest economic miracle in China is in Shanghai and around Shanghai. I managed to get a flood and coastal defence analysis with the Chinese government going, with our team who did the same for the British Isles, and it became clear to them that Shanghai will not survive to the end of the century unless we reduce greenhouse gas emissions and so once again I would say the Chinese politburo understands the nature of the problem.

So I think there's a realignment emerging in a positive way and of course assuming the American electorate gets it right then we may even see a fruitful solution emerging in a short time, Copenhagen is a very short time away.

Chair

Well before I thank David I'll just mention one special Miliband event that we've put on at short notice which is this time next week, 6.30 here in the Old Theatre, I will be having a conversation with Will Hutton and Martin Wolf from the *Financial Times* on the global financial crisis and where as I doubt either will reach tonight's levels of clarity it will be a first rate discussion from two leading commentators on how it's happened, what is happening and what are the next steps forward but before you all go I would like to once again thank David, it's the second time he's been here in recent years, it was a tour de force, David and all I can say is can you come back next week and carry on? Thank you.