AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

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GLOBAL WARMING: THE IMPERATIVES FOR ACTION FROM THE SCIENCE OF CLIMATE CHANGE

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February 13, 2004
Seattle, Washington

Thank you very much, and let me say once that it's a very great honor to be here to address you today.
I thought what I'd do is first of all just set the scene by telling you what my job is. It's a little different from the Chief Scientific Adviser to the President in this country.
The Office of Science and Technology has a staff of around 160 which split into two parts on the right hand side of this graph you see this picture you see the science and engineering base group which is essentially the side of it that operates as a fund awarding agency, so this is our research council funding agency. This was receiving 1.45 billion pounds a year in 1997. This year it's 2.3 billion pounds and it's due to rise to 2.9 billion pounds in 2005,2006. We have a director general of the research councils who looks after that side of it and that frees me to look at the transdepartmental science and technology group on the left hand side and you'll see that I have a number of subgroups there, science and government which aids me in dealing with crises such as foot and mouth disease or in being proactive. My international team that assists in all of our negotiations internationally involving science and technology and of course principally dealing with the European union-- I didn't mean dealing with. I meant negotiating with. And so roughly half of the international team is under the European union banner and the rest is dealing with the rest of the world. The foresight team is our mechanism for mining into our current science and technology capability for the benefit of the United kingdom, so this is a very important team. We look at no more than four projects at any one time and I'm going to give you an example of how we operate on one of these projects. LINK scheme is a means of funding to get industry to interact with our higher education institutes, science review enables me to review the science capability of all government departments, "science in society" is a new team we're trying to deal with what I consider to be the real risk to the UK and I believe to all the other G8 nations as we move ahead which is young people not seeming to be so keen to coming into science and technology careers. So I'm personally responsible to the Prime Minister for this very broad ranging business of science across all aspects of government. I have a license to interfere. I have interfered as is well-known and I believe this is well recognized to be a good thing for somebody to do at least it's recognized as such after I've done the interfering.
In order to assist me in this process I have now been appointed chief scientific advisors in each government department, responsible to me and responsible to the secretary of state in that department, and I think that the visibility of science in the UK government is increasing very rapidly, by which I mean that the government is very evidence based in terms of the policy it receives and it recognizes that science and technology is a very key part of evidence-based policy advice going to ministers. One of my activities is to write funding applications to the chancellor of the executor and I recently done a reanalysis after my predecessor Bob May's analysis of the state of science amongst nations around the earth and this is an analysis which you may or may not like because the curve-- the lines in blue are the UK and in white the USA and it appears that the UK has a bigger footprint than the USA. If you look at the various corners of that footprint you'll see citations per unit of GDP, citations per unit of PUBERD {public expenditure and research and development}. On that unit for a long time we are the highest in the world. In other words, our science output per dollars spent in the science base is well above our competitors around the world.
This, of course is an argument that we have a great strength in science in the UK. It's a great historical strength and government has accepted that we need to build that up and benefit from that great strength, and that's the argument I'm currently making. Now, in my time in government, I've had a number of jobs to do which I can put under the heading of reactive or proactive, and I simply list some of these here and amongst the proactive and very early on is climate change and that really is the subject of what I'm going to

talk to you about, so the role of the Chief Scientific Adviser in the proactive sense is very much selecting for oneself what the priorities are and within the limitations of budget and staff capabilities.

Now, in terms of the climate change, let me just then take you through what I had to take myself through when I came into this job, and whether it's foot and mouth disease or BSE or whatever, it's always a rapid learning process to catch up with the state of science around the world. Of course the greenhouse effect first set out by that great French mathematician Fourier in 1820 is illustrated here in terms of sunlight reaching the earth-- about 30 percent of it is reflected off the clouds of ice cover but about 70 percent of it gets through. Of course, it heats up the earth, it heats up the air as it comes through, and infrared radiation, black body radiation, it can escape back out. Most of the atmosphere is transparent to that infrared radiation. Oxygen and nitrogen don't absorb it, but there are molecules such as carbon dioxide, methane, nitric oxide, sulphur dioxide, CFCs, which do absorb in the infrared. Now, to maintain a heat balance of input and output, the temperature of the earth can change, and that's what Fourier understood and Tyndall and after Arrhenius clearly understood the role of carbon dioxide in that process so the higher the carbon dioxide content as Arrhenius calculated in the atmosphere, the higher would the temperature of the earth would have to be so as to maintain the equilibrium between incoming and outgoing heat.

Now, that is essential to understanding what comes because it means that carbon dioxide levels methane leaves, et cetera, are crucial to the climate that we experience. This is one of a selection of many graphs that I've seen and this perhaps is my favorite indicating what has happened to carbon dioxide levels over the last 60,000 years. So on the left-hand side of this graph is 60,000

years ago and at zero is the present time. This data is taken from ice cores from the Antarctic and the tremendously careful reconstruction of our past from those ice cores has produced the most wonderful data in terms of recording our past.

Back to currently about 420,000 years the ice in the Antarctic that is available would cover a time span of around 600,000 years. Now, of course the ice has been gathering on the Antarctic for much longer than that but deeper than that the ice flows away and is not available for ice core measurements, but it's been measured back we see that the carbon dioxide level it is the atmosphere were about 200 parts per million during the last ice age.

We come out of the last ice age that is the blue point on the data we graph here, rise to about 260 to 270 parts per million, then we then come into our current warm period which is a period of about 10,000, 11,000 years and this of course is our period of civilization, and I think it is an important point to make that during that period of time with some exceptions our coastlines have been rather constant and as a result we've been able to build cities in our coastlines with a fairly clear expectations that those cities would not be inundated.

As we came out of the last ice age, sea levels rose by an estimated 120 to 150 meters and we just need to bear that figure in mind because there's still a lot of ice sitting on land masses on Greenland and particularly on Antarctic and should that all melt we're going to see a significant rise in sea levels and another significant redrawing of coastlines.

And what you see in green are the beautiful measurements of carbon dioxide levels in the atmosphere made in Hawaii which indicate a vertical line on this kind of time scale. That sort of vertical line is a bit of a warning to those of us who do physical chemistry or physics. It looks a little like a phase transition and certainly climate scientists feel that all sorts of unpredictable-- difficult to predict events can be precipitated by such rapid changes in atmospheric carbon dioxide levels the latest data point is 372 parts per million {ppm}, which is off the top end of this graph and is therefore not shown. Now, in talking to people around the British government about these concerns I have to tell you that this graph had the greatest effect on people, the mere fact that carbon dioxide levels are now considerably higher than for the last 420,000 years at least and I understand from Dan Schrag, we can probably extrapolate back to around 40, 50 million years over which time we haven't seen carbon dioxide levels in our atmosphere as high as they are now, but let's recall that this graph is an upward moving graph at quite a high rate, so we're not at anything like the ultimate level. If we look around the globe, what is the evidence that we are seeing global warming. The most direct, the most obvious and in many way it is most beautiful evidence has been accumulated by Lonnie Thompson, the great American ice scientist who's been traveling around the world, particularly in the tropics and near the Equator where the weather is particularly constant, and he has been taking ice cores from the permanent ice at the top of these mountains. On the left here you see Mount Kilimanjaro at the top is a picture taken in 1912 in the summer and below that picture a picture taken by Lonnie Thompson in 1998 of the same peak, same view, same time of the year. He now estimates that the ice on that mountain top, which definitely dates back to the last ice age and therefore long before is not going to last more than about 15 years and this means that that ice cap, that so-called permanent ice cap will finally have been lost.

Now, if you are ever queried about whether or not to believe that there is global warming, just remind yourself of that data point, and it's not a singularity if you go around peaks around the world. This is an absolutely general phenomenon. Since I am in this part of the world, I'm showing on the right-hand side the South Cascade Glacier in Washington state and the top picture in 1928, the bottom picture in the year 2000. This is then a regular phenomenon. We have got global warming, and of course, the question is whether these two things I've shown you, carbon dioxide rise and loss of ice on these tropical mountains are related to each other.

The effects of the warming-- I come back to the relationship. The effects of the warming are already very real and we're not here to discuss whether or not we will go into a period of global warming. We are already in the period of global warming, and we can already assess the damage that global warming is causing and an assessment of the number of people who are dying prematurely around the world as a side effect of climate change, that is extreme events occurring more often than they would otherwise have occurred is around 160,000. We've had a very severe summer in Europe over the last year and prior to that we had very severe flooding. John Shellnhuber has shown that this coupling of flooding and hot summers is an event-- a kind of train of events that we can expect to occur as we move on into this global warming period. We estimate that in Europe something like 30,000 people died prematurely during this summer arising from this extreme event. It is pretty clear to us now that global warming is a very serious issue and we can look across the climate models to see whether predictions can be made. Now, everyone is putting large error margins on these climate models and quite rightly, but nevertheless, they are a useful predictor of what might happen so that we can begin to act.

The climate models are predicting an increase between 1.4 and 5.8 degrees centigrade over the next 100 years. That variability is not all difficulty with the models but difficulty with us, so it is a question of for how long we will continue to burn fossil fuels as the current rate. The effects of climate change are manifest here and unfortunately if you move down this picture you'll see towards the bottom that many of these effects are distinctively problematic effects for all of our societies, disrupted energy demand, coastal erosion, flooding and storm damage, transport disruption, agriculture problems all the way to the tourism industry based on snow. But there's something considerably more serious ahead of us. This is a series of estimates from the Hadley Centre in the UK based on the year 2080 and in the top map of the world you will see the number of estimates of the number of people who will have their homes permanently flooded as a result of the events that we're now looking ahead to, and we can then total this up and we're talking about a number of people around the world losing their homes by that time which is approaching the population of the United States of America.

Now, these people are not in the United States of America, as you can see from that diagram, nor will that happen overnight. The important thing to recognize is that this is going to be a slow process of attrition, but the economic and political and social destabilization that will result from that process is going to be massive and I doubt that any of us will remain unaffected by that. The bottom two graphs indicate that-- the top one is based on business as usual, we carry on burning fossil fuels at the rate we are now. The bottom two graphs are to indicate that there is some mitigation of this problem possible. On the right-hand bottom graph you'll see that if we managed to stabilize the level of carbon dioxide at 550 ppm, and remember that we are currently likely to achieve more like 900 to 1200 ppm, if we can stabilize it at 550 ppm, the number of homes flooded would be substantially reduced at least on the basis of this model. Now, the temperatures over the past 100 years or so is shown on this part here which is rather well known to climate scientists. It's interesting to point out that in 1938 the British Meteorologist Callander announced that we were suffering from global warming, and he attributed it to carbon dioxide levels increasing. Now, at that time this was largely, discounted but this is the first of many times that people have stated that we have global warming and that it's carbon dioxide and other greenhouse gas related. The time for discounting these stories has now long past and we have to accept if you look at the right hand part of this curve that it's already happening. Now, I say it's already happening. What about that causal connection? I wouldn't bet on it not being causally connected. What you see here is a simulated global warming from the Hadley Centre which indicates in red the graph shows the observed change in temperature over that period of 1850 to 2000 and in blue the simulation by the Hadley Centre model.

So in other words, they're looking back in time to see whether the model they're using to predict weather change works over this time scale and what is included in the modeling there are changes in solar output, volcanic activity, and also changes due to our combustion of fossil fuels and generation of methane and other greenhouse gases. It's only by including the latter that the general upward trend from left to right is shown in their models. If they take out the anthropogenic effects from this curve then that general increase across there of .6 degrees centigrade disappears. There are a number of very difficult effects to model and I just list these here to tell you that the current state of climate science is that it's now accepted that we have global warming. It's now accepted that this is largely due to anthropogenic effects. That part of it is not up for argument anymore. What is up for argument is what can we expect to see into the future, and the reason it's up for argument is that we have a massively complex system, the earth itself.

These are just a number of difficult nonlinear feedback phenomena that I've come across and there are many, many others. We've heard a lot of talk about the weakening of the thermo haline currents, the famous global heat conveyer that carries temperature-- heat up into the European region and raises our temperature by an estimated 5 to 10 degrees centigrade. Of course if we lose that, the effect on Europe would be absolutely devastating. We would return not to a hot period but of course to an ice age. How would we lose that? Well, if you pour an awful lot of unsalted water into the sea, it's possible to reverse it, and how would you find that water? It would be from melting ice. So that is the risk in that case. Equatorial forests may in the future, as they get warmer, switch to become net emitters of carbon dioxide of course a big nonlinear effect is the loss of ice leading to the loss of reflectivity and hence greater absorption of energy from the sun and speeding up this warming process. I don't think any of the nonlinear feedback effects are particularly attractive you can hunt around for negative nonlinear effects but again I wouldn't rely on that either. Now, the question is for political activity. Do we need to adapt, by which I mean prepare ourselves against the effects of climate change? Do we need to mitigate by which I mean should we attempt to switch our dependence on fossil fuels to other energy sources? Or should we ignore these effects and anticipate that they will either go away, that they are incorrect science-based effects or that market forces alone will operate. I don't believe we can rely on market forces. If we go on burning all of the coal, gas and oil available then we will be pushing ourselves up into that thousand ppm bracket.

Recall, please, that the long-time carbon dioxide level in the atmosphere going back millions of years was never exceeding 300 ppm until the present time. So what do we need to do? We need to adapt. We're already seeing change and in the United Kingdom I set up a team under my foresight activity to look at the flood and coastal defense problems for the United Kingdom on a long time scale. Now, obviously the government department involved dealing with the environment does look at these matters but on a relatively short time scale, five years would be their sort of purview and what we were looking at was a 30- to 80-year period and in doing this project we engaged something like 50 to 100 scientists in the process.

It's taken us about 18 months to reach completion, and I expect to get the results to the Prime Minister in April this year. The first part of the program was to get climate scientists and modelers to model what the risks to the UK would be and the second part of the program was to see what actions would need to be taken by government perhaps beginning now so as to prepare to adapt to the worst of these effects. The work is sponsored by a government department and, in particular, the minister sits on the board that runs it and several other government departments such as transport, which is fairly obvious, but also the Office of the Deputy Prime Minister which deals with planning is directly involved. This is just one out put from this very detailed computational analysis on a fine scale of the-- and expectation of changes in our flood and coastal defense risks. Now, the problems are twofold that the flooding increases with climate change as the vapor pressure of water many the air increases and we get much higher precipitation concentrated into certain parts of the year. And as a result of the fluvial run off, flooding of homes is already increasing. Now, something like 10 percent of the housing within England is in flood plains as distinct from 20 years ago. What you see on the left-hand side is the anticipated change in risk which is measured as economic damage to residential and commercial properties as we extend forward to 2080 with a business as usual scenario and high increase can be characterized by an event that might have been a one in 100 year event becoming a one in three year event, so if you were anticipating being flooded once every 300 years you could now expect it to happen once every three years which has clear implications. The coastline is particularly vulnerable. About two thirds of our coastline will suffer very severe erosion under this scenario and so of course those residences along the coastline suffer from a double whammy from fluvial flooding and from coastline erosion. Some years ago in the UK there was an understanding that the flood risk to London from the Thames flooding was increasing. It took a couple of floods to demonstrate that and the net result of this is that a decision was made at great expense to establish the Thames barrier, which I show in this picture. When the Thames barrier was completed in 1982, it was expected that it would be used roughly once every three to five years and in that first period that is how often it was used.

Now, if I tell you that in the year 2000 to 2001 the Thames barrier was used 24 times, you will see that the effect of flooding on the Thames both fluvial and from the storms at sea has increased very substantially. What I show here is the frequency of usage of the Thames barrier over that time since construction to the present day. 2000-2001 was a freak year, but you'll see that we've now risen from once every three to four years to an average of six or seven times a year, and that is not just an indication of flood increases in the UK.

These measurements can be made at other points around the world, and that is a key message that I wanted to carry to you from our particular analysis that here we've been looking at one part of the world in fine detail. It's not even a part of the world that on the global map appears is under any severe risk, but the risk to the UK is simply massive. If I tell you how do we measure that, one of those floods breaking through the Thames barrier today, just one of those floods would cause an estimated 30 billion pounds of damage. That's two percent of our GDP and that would lead to a massive destabilization of our country and the economy. As you might imagine, we're taking a great deal of care with that barrier. Now, of course money is considerably better spent on mitigation. In our calculations we looked at four different scenarios on the flood and coastal defense risks to the UK, and the risk on the scenario with the least amount of carbon dioxide emission by 2080 is considerably reduced. It's a risk that we can begin to adapt to in many places, but on the business as usual scenario, it really is a rather disastrous situation and remember that it's getting worse all the time. 2080 is just one point in time, so money is considerably better spent in mitigating than in adapting. That is a very clear message from our work. This isn't to say that adaptation isn't going to be required. It's already required, but we must mitigate as well. How do we mitigate? We need to improve our efficiency of energy usage, a simple win/win. We're investing heavily in research development and demonstration in renewable energy carbon sequestration and with the big international cooperation in fusion so looking at short and longer terms. We feel that we ought to be looking towards the future to see whether we can pick a particular level of carbon dioxide that we might realistically expect we could mitigate towards--in other words, let us say take 450 ppm as a possible target for maintaining our carbon dioxide levels.

We would still have all of us to adapt very significantly at that level, but I do think we'll have to engage significantly in an operation that we're underworking at the moment and that is north, south, science engineering and technology capacity building, developing countries are a big part of our globe, and they will play a big part in the production of carbon dioxide unless there is technology transfer from north to south to enable them to leapfrog into the new technologies that are being and will be developed in the north to cope with these problems. If we look across the world at the carbon dioxide emission measured as tons per person, you'll see that in the United States you each are emitting around 21 tons per person per annum. I am not saying that you're sitting there breathing faster than the rest of the world. And of course the graph is somewhat related to GDP, somewhat. It's not totally related to GDP at all though. Look down the curve and you'll see that Sweden with quite a high per capita GDP is very low down and if you go from one country to another, a very clear outcome is that at least in Europe a major factor is what is the energy source on to the grid. Those countries such as France with a high amount of nuclear fission energy on the grid not carbon dioxide producing are low down on this parameter or Sweden, which like Washington, has a large amount of energy from hydroelectric power is low down on this curve. So clearly we have to look very, very carefully at this question. Now, this is per person and China and India are on the right appear low on this graph and multiplied by one billion and you have a large amount of carbon dioxide. That clearly is an issue that we all have to take on board. This is just to remind us in terms of how we use energy where we will need to look for alternative energy sources. And the plot is really intended to remind all of us that transport is a key factor. We're not really going to substantially remove the problem until we can get away from the extensive use of oil in transport and this does mean that we need to look at exciting new technologies into the future which will move us away from our current dependence on fossil fuels. What is the UK government doing? We're using international bodies as extensively as we can to see that we can get international commitment to reducing carbon dioxide emission and other greenhouse gases, particularly under the united nations framework program for climate change. The white paper published last year by the British government has committed us to reducing our carbon dioxide emission levels and other greenhouse gases by 60 percent by the year 2050. This is extremely ambitious, but it is a real commitment, and we plan to do this despite the fact that there are not other countries making the same announcement. It's not a reduction that we plan to leave until some years into the future. We plan to be on an approximately straight line between 1990 and 2050, so at any point between now and 2050 we can see if we are on target or not. We expect this to be a bumpy ride. One of the factors in the energy business is the long life of power stations, of utility power stations, and so it's only when power stations come up for renewal that there's an opportunity to move into new technologies. This is why we have to look well into the future and not wait for time to pass. So we are committed to that action and we're already in the process of gaining considerably in the energy efficiency process and, in particular, in our use of renewable energy sources and over the next few years we're monitoring very closely just how well we can do and we will continually review our mechanisms for achieving it, but we're also and perhaps most particularly investing in research and development.

One of the promises to the country from the Chief Scientific Adviser is that if we get into this early, we start playing the economic game in the sense that we get into the technologies that we can export to other countries that undoubtedly will need alternatives to fossil fuel energy sources and so we are investing in research development and demonstration. We're also looking as far ahead as we can for international partnerships. On the left is the picture of the ITER fusion experiment which is the next stage on from the joint European torus based at Culham, England. JET and JT 60 in Japan have now produced, at long last, everything they were designed for, and we're now ready for the next stage which is to build ITER to test whether we can get energy out of fusion in such a tokamak device on a useful basis; in other words, get energy onto grids from fusion as we stretch off into the future. Now, I hope you can see that we all believe those of us behind this that we need to be looking many, many years ahead. If we're going to be looking at changing our source of power, we really need to be thinking ahead, so the argument that ITER is unlikely to put energy on the grid for another 35 to 40 years is really a thoroughly insufficient argument to suggest that we shouldn't spend 5 billion dollars on building that machine to see if we can make it work. It will pay us off handsomely if it does. I personally think it's worth every effort, and I'm delighted that we have an international team involving the European Union, Russia and Japan as the first designers of the project and now China, Korea and of course the United States coming on board, what is going to be the biggest fully international science and technology project that has ever been. I believe like landing a man on the moon if there was a will to get this project to work, it could produce power onto grids in a considerably shorter time. It's matter of putting money in the project. On the right-hand side, I show the General Motors skateboard car concept because I think it's going to be very important as we move ahead not only to find alternatives to the use of oil in transport for cars but that we find technologically attractive alternatives, and the fuel cell, the hydrogen fuel cell provides just that capability. The skateboard car is a totally new concept. It should appeal to the Formula One instincts of the little boy in all of us as well as the instincts to save the planet, so I think the skateboard car is a great concept. Incidentally, the only moving parts are the wheels and the brakes and the driving motors are in the wheels and it's a drive by wire. You would of course drop a shell onto it with seats, et cetera. One of the energy sources that I feel we're developing perhaps more rapidly than anywhere else in the world the tidal turbines, and we believe we can farm sufficient energy from our major tidal sources around the UK to provide a very significant source of energy. The key breakthrough is in having totally underwater turbines which don't disturb surface traffic, and there is even now a development of an underwater turbine with no moving parts underwater. If anyone is interested, I can explain how it works. The international challenge of course is that it's all very well for the UK producing two percent of the world's carbon dioxide to be reducing its emissions to perhaps one percent. That's not going to help us get rid of climate change, so what we must have is global collaboration. I think that in terms of the energy futures, we want to work -- by "we," I now mean the European union with the United States and other countries -- on seeking alternative technologies. The marketplace will choose the winners, but I do believe in research we need a very broad menu approach to tackle this critically important problem. Let me say in terms of the international community what of course we need is global agreement on how to move forward. The European Union is fully signed up to the Kyoto agreement. We in Britain are already onto carbon trading and in 2005 the European Union will have introduced carbon trading. Once again, the idea is to get ahead of the game, and we can see and so do our businesses, real economic advantage on getting into that early. At the same time, we're not going to make much progress on that until Australia, Russia and of course the United States come on board with us. If those countries feel that this is not the route forward, then of course we must discuss alternatives. This is far too important a problem not to be discussing alternatives, but I think what the UK government's position is, and I do think this is the right position, is that we shouldn't be discussing alternatives unless it's recognized that these alternatives are put in front of us on the basis that rapid action is required and that alternatives are not put before us on the basis of let's discuss these alternatives for another ten years. We happen to think that we don't have a lot of time for action, that action is required on a two or three year basis rather than on a basis of decades and this really must be the time for countries to put their thinking caps on and get together on this critically important issue. I just leave you with this quote from Spencer Weart, he's written a lovely book which is the history of the development of our understanding of climate change. It's a detailed history of the thousand or so scientists who have contributed some quite remarkable pieces of work to our current understanding. What we have through that work is a capability from our scientific community to understand what the needs are into the future. Now the question is: Will the political system understand what the scientists are telling them sufficiently well to convey that through into the political agreement that is going to be absolutely necessary to deal with this problem? So we have hard decisions to make. "Our response to the threat of global warming will affect our personal well-being, the evolution of how man, society, indeed, all life on our planet." I don't think that's an overstatement.

Thank you very much.