CLIMATE CHANGE

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Part 1

Good morning and welcome to our lecture this morning on Climate Change. I understand that you have perhaps been doing a little bit of reading about this and you probably know a little bit through general knowledge, through reading the newspapers and magazines and watching TV, etc. It's a very big topic and there are many aspects we could look at. This morning we're going to concentrate on these main areas.

We talk about climate change in terms of global warming that's occurring but we need to put that into the context of climate change over the history of the Earth. The Earth has a long history. It's four thousand million years old and we need to put the context of what is happening with respect to climate change into that history, into that pattern of the history of climate change on the Earth. So we'll start by looking at the past rhythms in climate. Now, you're probably all familiar with the link between global warming or climate change, increasing temperature, and increasing concentrations of carbon dioxide in the atmosphere. Carbon dioxide is a so-called greenhouse gas. Do you know what we mean by greenhouse gas? Anyone suggest what is meant by greenhouse gas? [member of the audience responds – mostly inaudible:]

We know what a greenhouse is. A greenhouse is a construction made from glass and it's commonly used - you'll see it in many places in this country - to enhance the plant growth. Because the glass of a greenhouse is able to allow sunlight to pass thorough it but it traps heat energy that is reflected back from the surfaces inside the greenhouse. So we can say, its' - the greenhouse, the glass is transparent to light energy, to sunlight energy but it's opaque to heat energy that is reflected from the surfaces inside the greenhouse. So if you go into a glasshouse or a conservatory, a house in a room made of glass, it would be nice and warm on a sunny day. Warmer than outside. Perhaps a quick diagram to represent what we mean by a greenhouse gas from this analogy will be helpful.

So this is the surface of planet Earth, and the sun, the sun is shining nicely not like today, but a nice day in summer. So the sun is shining nicely and sunlight energy is reaching the earth's surface. So this is a very simple explanation of what a greenhouse gas is, this diagram. So sunlight energy hits the earth's surface, some of it will be absorbed, some of it will be reflected. Some of it will be re-emitted as heat. So these arrows represent heat. These arrows represent light. Now the greenhouse gases are ones which are present in the atmosphere and have a very special property. We don't need to worry about the mechanics of it or the details of it. But we do need to understand that these greenhouse gases have special properties, that allow the right energy to pass through them, but they prevent the transmission of this heat energy. So if the blue represents the greenhouse gases in the atmosphere, we can see that they act rather like a

blanket, it's rather like having a blanket around the earth. And they keep this earth warmer than it would be otherwise. It's possible that without the greenhouse gases the planet would be cooler and life would not have developed as we know it now.

Part 2

So that is what we mean by greenhouse gas. Carbon dioxide is the best known greenhouse gas, but there are others, and we will find out about these later. So these greenhouse gases allow the sun light to pass through them, but they trap the heat energy that is reflected from the surface of the earth. So this is, the surface of the earth is kept warmer than it would be otherwise. The greenhouse gases could be regarded rather like as a blanket, around the earth, keeping it warmer than it would be otherwise.

So in our lecture this morning, we start by looking at past rhythms in climate, and the concentrations of this very important gas carbon dioxide. And then we will look at evidence for the current global warming, and alongside that we look at how carbon dioxide has changed in that, say, recent period. As well as carbon dioxide there are other gases, other greenhouse gases, and we will look at a summary of those too at the end.

So beginning by looking at past rhythms in climate, and I suggest you look at this graph. This goes back eight hundred and fifty thousand years. So this is now. We are now at nought and this is going back in time. You will notice that there are, well this, we ought to point out that this vertical axis is showing temperature. So the graph is showing temperature changes against time. Is everybody clear on that? And you'll note that there have been fluctuations in temperature over the history of the earth. So it's not unusual that there are fluctuations in temperature. The coldest times, much colder than now, are called glacial periods. Heard of glaciers? It means that it's a very cold time. So times when temperatures were lower than they are now, are called glacial periods.

We're now in what we call an interglacial period between glacial periods. Interglacial periods are when it's warmer, are the warmest times. So these, at the peaks of the temperatures, would be interglacial periods, at the lowest temperatures, we will be in the glacial periods. As you can see from the graph we are now in an interglacial period, does that make sense to everyone? So there has been this regular pattern of temperature changes. This slide reminds us of that. Climate has oscillated between glacial periods - otherwise they are called Ice Ages, which is a term you may be more familiar with - ice ages and interglacial periods. So that's over the last 2 and a half million years. Now during the glacial or ice ages it was colder than it is now. If you had been standing here in southern England, in Berkshire you would have been, well it wouldn't have been very pleasant because you would have been standing on ice. During the last ice age, and in previous ice ages, ice sheets one and three quarter miles thick covered the surface of the earth as far south as Europe and North America. So you can imagine that with these changing, fluctuating temperatures there has been a movement southwards of ice, during the very cold periods, and then in the interglacial periods when it gets warmer, the ice retreats northwards. Does that make sense? So in the height of the last ice age, which ended about 10,000 years ago this area would have been covered with ice. And that actually has noticeable effects on the geology of the area but we don't need to concern ourselves with

that today. Just be aware of the fact that there is this history of alternating glacial and interglacial periods. And the last ice age ended about 10,000 years ago so we are now in an interglacial period.

Part 3

So that gives you a background as to how temperatures have varied over the history of the earth. But what about the other factor we're interested in – the concentration of carbon dioxide in the atmosphere. What do we know about past concentrations of carbon dioxide in the atmosphere? Now you might think that's rather a difficult thing to investigate. But there is a very clever method that scientists use, to look, to discover, what the composition of the atmosphere was in the past. It's possible to take ice cores, so if you go up to Antarctica say, you can drill an ice core. So that means that you take a sharp metal cutting device that is like a cylinder, and drill down into the ice, and then pull the ice core out. So you have a long core of ice, a long cylinder of ice. This ice can be stored, and many cores can be taken and then they can be analyzed. Now the deepest part of the core will correspond to the ice that is oldest, does that make sense? So you actually can age your ice. So if you go to the deepest, oldest part of the core you can look at what the atmosphere was like that, and you can go up and move to the uppermost part of the core that will be more recent ice and then you can analyze that ice. So you can get information about the composition of the atmosphere over the past.

Because within the ice, there are little bubbles of air, little bubbles of air that were trapped when the ice was formed. Does that make sense to everybody? So when ice forms, it traps little bubbles of air. And that air can now be analyzed to give us an idea of what the atmosphere was like in the past. So this slide is just introducing that concept. It says that analysis of bubbles of air trapped in ice cores, drilled from Greenland and Antarctica, so you now understand how those ice cores were drilled? And what the method is to look at the composition of the atmosphere in the past. It involves analysing the little bubbles of air, that were trapped, years ago.

Now if we look at the composition of those bubbles of air, we can analyze how much carbon dioxide was present in the atmosphere years ago. We also can, we also have information about the temperature at that time, and the next graph shows us the results of data derived from ice cores. Now we have 3 graphs here. The middle one, the middle line is showing how temperature has changed. The uppermost graph, the uppermost line is showing how carbon dioxide has varied. The bottom one is of interest because this is the graph for methane. CH4 is the chemical formula for methane. The bottom line shows how methane concentrations have varied. We are interested in methane because it, like carbon dioxide is a greenhouse gas, so it works like that. It's one of the gasses that contribute to that blanket effect. The most noticeable feature of this data, is that all 3 graphs vary, together, can you see that? All 3 graphs show the same fluctuations up and down together.

Part 4

Suggesting there is a close link between changes in temperature, represented by this middle graph, and changes in concentration of carbon dioxide, the green house gases, and methane in the atmosphere. So this data is suggesting that over time, when concentrations of carbon dioxide and methane have been highest, so have temperatures been highest. We can say that these three variables co-vary, they change together. Does that make sense? So just reminding us of our conclusion from that data. The ice core data shows that atmospheric carbon dioxide and temperature have co-varied over the past 400,000 years and this supports the idea that concentration of atmospheric carbon dioxide and temperature are closely linked. When CO2 increases so does temperature and vice-versa. Alright?

That also applies to methane, because methane concentrations are varying in the same way as carbon dioxide concentrations. So, we are demonstrating a link between temperature changes on Earth, and concentrations of these green house gases: carbon dioxide and methane. Does that make sense for everyone so far?

So, we've looked at the information about what's happened in the past. But we are now concerned, in recent times, with a warming of temperatures, that is different in one very important respect from the previous patterns of temperature change. And that is, that the increase in temperature which is occurring now, that we call Global Warming, and that we are concerned about now, is happening much more quickly than has ever happened before. So, if you look back over the history of climate change, yes, there were fluctuations, but now the increase in temperature that we are measuring is happening on a much more quicker timescale. We'll have a look at that in more detail a little bit later. But that's something to bear in mind.

So, looking at global temperatures, remember than in the previous graphs we were looking at thousands of years, weren't we. This access… we're showing thousands of years, millions of years even, and how temperatures changed over those thousands of years. This graph is looking at our more recent past. It only goes back to 1860. So we're looking at just one less than 150 or less years. So we're looking at a short time-scale, and yet within that timescale this graph, and I hope you'll have it in front of you, is showing that overall there has been an increase in temperature over that time.

Now, this graph is constructed in a way that shows the average global temperature over this time period, and fluctuations below and above it during that period. So until, sort of 1940s, the temperatures were all lower than the average, and then until now the temperatures are largely higher than the average. The most important thing to get out of this is that overall, there has been an increase in temperature. Does everybody see that? Yeah? So that is the most important thing that the graph is showing, that overall, over this period there has been an increase in temperature. So that's one piece of evidence for the most recent period of global warming, the one we are concerned about as an environmental issue.

But what are other pieces of evidence for global warming? Measurements are showing that sea levels are rising. Global sea level has risen by about 10 to 25 centimetres over the last 100 years. There are two factors that produce this increase in sea level. One, is that if you heat water, what does it do? It expands.

Yeah? If you heat water it expands, and even if you heat the oceans by a small amount, they too expand and sea level rises. So that's one reason why sea level is rising: because of thermal expansion. Another factor, the second factor that's leading to increase in sea level, is that with increased global temperatures, ice caps are melting, glaciers are melting, and the enormous ice sheets of Greenland and Antartica are melting. And all the water that is released from that melting ice is going into the oceans and raising their sea level.

Part 5

So, sea level rise and melting of the ice caps is evidence for global warming. You may… Do you know what *permafrost* is? Probably not. *Permafrost* is an area that has frozen ground. So it is a sort of eco-system. The word *permafrost* refers to frozen ground. With warming temperatures, that frozen soil and ground is melting and the water is being released. So, these are all observations which scientists are making, which are suggesting that global warming is occurring on a scale that has not been experienced before, in that it is happening quickly.

So more evidence for global warming. I'm sure you will have read about the changing weather patterns, the problems of storms and floods. You will have read about this in newspapers, heard about it on the news. One - in England, we suffered the wettest winter in the year 2000, wettest winter on record. These… there are many pieces of evidence. Many, many examples that our weather patterns are changing. These are just small little bits of the pattern, so little examples within the overall pattern. But overall, the meteorologists are suggesting that there are changing patterns of weather, which could be attributed to global warming, to an increasing global temperature.

There is also evidence from the plants and animals living in the natural world. We are cosseted for changing temperature to some degree in that we are warm in our houses or cool in our houses, but the natural world, the plants and the animals, are open to the elements and therefore they are good indicators of changing environments. And there are many examples of animals and plants changing their patterns of behaviour, reproduction, in response to the changes in temperature linked with global warming. One little example of a change in animals' behaviour is that it's being… it is observed that our birds in England are nesting two weeks earlier than 30 years ago. So, Spring is coming earlier, it's getting warmer earlier in the Spring. So, that's just one little example of how, in this case an animal, is indicating that the climate is changing.

Another indicator of changing temperatures is that El Nino… has anyone… have you heard of El Nino? Do you know what it is? Yes? It's a particular pattern of weather that is due to a switch in the direction and intensity of ocean currents and winds in the Pacific Ocean. Now, this is an event that in the past has typically occurred, every four to seven years. It's an obvious effect because it leads to a bonanza of fish being available at particular times on the northern coast of South America. But with global warming it seems that the frequency of El Nino is changing. It's becoming more frequent, and it's causing these massive effects where the disruption, droughts in the southern United States, etc. So, the most important point to realise here, is that El Nino, which has had a regular sort of seven year pattern, is changing. And that change, the frequency… the fact that

it's becoming more frequent is linked, is thought to be linked, to global warming, a change in our climate.

So, if you go back to the first sheet you had, where we made a list of the main topics we are going to cover today, you'll see that we have by now looked at past rhythms in climate and concentrations of atmospheric carbon dioxide, those long term changes. We've looked at now at evidence for global warming.

Part 6

We have already said that there is a link between global warming and increased concentrations of greenhouse gasses. We have seen the data that suggests that in recent - in the last 150 years there has been an increase in temperature that is unusual. It's happening more quickly than one would have expected. The next question to ask is how does this relate - is there any evidence that carbon dioxide concentrations have changed alongside these increases in temperature over the last 150 or so years? So we need to look at the evidence for increased levels of atmospheric carbon dioxide alongside the evidence that we have looked at for temperature changes, does that make sense? So next we need to look at how carbon dioxide concentrations have changed in the last 150 or so years.

And this brings us to a very, very important graph. This has been described as one of the most important graphs and figures of the 20th century. It is sometimes called the Keeling Curve, k-e-e-l-i-n-g after the man who first published this set of data. This data comes from an island in Hawaii called Mauna Loa; it's sometimes also called the Mauna Loa curve. So Mauna Loa is a mountain - it's actually an extinct volcano - in Hawaii. This is an important site because it is well away from pollution. So it is not affected by man's pollution at that point, by local pollution you could say. And in Mauna Loa there is a station which records changes in temperature, composition of the atmosphere etc. So it's a meteorological station. And one of the measurements it makes is of carbon dioxide concentration in the atmosphere. And this is the data that goes back to the 1950's. This is the data for carbon dioxide concentration in the atmosphere.

Looking first at the red line, the graph shows a general trend of an increase in carbon dioxide concentration in the atmosphere from – well you tell me what is the value in 1959, can you read it? 300 and – yes it's just over half way between these two isn't it, so I say 317. Something like that. It's difficult to be absolutely precise but in that region. So the concentration of carbon dioxide has increased from, shall we say 317 p.p.m. by volume, in 1959, to – the graph actually goes up to 1998 – what is the value there? You can probably see it better than me because – what would you say it is? 365, yes, don't forget the units, p.p.m. by volume. So overall there is a general trend of increasing concentrations of carbon dioxide in the atmosphere. And that was a very, very important finding by the scientist, Keeling.

One other point that we should look at is this fluctuation in carbon dioxide concentration. Can you see that the fluctuations are on an annual basis? So in each year there is a high and a low.

Part 7

Are any of you biologists? No? Yes? No? Well in that case you probably won't be able to tell me why there are these annual fluctuations in carbon dioxide. Anyone want to have a go? Say now, remember, if you do. In summer if you go out now, summer's coming up and the trees are green, covered in leaves and that means they are photosynthesising. And in that process of photosynthesis they absorb carbon dioxide in order to make their own food. So they are very busy at the moment absorbing sunlight and carbon dioxide to make their own food. So that's in the summer. Plants absorb carbon dioxide, yes? But what happens in the winter? Were you here in the winter? How did the trees look in the winter, in December? Were they green, no, they were bare they had lost, the deciduous trees had lost their leaves. That means that in winter they are unable to make their food, they are unable to photosynthesise. And therefore they don't absorb carbon dioxide in winter. So these annual fluctuations in carbon dioxide, with a maximum in one season and a minimum in the next, can be attributed to seasonal changes in rates of photosynthesis. So that's one little sort of explanation, added sort of, bit of information that comes out of that graph.

So this is a very important, what we might call a key image of the 20th century. Because it highlighted the fact that there has been an increase in carbon dioxide concentration over this period of time. And if you put that graph against the graph that we had earlier showing changes in temperature, you will see that they correspond to one another. So we can make a link between these increasing concentrations of carbon dioxide in the atmosphere, and increasing temperatures, global temperatures, which are being observed and measured. Not only does the Mauna Loa data show how atmospheric carbon dioxide concentrations have increased, but if we combine the data with ice core measurements, we get a similar pattern of increase. So this graph is showing here an outside concentration, here time going back to the 1700's in this case. Again we can see an upward trend in carbon dioxide concentration but most importantly, an increasingly steep upward trend in carbon dioxide concentration. And – well can anyone suggest why carbon dioxide concentrations are increasing in this period from the sort of mid 1800's? What is the source of this increasing carbon dioxide in the atmosphere? [member of audience replies – inaudible].

Absolutely. We are burning fossil fuels. And l the carbon dioxide that was locked up in these fossil fuels millions of years ago is now being released into the atmosphere and increasing the concentration of carbon dioxide in the atmosphere and as a consequence, because the carbon dioxide acts as a greenhouse gas, increasing global temperatures. So as we drive around in our cars we use oil, coal, all the fossil fuels, we are releasing carbon dioxide that was locked up in the earth's structure millions of years ago. We are releasing it into the atmosphere and that carbon dioxide, we can measure now, and we recognise that it is producing a warming effect.

Part 8

So, we have a link here between increasing concentrations of carbon… of increasing temperature, and increasing concentrations of carbon dioxide. Can you think of any other activities of humans that might be increasing concentrations

of carbon dioxide in the atmosphere? [member of audience replies – inaudible] Yes. Through the burning of fuels, absolutely, fossil fuel. There is one other factor which is important that goes back to biology - you see I'm a biologist by training, and I keep coming back to the importance of the natural world - and that is that as we cut down forests, we called that deforestation, as we cut down forests the trees are less able to absorb carbon dioxide in photosynthesis, and therefore the carbon dioxide that we are releasing through fossil fuels is not being re-absorbed by plants as efficiently. So as we cut down the Amazonian rainforest we are reducing the natural ability of the world to maintain its balance of carbon dioxide in the atmosphere. Does that make sense?

So there are two big factors, that… two… what we call anthropogenic factors. Do you know that word? Can anyone tell me what that word means, *anthropogenic*? It's a nice word. Do you know what anthropology is? Anthropology is the study of human populations. The word *anthropogenic* means *human related*. And a good way of describing the warming effect that we are detecting in the last hundred or so years is *anthropogenic* global warming, Global warming that can be linked to human activities, like burning fossil fuels, and deforestation, large scale deforestation.

So, we've made a link between increasing global temperatures, increasing concentrations of carbon dioxide, and human activities, so we can call that concept *anthropogenic global warming*. The global warming that has occurred in the last hundred and fifty or so years since the Industrial Revolution, since large scale burning of fossil fuels and deforestation.

Just to round this off, we should not forget that there are other gases other than carbon dioxide, that act as greenhouse gases; we have already mentioned methane, but nitrous oxide, CFCs, the things that we use in our refrigerators and air conditioning systems, and these other substances, other gases are also greenhouse gases. So you have that table in your notes as a reminder of other gases which we should consider with respect to this problem.

Because of course, now, we've recognised that global warming is occurring, we now have decided what to do about it, that's not what I'm going to deal with today, but it is the next question that needs to be asked. So, just in conclusion I would say that at the moment at the beginning of the 21st century, climate change is one of the biggest threats to humankind and it is your generation that has to deal with it and solve it. And that solution will require a political will, and good international relationships and co-operation between all the nations of the world. So you need to know how other people work, how they think, and there needs to be a single view as to how to solve this problem. OK, that's as much as I want to say today. It's ten to eleven, but do you have any questions or points you'd like to make?