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Confronting Climate Change

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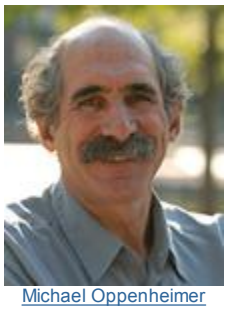
Michael Oppenheimer


Joanne J. Myers

Introduction

JOANNE MYERS: Good morning. I'm Joanne Myers, Director of Public Affairs Programs, and on behalf of the Carnegie Council I'd like to thank you all for joining us this morning.

Today our guest, Michael Oppenheimer, will be discussing **Confronting Climate Change**. Michael is a widely acclaimed scholar and policymaker, and I think you all will be fascinated by what he has to say.

As our planet continues to heat up, skepticism is finally beginning to wane about the effects of global warming and climate change. Even though these issues have become highly politicized, increasing media coverage has made them part of our mainstream dialogue. Today the reality of climate change is no longer a distant threat, but is seen by many as an imminent danger.

In February of this year, a report was issued by the Intergovernmental Panel on Climate Change. This panel was set up under the auspices of the United Nations to produce a global consensus on the science and economics of this pressing topic. Our guest this morning was one of the lead authors.

The report concluded that the warming of the Earth's climate system is unequivocal, and that human activity has very likely been the driving force in that change over the last 50 years. Additional data indicated that climate change is already having significant impacts on certain regions, particularly in developing countries and on most ecosystems. This study added new momentum to the debate that now seems centered less over whether humans are warming our planet and more about what can be done to slow down or stop this calamitous trend.

These findings come as a growing number of policy experts warn that environmental challenges are quickly emerging as the most important security threat in the 21st century, with the potential to affect every portion of the planet. For example, scientists expect global warming to trigger extreme weather events, such as long and intense droughts, which could imperil the world's food supply, as rising temperatures render fertile areas unfit for growing crops or for animals to graze upon.

Furthermore, increasingly frequent and violent storms could also produce flooding, tornadoes, and cyclones. Sea levels will continue to rise. Glaciers will retreat even further and snow cover will decline. And a warmer world could give rise to infectious diseases whose spread could affect thousands.

In the end, the advent of any one of these events may will represent a challenge to international security, perhaps just as dangerous and more intractable than the arms race between the United States and the Soviet Union during the Cold War. And, even though last week's participants in the 166-country, United Nations-hosted talks in Germany were still struggling to find a way to bring the United States and large developing countries to the negotiating table in an effort to extend the Kyoto Treaty, there is no better time than the present to make radically responsible decisions about how we are going to live on this planet.

While some will contend that there is a great deal left to understand about global warming and climate change, I would claim that what is needed is effective communication. By now we know that dialogue begins with finding the right people to convey the message. Today our guest, Michael Oppenheimer, is one such person.

Professor Oppenheimer is a visionary scientist who cares deeply about our planet. Although you all should have received a copy of this c.v., which I hope you have read, I would like to point out that his impact on the environmental movement and his concern for global warming and climate change is far broader than his c.v. might suggest, and his c.v. is extremely inclusive.

As this report concluded: "Climate change may threaten mankind, but mankind has a good chance of averting the consequences if it puts its mind to it." Professor Oppenheimer is doing just that.

It is a pleasure to turn the floor over to our guest this morning. Please join me in welcoming Michael Oppenheimer.

Remarks

MICHAEL OPPENHEIMER: Thank you, and thank you for inviting me here today. It's a little early in the day to land a heavy problem on your heads like this.

What I want to do is try to get you to understand why we arrive at the situation we do today, where, much to the surprise of many people, and probably at least a few of you, this issue has exploded in the public arena. Well, how did we get there, why now, and where did this issue come from? So I am going to give kind of a historical perspective to start out with and explain to you the origins of the issue, how it gradually became of concern to the scientific community, and why it has become a large-scale public concern today. Also, there is so much that has happened, I have to say that in order for me to be able to speak off-the-cuff about this, I have to do it historically, because that's the way I think about things, and it will help me present, I think, a more coherent story for you.

After describing where this issue came from, I'm going to talk a little bit about the recent scientific findings, which situate the question as our political leaders are viewing it right now, and then talk about the political context a little bit. And finally, how I expect the problem will be solved and where we'll go in the future.

So let me outline just what is this problem, what is global warming, and what is the greenhouse effect.

There are certain gases that exist naturally in the atmosphere—water vapor, carbon dioxide, methane, swamp gas, nitrous oxide (which you know as laughing gas)—which are transparent to sunlight. The sunlight comes through them and warms the Earth's surface. But those same gases trap some of that heat as it tries to radiate back into space, so they form kind of an invisible blanket. That's the greenhouse effect—and it's a good thing, because without the greenhouse effect, Earth would be about 60° F colder than it is today, it would be a frozen desert, and human life and much other life would never have evolved.

The greenhouse problem arises because human beings are adding to the levels of these gases, causing a buildup in the greenhouse effect, and that buildup inevitably will warm Earth. In fact, it already has. Earth is almost a degree-and-a-half Fahrenheit warmer than it was 150 years ago, when the first comprehensive global thermometer-based measurements of temperature were put in place.

Now, the existence of the greenhouse effect was postulated almost 200 years ago by the famous French mathematician Fourier. The notion that burning goal oil and natural gas, the primary sources of human-made carbon dioxide, would lead to a buildup in the greenhouse effect and an inevitable warming of the Earth was asserted over 100 years ago by Svante Arrhenius, who is a Swedish scientist who won the Nobel Prize for something entirely different, the ionic theory of liquids as solutions, in either 1901 or 1903.

I recognize some of my Swedish friends are in the audience, and they may have heard this story. I knew Arrhenius's grandson, whose name was Erik. He worked at the World Bank some years ago. He talked at some length about his grandfather, who he said was a black sheep in the family, despite winning the Nobel Prize, because the greenhouse theory was regarded as a totally crackpot thing, and he was an embarrassment, despite his fame in the scientific community.

Nevertheless, time has proved Arrhenius to be correct. But it took a long time, because between the time he discovered the greenhouse theory and the mid-1960s only a very, very, very small handful of scientists ever worked on, thought about, or mentioned it. Most scientists never heard of it. Most average people, of course, never heard of it. It was totally arcane and irrelevant to the main business of thinking about climate. I'd say the number of scientific papers on the idea of global warming between 1896, when Arrhenius did his work, and the mid-1960s was maybe 10 or 20, that's it.

In the mid-1960s things changed. What happened? Two things happened. First of all, the first high-speed computers became available and people were looking around for things to do with them. One of the things that happened was that human beings, because of all the problems that were always occurring due to weather, decided they needed a way to predict the weather better than they had. Previous weather prediction basically was

based on looking out the window, or a sophisticated version thereof, but still not much better than that.

Well, you can't look out the window to project something like global warming. It's just too far ahead and the details are too complicated. So in the mid-1960s a couple of groups, particularly one at Princeton, started working on applying high-speed computers to creating what are called models or simulations or approximations of the climate, where you could actually put down all the physical equations for how air moves around and how it is heated by the sun, et cetera, and predict what the climate will do. These were originally conceived of as weather-forecasting models; that is, what's going to happen over the next few days. Climate is average weather over the long term.

One of the scientists began asking the question of: What happens if you tweak the basic contents of the atmosphere? Starting in 1957, a scientist had started to actually measure carbon dioxide atop a mountain in Hawaii and provided the first evidence that carbon dioxide was actually building up. Previous to that, the reason most people had disregarded the greenhouse theory is because they knew that the ocean can absorb dioxide, and the ocean is so vast it was assumed that most of the carbon dioxide that humans produced by coal burning would just dissolve in the ocean and disappear, and therefore that Arrhenius was wrong. But [Charles] Dave Keeling started these measurements in Hawaii and proved that carbon dioxide in fact was building up, that humans had to be the cause.

So come to the 1960s, and the computer analysts started looking at this data and putting it into their computer models and trying to ask "what will this do to the climate?" And, lo and behold, the modern computer simulations verified that Arrhenius had been correct 70 years before, and that a warming of, they reckoned, 4° F would occur eventually if the amount of carbon dioxide doubled in the atmosphere.

In the 1970s it was discovered that other gases could contribute to this problem. As I said, methane. A lot of methane leaks from natural gas pipelines because methane is the major component of natural gas. It is produced at the bottom of swamps naturally, but it is also produced, say, at the bottom of a landfill because the same anaerobic conditions exist. It's a byproduct of various agricultural activities. I could go down a list of other gases, but all of a sudden there was a whole bunch of gases that contribute to global warming.

Governments started to get interested in the late 1970s because, if you remember the last time we were worried about an oil supply disruption, at that time there were suggestions, as there are today, to start making oil out of coal, synthetic fuels, as the Nazis had done during World War II. It turns out that to do that you actually have to put in as much energy as you will eventually get out of the liquid fuel you produce, which would double the amount of carbon dioxide. So all of a sudden, there were some scientists running around who had these new computer simulations in their pockets saying, "That's a bad idea."

That first got the attention of government officials. It got the attention of somehow—and I don't know how—Helmut Schmidt, who was then the Prime Minister of Germany. It got the attention of Abe Ribicoff, who was a senator from Connecticut you may remember. And it got the attention of Gus Speth, who was head of Carter's, who was then president, Council of Environmental Quality.

That started a whole process, which I won't go into the details of, that got the National Academy involved, the Congress involved. Al Gore, who had been worried about this problem from an academic point of view since he was in college, started holding hearings. The late Senator Paul Tsongas actually held the first hearing, I think in 1977, in the Congress.

Some political activity started, but it was still at the level of "this is just a theory," until 1985, when scientists got together under UN auspices as a group. There were by then hundreds of scientists who were interested in this problem. Most of them don't care about politics, don't want to know about political leaders, look askance at the whole business of public decision-making—just it's got nothing to do with them.

But a bunch of them were what you might call instigators—or, nicely, in the political science literature they're called "policy entrepreneurs"—and they brought their colleagues together at a big meeting in Austria where there were several hundred scientists. They came out with a rather remarkable statement that said: "Global warming is a real problem; it's going to get worse; and"—and this is the most interesting part—"that the past has always been regarded as a guide to what we should do in the future, to what climate is going to do, but in fact the past is no longer a reliable guide to the future. You can rip up all your information about what the climate has done in the past. So, for instance, insurance companies' rating for hurricane frequency: forget it, it's all going to change. And, most importantly, the government should go ahead and negotiate an international treaty to limit global warming." It's a very powerful statement for scientists to make.

A couple of years later, scientists drilling in the middle of Antarctica, an international French/Russian team, were drilling with a device that looks like an oil rig. They pulled up cores of ice by drilling deeper and deeper. The center of Antarctica is about 12,000 feet deep; there's that much ice over the continent. They pulled up this huge

core, and in the core there are little air bubbles. The reason there are air bubbles is because ice is formed from snow, and when the snowflakes form—you know, think about it—they have points that go like this and air gets trapped. If you look at an ice cube, after all, which is formed from a somewhat different process, it's got air trapped in it. Same thing. That's what an ice core looks like.

They pull this up, and they take it into a clean room, and they shave the ice away under pristine conditions and they release the air in the bubble. It turns out the air has the same properties that it had when it was first laid down. How old is that ice? The ice at the bottom of these ice cores now turns out to be over 700,000 years old. So all of a sudden, we had out of nowhere a record of Earth's atmosphere from 700,000 years ago and forward. The original core was actually 125,000, then they found an older one of 400,000, and now over 700,000.

When you look at that air, what you see is the carbon dioxide and the other greenhouse gases went up and down over time and that Earth's temperature went up and down in perfect correlation. This was a tremendous substantiation for the scientists that carbon dioxide, methane, et cetera, were related over time. The cause and effect was complicated, and it's still not fully understood, but what we do know is you cannot account of the changes in Earth's temperature over the last 700,000 years unless you include the greenhouse effect as one of the driving forces.

The reason climate changes naturally is Earth's orbit changes periodically over thousands of years, tens of thousands of years. This changes the pattern of sunlight on Earth's surface. That pattern of sunlight affects the way trees use and release carbon dioxide, and that changes the greenhouse effect.

What we also saw over that period of time is that Earth had never been much warmer in that 700,000-year period than it was today. We're in a very warm period. The cold periods are called glacial ages, where ice was 1,000 feet thick over here, for instance.

Number two, it turns out that carbon dioxide is much higher now than it ever was in the whole 700,000-year period. The carbon dioxide level is now almost 0.4 percent of the atmosphere's total content. It has never really been higher than about 0.3 percent. So it is about 30 percent higher than it has been in 700,000 years. That was another indication that the temperature must inevitably increase.

The last time carbon dioxide was this high was about 20 million years ago, and 20 million years ago it was a much warmer planet. The last time it was as high as it's projected to get by the end of this century—if we do nothing about the emissions, the climate will be equivalent to what it was 55 million years ago. Fifty-five million years ago was almost as far back as dinosaurs were dominant. Earth was semi-tropical to tropical. There were no ice sheets. If that happened today, sea level would be hundreds of feet higher.

So there is a strong case that we are headed in a direction which will remake the face of the Earth. It has happened before, but it happened over tens of millions of years. We're going to do all that in the course of 100 years if we don't stem the emissions of these gases.

During the 1990s there was tremendous progress. All of a sudden, there were thousands of experts involved in this problem. It grabbed the attention of the scientific community. By the mid-1990s, we were able to demonstrate, through very sophisticated computer techniques and other methods, that most of the warming to date is likely due to the buildup of the greenhouse gases. That is, the fact that Earth is more than a degree Fahrenheit warmer today than it was 150 years ago is likely—in fact, very likely—due to the fact that we are putting all these gases into the atmosphere.

A second thing happened starting in the late 1990s, which is only sort of coming to full fruition today and has a lot to do with the reason that your attention is on this problem. That is that the actual changes in the climate that that 1.5-degree-or-so warming is capable of bringing about have started to become so large that they have been noticeable, not just to scientists, but to the average person in the street. It's hotter. There are more heat waves. There's less very cold weather. Hurricanes are more intense. Drought is more frequent in certain parts of the world.

Perhaps most troubling over the long term, the sea level is rising. It has risen about seven inches over the past century. Most of that rise is due to the greenhouse gas buildup. That may not sound like a lot, but on a typical East Coast beach here, if you raise sea level by one foot you take away 100 feet of land inland due to submergence and erosion.

So big changes have already begun. The climate is already changing. Really the question today is: How fast can these political systems mobilize themselves to stem the warming, to reduce the levels of the gases, so we don't get into a problem where we have such a large, fast warming that we simply cannot cope?

What do the projections show today as far as the possible level of warming? There's a lot of uncertainty about

how much Earth could warm. The uncertainty is basically for two reasons, and I think it's pretty easy to appreciate why this is the case.

Reason number one: In order to understand how much it is going to warm, you have to understand how much of this gas is going to be building up in the atmosphere over the next century. How do you do that? Well, where do these gases come from? They come from cars, they come from using electricity, they come from cutting and burning trees (deforestation is an important component), they come from heating your home, they come from air conditioning, they come from industry. A lot of stuff.

Why does that activity happen? Well, it's all driven by the rate of population growth—more people driving more cars, using more refrigerators, cutting more trees for agriculture, and so forth.

It's driven by the technology we use. You tell me. In 100 years, are we going to be driving cars? Is everybody going to have their own personal levitation device? How is it going to be powered? Is it going to be powered by gasoline, hydrogen, solar energy? I don't know.

How many people are going to be on the surface of Earth? When I started with this problem 25 years ago, the projections were we'd reach 15 billion. Now they're down to about 9 billion. And that's good news, by the way. There have been big changes in fertility in most countries.

How do you project? Well, what you do is, because there's obviously a lot of uncertainty, you get a bunch of experts in a room. Shell Oil is actually the company that pioneered this method. You lock the room. It's dark and there are no windows usually. It's usually a sunny and nice day outside and you'd really prefer to be somewhere else. You lock these people in a room for a week or so and you say, "Give us some scenarios, give us some possibilities." That's what has been done.

The possibilities range like this: from a modest growth in emissions to a huge growth in emissions. I won't give you the numbers. It's not worth thinking about. You can find them by looking at these reports from the Intergovernmental Panel on Climate Change. So that's one source of uncertainty.

The other source of uncertainty is these wonderful computer models we've been building for 40 years are still nowhere near up to the job of precision that they would need to be to fully accurately project the climate for the future.

Let me tell you the main reason. The climate system is very complex. As you warm Earth's surface, you warm the oceans. As you warm the oceans, you put more water vapor in the atmosphere. Water vapor itself is a greenhouse gas, but in addition it forms clouds. Clouds can either reflect sunlight—the low, heavy clouds, fog-type clouds, reflect sunlight—but the Sirius clouds, the light, veil-like clouds that you see coming in ahead of a cold front, actually trap heat just like greenhouse gases. We don't know, and we cannot really accurately say, whether we are going to get more of this kind of cloud or more of that kind of cloud and whether we'll get more of this kind of cloud near the equator and more of that kind of cloud near the poles where there's less sunlight and it matters less.

It's a mess, and it is not going to be resolved quickly. So there is a big uncertainty in what's called the sensitivity of the climate. When you combine those two uncertainties, over this century we will either have, at the low end, a modest warming of about 2° F, which would mean higher sea level, more intense storms, more heat waves. But, for a country like the United States, it would be manageable. For many developing countries, it will still create terrific problems, particularly along the coast.

At the high end, you would have about an 11.5° F warming, if these projects are correct, which most of my colleagues think is a out-and-out disaster, so much warming so fast we would not be able to cope with it, even in a rich country like the United States, much less in developing countries.

We could get either end or we could get anything in between. I can't tell you which. I'm not even able to rank the probability. I can just tell you this is what's called a risk management exercise. We have to deal with the fact of the reality of the warming but the reality of the uncertainty.

Now, why has this issue gotten such public attention lately? Actually, the global political system has been working on this problem since 1992, where at the Earth Summit in Rio, countries, including the United States, signed and ratified the UN Framework Convention on Climate Change, which was a voluntary agreement to begin the process of reducing emissions. The United States actually ratified that treaty unanimously in the first Bush Administration. It has been a long time since we've ratified an environmental treaty.

That was followed by the Kyoto Protocol, which was a child of the UN Framework Convention on Climate Change, which has been ratified by all industrialized countries, except the United States and Australia, and of course is

being implemented in Europe to greater or lesser success, and is providing a model for how you move forward on this problem. It is not going to solve the problem, obviously, particularly without U.S. participation, and certainly without the mandatory participation by big developing country emitters, which the Kyoto Protocol does not envision. But it was always envisioned as an experiment and a first step to start seeing how we could reduce emissions effectively, and that it has been. It has taught countries how to move forward.

What happened in the last few years is that the public finally got onto this issue. The reasons for that are not fully understood. Academics will write papers about this five or ten years from now, when it will no longer be of interest to anybody because the world will have moved on. Eventually we'll understand it.

But my view is—I think others see it more or less similarly—that we had a couple of very bad hurricane seasons at the same time scientists were able to say hurricanes were becoming more intense due to global warming. Although those hurricanes may not have been affected—as a statistical thing, you can never really say—it made clear what the scale of damages can be and how climate events are very hard for humans to deal with, even in a sophisticated society like ours.

In that way Hurricane Katrina was a monument. It was an incredible symbolic event because it showed—I cannot tell you, because I feel it in the depths of my heart—how incompetent government has been at all levels at anticipating the problem; protecting people from it in advance, a situation they knew would eventually happen; helping them during the event; and then, even to this day, helping restore that city. No one would have predicted that in this day and age half an American city would disappear overnight and be still disappeared a couple of years later. Unbelievable, just unbelievable. That's a learning experience for all of us on how difficult it will be to deal with this problem if we don't get it under control first.

The second thing that happened actually happened two years before. In Europe a large heat wave occurred in 2003. Forty thousand deaths are attributed to that heat wave. Again, it was an unusual event. It was not so clear it could have been anticipated, but the fact that once it got going governments were incompetent at all levels to deal with the potential fallout was an astounding lesson to everybody.

If you had asked my colleagues in the scientific community before that event "How many people could die if we get one of these large heat waves?" they would have said "a few hundred."
So this just shows you how we can't even imagine the sorts of things that really are going to be plausible in the world we are going into.

Another thing that happened was the pictures constantly occurring about the melting of the Arctic, about the threat to polar bears, which is an iconic species for a lot of people. The energy price rise that started to happen put people's attention on the whole fossil fuel problem. Al Gore's movie and other high-quality productions that were starting to happen at that time grabbed the attention of the public through the media. And then there was a political change in the United States.

All these effects—there are probably a few others I'm forgetting—fed back on each other. All of a sudden, there's a moment that has arrived where the public's attention is on the issue, where politicians' attention is on the issue.

At the same time, there is a tremendous amount of political energy that has been released because of the vacuum in Washington, where states have moved ahead to develop their own restrictions on greenhouse gases—not just California, which you may have heard of, but also there's a compact among Northeastern states, and about 25 of the states in the United States actually have a planning process in place. Many of those actions will lead to greenhouse gas limits.

This is a classic picture in the U.S. regulatory system. Frequently—not always—activity starts at the state level. Then, frequently, the business community, which doesn't want to see 50 different kinds of regulation, goes to Washington and says, "Help. Do something." I think that's what we are going to be seeing.

All of that has been facilitated by a monumental Supreme Court decision about six weeks ago, which not only validates some of these state actions, I think indirectly, but also gives states and perhaps individuals standing to go into court to sue the emitters. This will create chaos in the political system eventually, much as the asbestos lawsuits created chaos in that industry. I think that again is an additional pressure.

So my personal belief is we are going to see action very, very soon in Washington on the greenhouse gas problem because there are too many things happening from too many different directions.

At the same time, the Kyoto parties are moving to negotiate what ought to be the new Framework for beyond the conclusion of the Kyoto Protocol process in 2012.

I think, again, these events are going to come together. What I anticipate is the United States is likely to

implement a serious domestic program at the federal level over the next two years. That problem will allow the United States to go back into the international negotiations eventually and claim that it is now the world's leader on climate change—which it may very well be by that time—and will facilitate an eventual grand bargain, which will involve the developing countries. I think the United States will start to try to engage developing countries, like China, even before they march back into the negotiations.

So an optimistic view—and I am an optimist—is that we are at long last on the verge of really grappling with this problem in a comprehensive, first national way, and then a global way.

Will things happen that we don't want to see happen? Yes. Because there are big uncertainties, are there risks of big changes, like the loss of big chunks of the ice sheets and a spectacular sea level rise, big changes that maybe can't be avoided, or will we cross some tipping point we didn't even realize? It's possible. I'd say the chances are quite a bit less than 50/50 at this point. I think that every year that we wait and add emissions to the atmosphere the chances grow. If we do nothing for the next 10 or 15 years, I think the chances are we will miss one of those tipping points and we will have truly unfortunate consequences.

But we do have this chance, and I think we will likely grab it. I was born an optimist, and I could be wrong, but that's the way I see it now.

Thank you.

Questions and Answers

QUESTION: I'm so happy that you're both honest and an optimist.

MICHAEL OPPENHEIMER: I didn't say I was honest. I said I was an optimist.

QUESTIONER: Well, it sounds like you were honest, because you're presenting a range of possibilities. When one presents these catastrophic possibilities, of course it's very upsetting, and what price do you pay or where do you go? I just wonder, as an intelligent person trying to keep up with this—we read various reports from some scientists who really have evidence that in the billions of years the planet has been going, et cetera, et cetera, from the Al Gore movie that has had a lot of criticism—how do we distinguish, as nonscientists, where the truth lies in this very exaggerated series of disputations?

MICHAEL OPPENHEIMER: First of all, let me just say on Al Gore's movie, because I'm always asked about it, I've seen hundreds of academic presentations by renowned scientists on this issue, and I have to say that Gore made no more, and in many cases fewer, mistakes in that movie than I've seen many scientists make. It is not possible to talk about an issue that is so broad, that covers so many areas, and get everything right. I saw the movie three times. I picked up one thing that I really thought was flat-out wrong.

He said a few things that I would have said differently and that some scientists would have said differently, but I've seen a lot of scientists give that presentation and they've all got their view and they've all got their pitch. Nobody is without a view, and that's fine.

So that's just on that issue.

In terms of how you judge, there has been a lot of noise in the public space about this problem, and it does not represent any big difference in the scientific community. What it represents is that, as with any complex problem, there are always some people who for honest reasons have a different opinion. It's always true of every scientific problem.

There's a famous biologist who still thinks that AIDS is not caused by HIV, and he talks about it publicly and frequently. That doesn't mean he's right.

So the government set up these assessment panels to try to figure out where the weight of the community is. The National Research Council of the National Academy of Sciences reports frequently on this problem. The United Nations set up the Intergovernmental Panel on Climate Change to report on the problem. This stuff is all freely available, and actually written in something that approaches laymen's English, parts of it anyway. You can go the websites, you can read it yourself, and you make your own judgment.

I can just say that there are about 2,500 experts that are entrained by the Intergovernmental Panel on Climate Change, and they actually entrain the critics also. If there are 2,495 that think this and five that think this, then you make your own decision. Scientists can be wrong. But it's a risk management exercise. Judge for yourself who you'd rather listen to in making your decisions about what the right way to go is. That's what governments are supposed to do.

QUESTION: I just attended a conference all day and part of the evening called Forum of the Americas, and the theme was sustainable development. You added insights that didn't even show up in that conference, so I thank you for that, particularly the historical business you gave us.

But I was surprised that you said that the time would come when we would renegotiate the Kyoto Treaty to take effect when it expires in 2012. Why not elect Gore-Obama and get started in two years and put it into effect much sooner?

MICHAEL OPPENHEIMER: Obama might think it should be Obama-Gore, for instance.

First of all, the Kyoto Treaty. I didn't say "renegotiate the Kyoto Treaty." Kyoto is finished. The United States didn't participate.

QUESTIONER: What is 2012?

MICHAEL OPPENHEIMER: 2012 is the date which is the completion date. The countries that are participating in Kyoto have to do what they promised to do by that date. Some will meet it. Some will not meet it.

The issue politically on the international stage is: What do we do afterwards? If Kyoto is a first step, what's the next step? That's what is being negotiated.

I didn't suggest that we should wait until then. In fact, the U.S. political activity is moving ahead now.

California is implementing these regulations. The most interesting one would reduce emissions from their cars basically beginning with the 2009 model year. They were sued by the auto manufacturers. The auto manufacturers' suit had the legs were cut out from under it by the Supreme Court decision. They still have to get permission from EPA [Environmental Protection Agency]. They were down there this week—there was a story in the paper today—asking EPA for what they need, which is a waiver. If they don't get the waiver, they'll sue EPA. It's going to happen eventually.

QUESTION: If I understand you correctly—this is maybe not a very intelligent question—there are waves anyway. Over a long period of time, the world warms up and gets colder. I take it that in most of the previous hundreds of thousands of years there was no global policy there. So could you tell us a little more whether there is an analysis why it turned back and forth from warmer to colder? Are there self-corrective mechanisms somewhere that do make those changes back?

MICHAEL OPPENHEIMER: Excellent question.

The reason the Earth went through waves, as you put it, of warming and cooling over long periods of time had to do with these changes in Earth's orbit that I talked about. Earth's orbit has three different cycles at least—actually more—that it goes through. They have to do with the tilt of the axis of rotation, for instance, compared to the plane at which it revolves around the sun. That's one of the changes in the orbit. There are two other prime ones.

QUESTIONER: How does that alter them?

MICHAEL OPPENHEIMER: There are several theories about how that generates changes in Earth's climate. There's no doubt that it does, because the timing is just too perfect over, as I said, 700,000 years.

One theory, for instance, is that when Earth's orbit is in a particular inclination, the amount of sunlight reaching the Southern Hemisphere in their summer increases the pattern. And we know this; this does happen. The theory then is that that, for instance, increases the production of algae at the ocean's surface. There is a particularly rich area with a lot of nutrients where algae get produced. That algae production—of course, it's photosynthesis —sucks carbon dioxide out of the atmosphere. When the algae die, they sink to the bottom of the ocean. That means there's less carbon dioxide in the atmosphere, a lower greenhouse effect, and Earth starts cooling. When the Earth starts cooling, ice sheets start expanding. The ice sheets reflect sunlight because they are more reflective than the ocean or land that they cover. That's called a feedback. Earth gets get cooler. Further cooling further enhances the process. All of a sudden, you're in an ice age. That's one theory about how these orbital changes trigger the changes in climate.

Then it reverses itself. Earth's orbit goes in these regular cycles, we know that for sure. It changes the pattern of sunlight, we know that for sure. All of a sudden, the intense sunlight in the Southern Hemisphere during the summer starts switching and goes to the north. The carbon dioxide metabolism changes. Carbon dioxide is released back into the atmosphere by the ocean. The Earth warms again.

Those kinds of changes, which happen over tens of thousands of years and are triggered by changes in Earth's

orbit, are not what's going on now. What's going on now definitely is that the greenhouse gases are building up due to human activity, not due to these biological changes. There is nothing to reverse that except us reversing emissions.

Nor do we know of any limit in the climate system that would stop the warming. There could be one. Maybe when we get to 4-5 degrees warming there's something that happens that we don't know about. There's a lot we don't know. But we can't make policy based on a hope.

QUESTION: Thank you for being so comprehensive and enlightening for lay people. Your students are very fortunate to have you.

MICHAEL OPPENHEIMER: Thank you.

QUESTIONER: Two areas that need more explanation.

One, you've given us an example of how the democratic system in the United States can have a positive effect, if enough people talk about it and get to the politicians, the business people, and so forth. What about China, which has an enormous problem that affects everybody else and over a billion people?

Secondly, could you touch on alternative fuels and the possibilities, the Brazilian example and so forth?

MICHAEL OPPENHEIMER: First of all, let me answer the second half first. How would we solve this problem if we set out to do so?

Most analyses indicate that we could increase the efficiency with which we use energy, and therefore decrease the energy sector's contribution to greenhouse gas emissions, by about 20 percent. There are different views on whether it would cost anything or would be purely cost-free, because the extra investments at the front, like in more-efficient high-fuel-economy vehicles, pay back because you use less gasoline, for instance.

There are hundreds, maybe thousands, of individual steps like that that can be taken. The reckoning is over the next 30 years, 25 years, we could increase the world's efficiency by about 20 percent compared to what it would otherwise be by taking such measures. We just have chosen not to do so. Price of fuel isn't enough of an incentive. You need government action.

At the same time, switching to lower-carbon-content fuels, if the supplies are available, and it's not clear. An increase in natural gas usage temporarily to replace coal is one suggestion.

Another suggestion is an increased used of nuclear power to generate electricity. I myself think expansion of nuclear capacity at this point is a bad idea because we haven't solved the waste cycle problem, with the concomitant possibilities of diversion of fuel for nuclear proliferation and the targeting of nuclear power plants by terrorists. Those are solvable problems. It's just that we haven't solved them. I don't think they're going to be solved for several decades. So I actually don't think in the United States that expansion of nuclear power is a short-term solution, though it may be a long-term solution.

In the long term, when you get to replacing existing generation with new technologies, you're talking about an enhanced development of solar energy, and possibly a solar-hydrogen economy where hydrogen is generated from solar energy and piped around for people to use in factories, etc.

In the short term, one particularly promising alternative in the China context and the U.S. context is what's called carbon capture and storage, trapping carbon dioxide before it gets into the atmosphere from power plant stacks and burying it deep underground in reservoirs called deep saline aquifers of expended oil wells. That's a technology which we're finding out a lot about fast and could solve about a third of the problem.

On China, I actually have—again, I can't help it, and maybe I'm wrong; maybe I'm a Pollyanna—I have a more optimistic view than some have.

First of all, going directly to your point about political response, there is a developing public sector or civil sector in China with a strong environmental movement at the local level that the government is actually starting to listen to. China has terrible air pollution problems. It is not too much to imagine that the agenda of cleaning up the air pollution problem, together with the growing concern at the official level in China about their exposure to climate change and sea level rise, which is starting to penetrate at the highest levels of government, will come together and converge in a solution eventually which would change the incentives and actually see decreasing—maybe not decreasing coal use, but decreasing rates of growth in building coal-burning power plants and some serious examination of alternatives.

So I think China may be where we were 40 years ago, when we hadn't even touched our air pollution problem. We then got serious about it and started to do something about it. If you had asked people in 1950 or 1960, "Are we ever going to clean up the air? We're dying"—people would have said, "They'll never come to grips with it." Well, we did. These are problems that can be come to grips with.

The expenses are not that great. We're talking about a tenth of a percent, or maybe less. Some people think the net cost is actually negative; that is, you save money by doing many of these things. We just don't know.

I think China will come to grips with the problem, but this is not something that's going to happen overnight. If the United States doesn't lead the way and show that it can be done, I think China is less likely and will be much slower to try to come to grips with it.

QUESTION: There seems to be much more talk in Europe about using some form of a carbon tax as part of an approach to this problem, and there seem to be all kinds of different notions of what that means and what that could do. Do you have any views about whether this kind of an approach is going to get anywhere in this country?

MICHAEL OPPENHEIMER: In terms of policy instruments, the United States actually has a long experience with dealing with energy and effectively limiting greenhouse gases. For instance, the best-known example is the Corporate Average Fuel Economy standards. When you buy a motor vehicle, it has to get a certain mileage, or at least the fleet average has to get a certain mileage, or else the manufacturers pay a fine. A modernization and enhancement of the Fuel Economy standards is one thing that probably will be done.

Number two, when you buy an air conditioner or a refrigerator, those appliances have to satisfy standards set by the Department of Energy for electricity use and, therefore, for greenhouse gases coming out of the power plant indirectly. Those standards are upgraded regularly, except in the recent Administration, which stopped doing it. There is no reason those standards can't be toughened and the process accelerated, becoming yet more efficient. A typical refrigerator is three times more efficient than it was 30 years ago. That process needs to continue.

But to bring all these measures together there is another proposal, which is for a cap-and-trade system—that is, limit emissions of greenhouse gases; give producers of the fuels, for instance, emissions allowances; and allow them to be traded so that the companies that can do the reductions cheapest have an incentive to find new technologies to do so. The companies that can't do it as cheaply buy an emissions allowance from someone else. But the cap is always descending, so emissions are going down. That was used in Title IV of the Clean Air Act of 1990 and has been very effective in cleaning up the sulfur dioxide/acid rain problem.

Then there's the possibility of taxes. Taxes are an effective instrument, just like a carbon cap would be. The trouble is they're a politically difficult sell in this country. I was just having this discussion here at the table. The last time we tried to do a tax related to energy use was in 1993, and Clinton got his head handed to him for doing it. It's one of the reasons, it is believed, that the Democrats lost control of Congress in 1994. That has not been forgotten. It's not an easy political sell.

It doesn't matter in a way, because a carbon cap is as effective as a tax, but it is possible that a tax will eventually—you know, the U.S. political system may grow up in some way and we may learn to swallow more taxes. I don't know. I wouldn't bet on it for this round. Maybe for a future round.

One thing I say is not going to happen. Some people have talked about a rationalized international tax on carbon. That's not going to happen. I'll take any bet on that.

QUESTION: My question is more about the role of the consumer and the role of the market in terms of stopping this environmental degradation. You've spoken a lot about government initiatives, but it just seems to me in a lot of what I've been reading lately is the role of entrepreneurship and the educated consumer who wants to buy products that are environmentally positive, or whatever you want to say. It just seems to me that it's actually the market taking the lead and the government following the consumer.

MICHAEL OPPENHEIMER: Yes, certainly, that's a strong element of what's going on, and the big burst of excitement we've had over this and other environmental issues. It's a revisitation of something that has happened periodically before over the last few decades.

I want to say some elements of the private sector have been in some sense been quite progressive on this issue, and have for a long time pressed for greenhouse gas limits. The private sector is split in three parts.

Some firms—particularly some electric utilities, plus du Pont, more recently GE [General Electric], and some other companies—have pressed the government to actually do something about the problem, partly because they have reduced their own emissions, partly because they've got some new technologies which they think they're going to get an advantage from in a carbon-constrained world, partly for other reasons.

Then there's another group in the middle, which is the big body of companies, which are cautious, resistant to any change, don't take a public position on it, and, particularly with a hostile administration, haven't wanted to say "this is a good thing to do."

There is a third, shrinking group of companies which has taken the lead in propagating the views of this handful of scientists that there's really scientific controversies on this. These are the kind of "black hats," the most famous one of which is Exxon, which recently has claimed that now they believe in the problem and they're not going to spend money on this sort of activity anymore. We'll see.

But beyond that there are the consumers, and the consumers have gotten interested in this problem all of a sudden. There are things that people can do. It's a good idea for individuals, including yourselves, to do this sort of thing because it gives our leaders—who really don't lead, they follow—the courage to go out and pass laws that actually solve the problem.
Individuals aren't going to solve it, but they can prove that it can be done without great pain.

You hear a lot about compact fluorescent bulbs. Yeah, they work. Buy the bulbs. You hear about hybrids. Yeah, they work. Buy the hybrids. Look for the Energy STAR sticker, the EPA sticker, when you buy appliances. All that helps. It's not going to solve the problem, but it's one brick in the wall, and an important one.

QUESTION: On that note, if the individual level is not going to solve the problem, does the country participation or consciousness solve the problem too? My homework last night for this breakfast meeting was I was reading *The Lorax* with my two-year-old son. For those of you who don't know *The Lorax*, it is a classic Dr. Seuss book [about the environment].

So I started thinking about this environmental issue. One of the things that was concerning is when you think about this in a global context it reminds you of the parable of *The Tragedy of the Commons*, where we all individualistically act in our own self-interest.

You commented earlier that there's not going to be any international tax or regulatory or governing body. Do we ever actually address this problem, or is there a free-market way to address it? I work at Lehman Brothers. We're thinking about market solutions, so anything other than a market solution is some sort of an inefficient, short-term fix.

MICHAEL OPPENHEIMER: I think the answer is that you need both. A market doesn't exist without scarcity, and scarcity doesn't exist unless the governments get together and say there's going to be a limit on this stuff. That's when approaches like carbon trading become important.

I think it's very important with this problem not to make the mistake of thinking governments are going to mandate particular technologies. That would be a disaster. The government—our government, at least—has a terrible track record in the energy area of coming in and suggesting particular ways to go, like synfuels or like breeder reactors. They made mistake after mistake.

That doesn't mean the government shouldn't act. It means the government should take a step back, have a hands-off approach at the most general level—for instance, a carbon cap—and then you let companies decide what they can do. There's the little tricky question of how you allocate the permits, which is interesting, which is another discussion.

But your question really goes to international coordination and can you do it unless countries get together. There are many views on how to do this internationally.

There's the centralized view, which is embodied in Kyoto, which I believe in, which is that you really need a firm agreement which has specific targets and timetables. Otherwise, countries will never do what they're supposed to do, they'll never live up to it, we'll never get the coordination. I think that works. I think it will work.

There have been tougher problems solved. When I was a kid, we thought we'd get blown up in the nuclear exchange between two countries that couldn't stand each other. To me the problem of the United States and China and greenhouse gases is nothing compared to that problem. Somehow we've managed to survive at least this long without doing it.

So this greenhouse problem, it's nothing. It's like solving the air pollution problem, as far as I'm concerned, on a somewhat bigger scale. It's affordable. The politics are manageable.

The real difficulty, I think, is less at that level than domestically, where we have interest groups, where we have cross-cutting interests, where, in spite of the fact that solving the problem might be an economic good on the

whole, actually reduce energy dependence and so forth, it will certainly hurt certain constituencies, and those constituencies are powerful, will not let go easily.

So to my mind getting international agreement is less problematic in a way than the difficulty of getting in the United States the political deal that is going to move us forward. But, as I said before, I think that's on the verge of happening.

QUESTION: I'm a climatologist as well. In my view, the climate change problem—the temperature is one issue and sea level is one, but really the big one is the hydrological cycle, the changes in the cycle, and the impact on the food production in particular. Could you comment on this?

MICHAEL OPPENHEIMER: Yes. I'm glad you raised that.

One of the robust findings of the climate simulations is a drying in the tropics to sub-tropics in both hemispheres. You have a band of countries, ranging from Mexico, parts of sub-Sahara Africa, around the world at that latitude, and a similar band in the Southern [sic] Hemisphere, where there is projected to be less precipitation. Even though the atmosphere as a whole is going to get moister, the moisture is biased towards the higher latitudes when it falls.

In addition, the warming itself dries things out. So even in some places where you're going to get more precipitation, it will actually be dryer in terms of less available water for runoff, for drinking, for agriculture, because water will be re-evaporated before it has a chance to be used by human beings.

If you look at the projections for availability of water in some of these low-latitude developing countries, you have a very, very, very grim picture, and it affects food production. A lot of these areas are areas where malnutrition is endemic and starvation episodically occurs, even though we live in a world where there is on the whole enough food for everybody. We could still have 50-to-75 years from now plenty of food on the whole but more malnutrition and higher levels of episodic starvation in many of these low-latitude countries because they can't provide for themselves because the runoff isn't there. And the drinking water is getting shorter in supply too.

It's not just them. If you look at the predictions in this country, you see the same thing happening in Southern California and the Southwestern United States.

This problem and the sea level rise problem are to my mind the biggies that need to be dealt with. Again, these models are uncertain at the regional level. It's a risk management exercise. But if you look at the risks and you think about a world with almost twice as many people and a good chunk of them getting even less food than today, that's something you really need to think about when you think about international stability. So yes, it's a really big problem.

JOANNE MYERS: Thank you so much. You really made today special.