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TRANSCRIPT

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Global Warming: Intellectual History and Strategic Choices

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RESOURCES
FOR THE FUTURE

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I'm here because I loved Hans Landsberg. I served under him twice. He was an excellent analyst, but he was a superb leader. And he led by example. He was modest, courteous, friendly, and whenever a meeting appeared to be getting out of hand, instead of raising his voice, he spoke very softly. And pretty soon, we all emulated him, and things went quietly from then on.

If he were here today, he and I, and a few people in the audience, would have a very friendly laugh over the item that I think all of you have which refers to *Energy: The Next Twenty Years.* That's one of the projects on which I served with him.

There was also the book, *Nuclear Power: Issues and Choices.* I looked at both of those books – the nuclear one was published in 1977. *Energy: The Next Twenty Years* was published in 1979. The nuclear book, out of 400 pages, had two pages on carbon dioxide (CO_2).

If a book were published today called *Nuclear Power: Issues and Choices*, half the book would be on nuclear safety and half the book would be on the greenhouse problem. The whole point of nuclear energy today, [it] would be argued, is that nuclear power stations don't emit CO_2. That was barely mentioned back in 1977.

What about *Energy: The Next Twenty Years*, which was sponsored by RFF and was led by Hans Landsberg? That book [was] published in 1979, 21 years before the end of the millennium. The 600-page book had 10 scattered references among 600 pages, amounting to less than 10 pages. Can you imagine a book called "Energy: The Next Twenty Years" that missed the biggest energy story of the next 20 years? That we all missed it?
Part of what I'm going to talk about today is that this is a new subject. It is still new, and I want to suggest that you may be impatient with what's happening, but don't despair. I think it took the United States at least two decades to learn how to think about nuclear weapons policy after 1945. I think it's probably going to take us a couple of decades to learn how to think about homeland security, which we're still grappling with, and I think we're still trying to learn how to think about – especially to think collectively about, internationally – how to deal with global warming and the impending climate change and some of its consequences.

One of the questions is whether it's real. Are we witnessing global warming? Well, in one sense, in a thermometer sense, we are witnessing global warming. There is no question that just about the last decade and even some of the last few years have been very likely, in the last thousand or several thousand years, some of the hottest on record.

The climate change models don't really predict what has happened in the last 10 years. To some extent, this is unexpected potential confirmation of global warming theory, but most of the modelers of climate and climate change don't really accept the recent years as confirmation, but as something slightly, at least, unexpected.

On the question of whether what we're witnessing is anthropogenic, human-induced, global warming, I think it's probably too soon to conclude from the recent historical record that this is

the greenhouse problem. There are other explanations for what's been happening in the last 15 or 20 years.

It would only take a modest fraction of one percent of increased solar energy output to produce the warming that has been observed. And I don't think it's going to be ruled out that changes in insulation, as they call it, could be explaining it. There are other potential man-made sources of heat, including heat islands, urban areas that collect heat during the day time.

But if you look at the two unspecific universal science journals – one called *Science*, produced by the American Association for the Advancement of Science; the other, *Nature*, which has been in publication for, I think, 100 years – you have to go back about a dozen years to find any real dispute or doubt about the scientific basis for anticipating climate change due to global warming, due to the emission of greenhouse gases.

People sometimes ask, "Can we see the signal in the noise yet?" The problem is not looking for a signal in the noise – it's looking for the signal among a few potential alternative signals, like changes in solar output.

So, I think if we can't be sure from what we've observed for the last 10 or 15 years that this is the global warming due to human activity that we were worried about, I think we turn to the science, and I find the science fairly conclusive, as well as fairly simple. It's been known for more than 100 years that because of greenhouse gases on the planet Venus, water can't exist in liquid form. It's too hot. And it's been known for the same length of time that water can't exist in liquid form on Mars for a lack of greenhouse gases.

Water can exist in liquid form on Earth because we've always had a bountiful, but restricted, supply of greenhouse gases in the atmosphere. Without the greenhouse gases, there would be no life on Earth. If we have too much greenhouse gas, well, I don't think we have to worry about becoming a Venus, but we can get a very different climate.

You can test the theoretical basis for greenhouse gas, global warming, by putting carbon dioxide in a glassed-in chamber and shine infrared light through it, and measure what comes out the other side, and measure what happens to the temperature inside the chamber. And this way it could be easily determined that carbon dioxide in the atmosphere, as well as inside a laboratory chamber, could be absorbing infrared outgoing radiation and become warmer.

So, I think the science behind the expectation of human-induced global warming is pretty well beyond dispute. There may be somebody in the audience who will dispute this when I finish talking, but I don't find all that much to dispute. What there are, are many, many uncertainties: not so much uncertainty about whether global warming as a phenomenon is real, but uncertainties about how much warming there will be as a result of greenhouse gases; how that warming may change climates around the world; and how those climates may affect human life, welfare, productivity, nature.

Usually, a discussion of this begins with the question, "How much global warming could we expect if the concentration of greenhouse gases in the atmosphere doubled relative to before the Industrial Revolution?"

In 1979, a National Academy of Sciences Committee, headed by Jules Charney, estimated that for a doubling of CO_2 in the atmosphere – carbon dioxide was the only greenhouse gas recognized then – for a doubling of CO_2 in the atmosphere, the average surface global atmospheric temperature, averaged all over the Earth, where people live and where people didn't live, averaged over the equator, and the poles and everywhere, the average would be somewhere between 1.5 and 4.5 degrees Celsius.

Now that's a huge difference. If I went to the doctor and he said, "Schelling, if you don't watch your diet, you're going to put on much too much weight," and if I said, "Doctor, how much weight am I talking about?," and he said, "Well, probably within the range of 40 to 120 pounds," I'd say, "That's a lot of uncertainty, doctor."

The interesting thing is that there is no official revision of that wide range of uncertainty, where the upper limit is three times the lower limit. And it wasn't even necessarily upper and lower limits. I tried to find out what the 1.5 and the 4.5 limits were to represent. And it turned out that most of the members of the committee whom I could reach didn't remember how they picked the midpoint of 3 degrees Celsius as the most likely.

I later heard from somebody who should've known that what they did was collect all the studies they could find, throw out the ones that didn't make much sense, and discovered that the point estimates ranged from 1.5 to 4.5. They said, "Let's call that the range and let's pick the midpoint as the most likely." That may be an apocryphal story, but I don't think there's anybody who remembers well enough to dispute it.

Why hasn't that range been reduced in 25 years? The amount of money spent studying this subject in the last 20 years is at least 1,000, maybe 10,000, times as much as the money ever spent in all of history studying this subject. The number of scientists of all kinds involved around the world in the subject has increased somewhere between tenfold and a hundredfold. And why hasn't that basic uncertainty – what would be the average temperature change for a doubling of the concentration of greenhouse gases in the atmosphere – [decreased]?

I think there are two reasons why we have no authoritative statement of a revised figure with less uncertainty. One is that against an estimate that has stood for more than a quarter of a century, it takes a fairly confident organization to publish a new and competing estimate. And I think there is a reluctance to go up against an estimate that has been the gold standard for 25 years.

I think, more importantly, the determinants of climate change weren't nearly as well understood [then] as they are now. Climate change looked a lot simpler than it does now. I think there are several scientific fields that turn out, upon intense examination, to prove much more complicated than anybody realized. I think genetics is one of those. Genetics no longer looks like what it looked like 25 or 30 years ago when Watson and Crick were learning about DNA. Genetics was an incipient science compared with what it is now.

I think brain science has undergone the same kind of increasing complexity, especially with the ability now to monitor regions of the brain without penetrating the skull, and brain science has become vastly more complicated than it was 20 or 25 years ago.

When I first got into this business, I was on the first big National Academy of Science study in 1981, 1982, and 1983, where we had what I took to be the best scientists of all kinds on this subject – the atmospheric chemists, atmospheric physicists, and oceanographers, and meteorologists, and glaciologists, and agronomists, and forestry experts, and so forth. We treated the ocean as a very important part of climate change, but exclusively as a huge cooling reservoir that would slow down the perceived warming by anywhere from 10 to 50 years.

After all, four-fifths to five-sixths of the Earth's surface is water. Water has a very high specific heat. There is much more heat in the top hundred meters of oceans around the world – many, many times the amount of heat that can be contained in the atmosphere. And the atmosphere can't get much warmer as long as it's bathed in cool ocean over five-sixths of the Earth's surface. And therefore the witnessed global warming would have to wait until the top layers of the oceans around the world themselves got somewhat warmer. And the estimates were that that would take 10 to 50 years.

In other words, if you had a doubling of the concentration of gases in the atmosphere, and then it stayed that way, it would still be somewhere between a decade and half a century before equilibrium was reached and the temperature would have reached the appropriate level given that concentration of greenhouse gases.

Now the oceans are recognized as transporters of energy all around the globe. People have now traced the Gulf Stream. It's not just a gulf stream, it's what they call "the conveyer belt," that goes all the way down around the horn of Africa and eventually into the Indian Ocean, and there are similar currents around Antarctica and in the Pacific, and all of these transport heat and influence climate.

When I was on that committee, clouds played no role. Nobody knew what clouds did, whether they reflected incoming sunlight or absorbed outgoing radiation or both. Now it is understood that clouds can do both, depending on the sizes of the droplets; depending on whether the clouds have ice crystals or merely water droplets; depending on the elevation of the clouds; and depending on the geographical location of the clouds.

Indeed it is now thought that the clouds that do the reflecting, do a very good job of reflecting – and if there are changes in clouds, they may have the effect of either aggravating the global warming by absorbing more outgoing infrared radiation, or ameliorating the global warming by reflecting more incoming radiation.

Also, we paid no attention in 1981, 1982, 1983 to particulates in the atmosphere, what normally goes under the heading of "pollution," a lot of which is sulfur-based oxides. It turns out – and this had been known, but wasn't discussed in the early 1980s – it had been known that some volcanic eruptions, those that emit a lot of sulfur, can create a huge amount of global cooling. In

fact, Mt. Pinatubo in the Philippines, [erupting] a dozen years ago, emitted a lot of sulfur, and one can still detect the cooling effect of that in some of the surface ocean temperatures.

In the 19th century, there were two huge volcanic explosions: [one,] Mt. Tambora, in about 1815, lifted an unimaginable amount of stuff into the stratosphere, which stayed there for a number of years, and produced what, about 15 or 20 years ago, was being referred to as "nuclear warming" – namely, too much stuff in there blotting out the temperature. That was the year, I think, 1815, when a lot of lakes and ponds in New England never melted. There was ice all through summer, and [it] got the name of "the winter that didn't end."

So, there was plenty reason to believe that sulfur could have a cooling effect, and now there are beginning to be measurements. And it turns out that the estimates are that the amount of particulates – especially sulfur, aerosols – is probably enough to have masked, disguised, shielded, half or more of the global warming that should have been expected over the past decade or two.

So now the question is, "Are we seeing less global warming than we might if we cleaned up our air?" Because if we clean up the air, we get rid of that stuff that isn't good for children to breathe or even people my age. So it may be that we are masking some of the warming that would have occurred were it not that the Chinese and the Americans and the West and East Europeans had been putting a lot of reflective stuff in the sky.

What about the question, "If we knew how much warming we were going to expect, as a global average, what would we know about the climates that will change?" This is a whole different subject, of course, because what's expected is not that things will get warmer. On average, things will get warmer. We talk about 2, 3, 4 degrees Celsius warmer – half a dozen, seven degrees Fahrenheit warmer, on average – and it's expected that the warming will be more in the winter than in the summer, and more toward the poles than the equator.

How could 5 or 6 degrees Fahrenheit average difference have much of an effect? I don't know how many of you walked here this morning. When I walked here, the temperature was in the high 30s, I think. I couldn't tell the difference between 32 and 38 or between 38 and 46.

But it isn't just that warming is expected, it's thought that some places will get cooler. In fact, there are conjectures that if the Gulf Stream were interfered with by global warming, all of northern, western Europe would get very noticeably cooler. Because the reason why you can have almost a Portland, Oregon, climate in England, despite the fact that England is at about the southern reach of the Hudson's Bay, is because they've got a warm ocean and that the prevailing winds keep them warm, so cooling could occur.

Some places are expected to get wetter, some dryer, some windier, some less stormy, some cloudier, some sunnier. And the problem is how do you project all that with the kinds of theoretical science you have, and the database that you have, and the computer power that you have?

In particular, it is very difficult to make regional, especially local, estimates of climate change. And it's especially difficult how one is to know what's going to happen in the mountains. And one can say, "Well, except for a lot of Tibetan monks, nobody lives in the mountains. Why worry about it?" But the fact is that all of California agriculture depends on snow in the mountains. And a huge amount of agriculture in India, Pakistan, Bangladesh, Burma, depends on snow in the mountains.

Snow is not just moisture. Snow is moisture saved for when it's needed by agriculture. If the snow turned to rain, we get all the rain we want in the wintertime, when it's no good for crops. What we need is snow, which will hang in there in the Rocky Mountains until in Colorado and Montana, they need water to grow their crops. So what happens in the mountains is very important, and there isn't much good evidence available from the global climate modelers about what's going to happen in the mountains.

If we knew what a change in climate would be, we would still have to measure the impact on society. And here the problem is aggravated by the fact that we're really talking about the possibility of serious climate change in the second half of this century. It may get quite noticeable, even fairly serious within the next 30 or 40 years. But, the time to worry about, really, unless we mitigate very substantially the accumulation of greenhouse gases in the atmosphere, is the second half of this century.

How do we estimate the way people will be living, playing, working, what the health environment will be 75 years from now? Just think of all the changes in the last 75 years, or even the last 60 years. Before 50 years ago, we obviously had no nuclear energy, and that means no nuclear medicine. We had no electronics. We had no satellite communications. We had no GPS systems. We had no plastic. We had silk, rayon, and celluloid; no vaccines to speak of. We didn't have the science of genetics.

One way to think about this is to ask, "Suppose the kind of climate change now being thought about had been predicted for the year 2000, back in 1925. How would people have estimated the impact?" Well, my conjecture is first, they would have been much more focused on warmer winters than on hotter summers. Much more focused on whether they could travel in the wintertime, or whether snow and ice would remain the trouble it was at that time.

I have a hunch that one of the big issues would have been mud. In 1925, automobile tires were two and a half to three inches in diameter, they were pumped up to 60 pounds per square inch, they were as hard as a baseball bat, and they had no tread to speak of. Balloon tires were still a dozen years in the future. Cars were continually being stalled in mud all through the spring and summer, and farmers made a lot of money by bringing out a team of horses to pull the car out of the mud. Bicycles are no good in mud. And if children have to walk long distance to school on muddy roads, it's a real nuisance and it slows down their walking.

I think people would have said, "If we have drier summers and less mud, that'll be one environmental problem less to worry about." They might not have realized that by the time my children grew up, the nation [would be] almost paved solid. I think my grandchildren haven't yet seen a muddy road and wouldn't know what one was if I talked to them about it.

I sometimes ask myself, “Suppose a farm boy born in 1920, who lived as a child through the 1920s, and then as a teenager through the 1930s, stayed on the farm, same farm (farmers depend a lot on the outdoor weather, obviously). Suppose he were alive today, and we asked him what he had noticed about climate change, whether he had noticed any climate change and whether climate change was an important part of the change in his farming, his lifestyle, his environment.”

If we asked him, “What are the main differences in farming between now and 1925?” I think he would have said, “Well, first, the disappearance of the horse.” My memory of being a child on a farm was horses predominated. Horses were what farming was. But the horses virtually disappeared. I think he would have referred to artificial fertilizers that have come in. He would have referred to new grains like hybrid corn, which didn’t come in until the 1930s, like soybeans, which didn’t come in until the 1930s. He would have learned new techniques of cultivation and irrigation.

If you asked him, “Has climate affected your productivity?” he would probably say, “It’s very hard to know, because we keep adopting the crops that grow best in this soil and in this climate, and every now and then the Agricultural Extension Services tells us we would do better to change to a different kind of wheat.”

And if we ask, “Well, but don’t you feel the difference? You’re working outdoors so much,” he would say, “First I don’t work outdoors as much as I used to. And second, we now have beautifully insulated parkas and boots and I have a heater in my automobile. It’s very hard to know how much climate has changed.” Now, I say this to suggest that it’s going to be very hard for us to realize what life is going to be like 75 years from now. Let me give you a dramatic example.

One of the concerns about global warming is that where it takes the shape of actual warming, getting hotter in tropical areas, and tropical areas getting extended, is that there are many, many tropical diseases, usually vector-borne diseases transmitted by mosquitoes and fleas and flies and snails and things of that sort. They tend to spread more as the tropics spread and the pathogens tend to get more severe, more virulent. Nobody knows why, I don’t think, but they do.

And it’s even clear that mosquitoes become more active when it’s hotter. So, one might say the real problem is likely to be the health problem that comes when so many of these dreadful diseases that afflict people in these tropical areas become worse and more widespread.

Then you have to say, “Well, what are those countries going to look like in 75 years?” A good lesson I had came when I spent three weeks in Singapore a few years ago. Singapore is separated from Malaysia by one kilometer of seawater. They have identical climates. When Singapore separated from Malaysia about 40 years ago, they were identical in their development, and Singapore was essentially a mosquito swamp.

Singapore has now developed to where it probably has the highest standard of living in the world. Not quite measured in gross national product (GNP), but in the absence of poverty and

things like the extent of home ownership and the availability of health care and all of that. Singapore developed spectacularly. No malaria, except if a Singaporean goes to Malaysia for the weekend, he may get bit by a mosquito and come back with malaria. But then he gets quarantined, so it doesn't spread from him, and he gets good medical care, and it's not a life-threatening crisis of any sort.

Malaria is widespread in Malaysia. But if Malaysia can do in the next 40 years what Singapore actually did in the past 40 years – in other words, if Malaysia, in 80 years, could do what took Singapore 40 years – they will probably have malaria substantially under control. And for those who get malaria, they'll have a better health care infrastructure – meaning they can both quarantine people against the mosquitoes that would make the disease contagious and give them treatment so that malaria will not be life-threatening.

Currently, malaria kills at least a million people a year, most of them children. And I think that we have to think about the way that the world is going to look when climate change becomes very serious.

Now what is the impact likely to be on productivity? On GNP? On the material standard of living? I think there the answer is that in a country like the United States, not much. Hardly any market-oriented production in the United States or in Japan or Western Europe or Australia or Israel is much dependent on climate and weather.

You can do open-heart surgery in Alaska, Louisiana, Massachusetts, California, and Montana. You can do radio and television broadcasting. You can make motion pictures almost anywhere. You can do money and banking and insurance. You can do most kinds of manufacturing. You can assemble automobiles in Alaska. You don't because it's too far from the market. But you can assemble automobiles in almost any state in the lower 48 or in Hawaii.

Only a very few activities are affected by climate. The main one is agriculture: agriculture, forestry, and fisheries. But in the United States, agriculture, forestry, and fisheries are less than 3 percent of our gross domestic product. And if the cost of raising food doubled or tripled over the next 75 years, by then, our per-capita GNP will surely have at least doubled. So, the date at which we reach double today's per capita income, instead of being 2068, might be 2078, and not a very noticeable thing.

Sometimes people say, "Well, you can't do without food." But the issue is not whether we will lose production of food. The issue is whether food production will become much more expensive, whether the water will be much more expensive to deliver, and whether techniques of cultivation may require new kinds of machinery and maybe more labor … [and that's] leaving aside the fact that in the United States, we still suffer from agricultural surpluses.

About the only things besides agriculture that are affected, construction might benefit because cement doesn't harden below freezing, and if you have fewer days below freezing than construction can go at pace. Probably things like transportation, especially on the Great Lakes, but even road transportation may be a little better if there's less ice and snow. Outdoor recreation

is a major activity susceptible to climate. And it looks as though outdoor recreation in a country like the United States will benefit from the likely climate changes.

I noticed that you can even hold professional golf tournaments in any state in the union, or in Puerto Rico or Hawaii. I don't know whether they do in Alaska, but that's probably because it's too far away, not because the climate won't allow it. A lot of professional football and baseball has gone indoors, anyhow. So I think what we have to worry about is the developing countries, where a third of the GNP may be agricultural. And for maybe half the population, they live on agriculture, many of them subsistence agriculture.

They're the people who are much more vulnerable than we. We and Israel and France and Japan and all the rest of us, as I mentioned, are about 3 or 4 percent agriculture. But in Nigeria, Bangladesh, Paraguay, most people live off outdoor activity and growing things. And there I think is where we look for the most severe impacts of climate change.

I'm neglecting what may happen to our natural environment, what we enjoy. It's very hard to identify just how much that will change and how much people will notice the change. I typically observe that people prefer the kind of landscape in which they grew up: I think almost anybody in the Middle East or Greece would not like to see reforestation of the kind that existed 2,000 years ago, because they love the scenery they were brought up in.

But I think what we must recognize is that the real victims of climate change are going to be in the developing countries. And that also leads to the recognition that probably the best way for them to defend against the adverse effects of climate change is to develop as rapidly as they can. The sooner Malaysia can become like Singapore, the sooner it can worry less about the impact of climate change, on health, comfort, and productivity.

And the sooner China can develop so that most of China becomes like the most developed parts of China now, the less they will have to worry about climate change. And, the more developed they are, the better able they are to adapt, and the more wealthy they are in order to engage, if necessary, in more expensive ways of things like transporting water.

So I would say that the way to think about programs to mitigate climate change is partly to save the wildlife that we enjoy, partly to make sure that it doesn't become more uncomfortable, but mainly because about four-fifths of the world's population now, and seven-eighths of it soon, will be living in the countries that we call "undeveloped," and they are the ones who will suffer. They are also the ones who can benefit most from economic development.

Which leads me to conclude that we should not be demanding that the developing world make significant sacrifices to slow down global warming, because it's in their interest that they become less and less vulnerable to the kind of climate change that might happen. Furthermore, I think it's worth noticing if you look at what's happening in almost all the developing world – not all of it – but almost all the developing world, there's real economic progress. China dramatically, China gets a lot of attention. The same thing is even happening in countries we hear even less about, like Bangladesh. It's mostly sub-Saharan Africa where development is not occurring.

My guess is that it's a fair estimate that the people who live in the developing world now are much less well-off than their grandchildren and their great grandchildren are going to be. And if we organize the world to make huge sacrifices, in the interest of slowing climate change, and ask a Chinese teenager in the year 2090 whether he appreciates what the world has done for him, by making climate change not at all disastrous, I can imagine he or she saying, "Yeah, but what did you do for my grandparents? They were poor. They needed help. They needed medical care. They needed sanitation. They needed nutrition supplements. They needed maternity care. They needed all of those things. And what did you spend your money on? On giving me a nicer climate. Thank you, but I think you misdirected what should have been a foreign aid program."

This leads me to conclude that the right way to think about it – I don't think this is the right way to sell mitigation of climate change to the American public – but I think the way to think about it if we're an RFF audience is, what we do about climate change is primarily a foreign aid program. The people who will benefit are mainly the people living in what we now call "developing countries," who will be seven-eighths of the population toward the end of the century. They are the people who need protection against climate change that they are not yet prepared for.

I haven't told you what I think about Kyoto, or the Bush Administration, or how we should organize the world to cope with global warming. I tend to think that Kyoto may be deemed a success, but not because it will have accomplished much. I think Britain may meet its targets because the targets are based on 1990, which is just about the time that North Sea gas came in and supplanted coal.

Germany may meet its targets, but that's because just about 1990, the base year, East Germany was incorporated into West Germany and has undergone 15 years of eliminating obsolete, inefficient, coal-burning power plants, and they now burn a lot less coal to produce the same electricity. Russia and, I think, Ukraine are likely to meet their Kyoto commitments because just about 1990, the base year, Russia became independent and fell into an economic depression from which it hasn't yet sufficiently recovered. So it's not even emitting as much because it isn't using as much energy as it did in 1990.

And some of the small virtuous democracies of Northern Europe, the Dutch, the Finns, the Danes and so forth may meet their targets by buying what is called "hot air" – unused quotas from the Russians and the Ukrainians. So, it may look as if the Kyoto targets were met, but I don't think it will denote any strong, significant effort on the part of those in the Kyoto community who have commitments to meet.

My suggestion would be, in the future, don't expect binding commitments. Don't expect enforcement. Don't expect any agreement on what the ultimate concentration of greenhouse gases, whenever that gets stabilized, should be. I prefer to think that nations that undertake commitments should commit themselves to actions, not to consequences.

In 1997, at Kyoto, when Vice President Gore agreed to a U.S. commitment to reduce U.S. emissions 7 percent below the 1990 level – which was already estimated to be 30 to 40 percent

below what it would be in the year 2000 – I think neither he, nor anyone else in Kyoto, had any idea of what would be required to meet their emission commitments.

The energy crisis of the 1970s didn't last long enough to learn much about the long-run price elasticity of demand for motor fuel, or electricity, or any of the things that might be affected by higher energy prices. So, I think that to forecast the impact on U.S. emissions or the emissions of any other country, as a result of proposed policies and actions, is extraordinarily difficult.

And I think, furthermore, if somebody had wanted to go to the U.S. Senate to urge ratification of the Kyoto Treaty, the senators would have had to ask, "If we ratify this treaty, then what do we have to do? What taxes are we going to have to authorize? What subsidies are we going to have to authorize? What regulations are we going to have to impose? What's going to be required of us to reduce by about 30 percent, our 2012 emissions?"

And whoever was presenting the treaty for ratification would have had to say, "The truth is, we just don't know." Because we don't know. But, if somebody said, "We're going to raise a tax on electricity of this much. We're going to have a federal gasoline tax of this much. We're going to add 20 billion dollars a year to research and development of this list of alternative energy sources. We're going to impose regulations on everything from building construction codes to gasoline mileage of trucks and other vehicles," then the Congress could have seen what really was likely to happen.

Furthermore, if we had agreed with some international partners that this is something we were going to do, they could look and see whether we did what we said we'd do. It's very hard for anybody now to look and see whether the United States is possibly on target to meet its Kyoto commitments. We all know that we're not. On the other hand, 2012 is still six years away and somebody can say, "Well, you'd be surprised at what's going to happen over the next six years." I think nobody will be surprised.

Committing to action allows those committing to know what they're committed to, and those to whom they made the commitments can observe whether they're meeting their commitments. I have, as some of you know, a favorite example. I think there has never been an international regime of the magnitude of what's required here, that had any kind of enforceable participation, any kinds of penalties for failing to meet commitments, even any penalties for failing to make commitments.

And you can ask, then, "Well, is there any precedent for a regime for binding commitments with penalties on failing to meet them?" I think the answer is no. Theoretically, there's a good case that without enforceable commitments, you can't get cooperation. I find only one example of commitments that were met and commitments that were to actions not results, and that was the North Atlantic Treaty Organisation (NATO).

Sixteen nations – eighteen including the U.S. and Canada – made commitments to raise troops; train troops; equip troops; provide real estate for housing, maneuvers, and petroleum pipelines; and allowed – in the case of Germany – foreign troops on their soil. These were commitments; most of them began to be incurred back in 1949, 1950, and 1951. They were voluntarily

undertaken. They're taken very seriously through a process of reciprocal cross-examination, you might say – a negotiating process that had grown out of the process by which Marshall Plan aid was divided.

By the time NATO got into the business of making commitments, they had some practice at negotiating with each other under the Marshall Plan. And that was a huge infrastructure on which to base the NATO mechanism. But NATO, in my estimate, was an enormous success. And by and large, nations met their commitments, and it was entirely voluntary.

And I can leave that with you as the only model I can think of that has ever existed, that might lend itself to an agreement among a select group of countries – I would say the Organisation for Economic Co-operation and Development (OECD) countries. If the OECD countries can demonstrate over a period of 10 years that they really take this subject seriously, then I think it would be time to go to the Chinese, the Indians, the Brazilians, and the Indonesians and say, "Now that we've demonstrated we're serious, we'd like to talk to you about how we can help."

Thank you very much.

Molly Macauley, Moderator

Professor Schelling, thank you on behalf of RFF for the honor you've bestowed on us today. My job is to help field questions. It's hard for me to do that because I want to jump in with my own questions, but I'm going to allow our audience to do that first.

Kathy Daniel, Federal Highway Administration

Hi. I'm Kathy Daniel with the Federal Highway Administration, and I really appreciate your remarks. My father was born in 1909, and it's amazing, the changes that he saw from having an icebox and no radio and the Model T Ford and, you know, the moon launch. My concern is that when you were discussing all of the effects of global warming, the couple that you left out were flooding and increased storms, which the insurance industry has obviously noticed. And we in the transportation field have noticed because it affects coastal areas and a lot of our transportation infrastructure.

So, I guess while there are lots of wonderful things that would happen with global warming, flooding and increased storms are something pretty significant that could affect a lot of developed countries because of all that paving that you talked about. I would like to hear your comments.

Thomas Schelling

There are two kinds of flooding to worry about. One is catastrophic – the west Antarctic ice sheet, which consists of grounded ice. It's essentially an iceberg so big that it already rests on the bottom and has grown a couple of kilometers worth of ice above the sea level. If floating ice melts, it doesn't do anything to sea level. That's the principle of Archimedes.

But this grounded ice has a body sufficient that if it were to slide into the ocean, glaciate into the ocean – it is pinned by some islands that have helped hold it – it's thought that if the bottom water got warm enough, it might begin to moisten, melt some of the bottom of the ice, and lubricate it, and there's enough ice there that if that happened, it would raise sea level by 20 feet. That would be a horrendous thing.

Manhattan would be underwater unless they did as the Dutch do and build dykes around it. You'd have to go by boat from the White House to the Congress. In Boston, Beacon Hill would become a small island. About one third of the length of Florida would be underwater. There goes Disney World and Cape Canaveral. Just imagine, Copenhagen, Stockholm, Oslo, Naples, London, Yokohama, Manila, Seattle; all of these places would require either dykes or abandonment.

This was first thought of in the 1970s, and it was believed that that could happen within 75 or 100 years. The committee I was on got later information. One thing I should mention is a remarkable coincidence that just at the time people got worried about global warming, we got satellite reconnaissance. So we have satellite information we couldn't have dreamed of 40 or 50 years ago, and virtually all the new data that we ever get about things like how fast the glaciers are moving, how fast the glaciers are melting, whether it's snowing more on Greenland than it is melting – all of these things depend on satellite reconnaissance and it's just remarkable miracle that we got all of this new surveillance capability just at the time we wanted to study these things.

On that committee I was on in the early 1980s, it began to look as if the west Antarctic ice sheet might slowly disintegrate, but it would take several hundred years. We'd have warning in advance. More recent studies have been a little more alarmist. I'm not enough of a glaciologist to know how seriously to take them, but that's the one thing to worry about.

When I did worry about it, I went to the Netherlands to talk about how you protect against this kind of thing, and I had a contour map of Boston, where I was then living, and I calculated from the contour lines where to build a dyke against a 10 foot rise, assuming you could then raise it to 20 feet, if over a couple of centuries, sea-level rose.

They looked at my plan and they said, "Oh no, Schelling, that's not the way to do it. Think big. Build your dyke around the whole Boston Harbor; then evacuate the water from Boston Harbor. We'll pick up 50 square miles of prime downtown real estate. It'll be worth more than the cost of the dyke. You can build a circumferential highway on the dyke itself and build high rise condominiums." And when Katrina destroyed New Orleans, many years later, I realized that it may be that we should consult the Dutch more about how to do our defending.

Anyway, catastrophe, yes. Otherwise, without that, there is some measured rise in sea level due to a warming of the surface of the ocean. Water expands when it gets warmer. This might be worth half a meter in the course of a century. There is some melting of ice in glaciers. I don't think they are substantial in their contribution to sea level, but there's a little bit there. So I would say, over 100 years, you may get enough rise in sea level so that you may not want to build your

summer house quite as close to the beach as they used to. But the real thing to worry about would be what happens to the west Antarctic ice sheet. So I'd say, keep tuned on that.

About storms, the insurance industry is one of the few industries interested in mitigation of emissions because it recognizes the possibility that if hurricanes do become more frequent or more violent, they pay the bill. And it is an interesting characteristic of the insurance industry that just about everywhere they are regulated by state commissions that govern the rates they can charge.

And the insurance industry, you might think, ought to love more frequent and more serious hurricanes because they're in the business of selling insurance, and they'll do more business, and collect higher premiums, and that's what they are in business for. But they look to the fact, especially in a place like Florida, that a Florida insurance commissioner – I think it's an elected position, I'm not certain – the insurance commissioner to authorize a substantial rise in insurance rates makes him or her a very unpopular person.

Now, I don't think we have any good evidence yet as to whether the climate change that's anticipated is going to increase or decrease the severity of Caribbean hurricanes or hurricanes around the Philippines. I don't think it's clear whether there are going to be more windstorms. We may have fewer ice storms. But I think this is one of the things to look at and worry about. But I would say that, compared to the people in Bangladesh, who may suffer serious flooding if they get more rain and less snow in the winter, storms in this country do remarkably little damage, and they could easily do less.

I was on a National Academy of Sciences committee to look at the impact of Hurricane Andrew, which was the huge one about 18 years ago. Hurricane Andrew was the most damaging hurricane we had ever suffered by several fold. And one of the insurance companies went around looking at all the houses that were blown off their foundations and the houses that weren't, and tried to find what difference it made whether a house blew off its foundation or sat securely on the foundation.

And they came up with a very simple answer. Those houses that were built according to the building code survived, and those in which the contractor had cheated and not followed the building code had often been just yanked off the foundation. So this suggests that part of the damage can be avoided by paying more attention to the risks in the way that we build our buildings. And for, what you might call "domestic flooding," like what we had in New Orleans and we often get in North Dakota, I think there, part of the problem is to induce people to stop moving into the flood-prone areas.

Amy Royden-Bloom, National Association of Clean Air Agencies

Hi. Amy Royden-Bloom with the National Association of Clean Air Agencies. One impact you did not address is the impact on species. I've seen projections that the Arctic sea ice may melt by 2050, 2080, thus the death knell for polar bears. Penguins breeding are very dependent on their habitat. They're hardwired to breed at a certain time of year and the Adelie penguins have been

breeding when it's very muddy, and their eggs have been destroyed one year, a hundred percent loss of chicks.

There are some species that can't adapt quickly enough. And also with increased absorption of carbon dioxide into the oceans, it's increasing the acidity of the oceans, which also has an impact on marine life. So I'm not sure that more foreign aid will help address species loss from global warming. Thank you.

Thomas Schelling

I think you're correct in all of your observations. There are some ideas for mitigating the climate change in the Arctic. These are ideas mainly for trying to improve sunlight that reaches the Arctic. Otherwise, I'm afraid that the way things are going, penguins and polar bears, lots of animals, lots of fish – birds less, they can migrate much more easily than animals – lots of flowering plants, and so forth…

I didn't mention this, partly because it's hard to know how seriously people want to take the polar bears. I tend to think that saving the Bangladeshis from aggravated poverty is more important than saving penguins, but that's purely a matter of taste. And I can agree that other people may be more concerned about wildlife. I think we know very little about what Americans are willing to pay to preserve wildlife. A lot of the promotion of mitigation efforts uses penguins and polar bears like poster children. And I don't have any good idea of whether that makes Americans willing to pay a higher price for the gasoline they burn.

Ruben Kraiem, Covington and Burling

Thank you. Ruben Kraiem, from Covington and Burling. Professor Schilling, without meaning to offer too simplistic a view of the position that you articulated, if you were asked to advise, then, the government of India or Bangladesh or China, as to whether they should modify the path of development that they are on, specifically to mitigate the risk of climate change, would your advice to them be, if there is an economic cost to doing that, don't? Are they not independently presented by enough of a threat such that to try to run away from it through economic growth would be self-defeating? Or is that not the case?

Thomas C. Schelling

I think it's not the case. I think the Indian emissions of carbon dioxide are less than 5 percent of global emissions. If they could cut their emissions by a quarter, it would reduce global emissions by, at most, 1 percent. They probably wouldn't consider it worth the cost and the effort to reduce global emissions by one percent. If they were assured that global emissions would be drastically reduced by what the Germans, the French, the Americans, the Canadians, the British, the Italians, the Russians would do, then they might well say, "It's worth participating because without it, the whole program will collapse."

But I don't think they would gain enough from moderated climate change just from what they did about their own emissions. And as I mentioned, I think, probably the best way to make

themselves less susceptible to climate change is to proceed as best they can with their own development – particularly trying to improve agricultural production so that fewer people have to depend on agriculture for their living.

If the Indians came and said, "We'd be happy to cooperate in a greenhouse gas reduction regime, but we're going to need your financial help," then I think we and the European Union, Canada, Japan, and a few others ought to be prepared to say, "Plenty of help is on the way," probably by proposing, "If you want to do something that requires imported components, we'll finance the imported components, and you provide the labor."

An example: suppose China said, "As you know, we are rich in coal. We are a coal-based economy. We even cook supper in the countryside over coal briquettes and things of that sort. We would like to go nuclear or electricity, so that they could cook on electric stoves and so that we can otherwise continue our rapid development without burning coal. We'd be happy to build several hundred nuclear power plants over the coming quarter century, in order to avoid building that many coal-fired power plants."

Then the question would be, who would help them? And I think a possibility would be to say, "Well, you've got plenty of labor to do the construction. You can probably produce your own cement. But if you need reactor components, if you need electrical machinery and all that, through some agency, maybe the World Bank, maybe some other, more dedicated agency, we should be able to help."

And it wouldn't surprise me if within 10 years, we're going to be very much in the business of helping developing countries begin to participate in this. And we can ask them to put up the domestic resources required, but any imported components [we'd provide – that] might be a good way of limiting our commitment to helping them.

Richard Moss, The U.N. Foundation

Thanks, Tom, for a very engaging and stimulating presentation. Richard Moss, with the U.N. Foundation. I guess I'm struck by your optimism in how you've selected the uncertainties that you've talked about. Because you've talked about the uncertainties and climate science and that we still have 1.5 to 4.5 degrees Celsius as a range of temperature.

But you really didn't talk about the increasing confidence in detection and attribution studies that I think do point to the fact that we can find a human fingerprint on climate change, and that we are learning a lot as we go along here, and you're not really thinking about the uncertainty and the context of the decision that you're making there. I think you talked about uncertainties and the impacts and adaptation area – that kind of pointed to the hope that our society will be able to effectively respond to a change in climate as it evolves.

But you didn't point to the parts of the literature that say, "In fact, markets often times don't work perfectly, social organization doesn't always deploy where it needs to be to effectively respond to disasters where they occur." So you kind of looked only at one half of the uncertainty, not at the other half of the literature.

I think that when you spoke about mitigation cost, you didn't really deal with it in a very detailed way. But you did imply that mitigation would be extremely disastrous for the economy, that there would be very high costs involved. I think there's plenty of literature, if you wanted to sample from that other part of the range of uncertainty, which indicates that there might, in fact, be some economic benefits, depending on how we organize ourselves and what sorts of policies we use.

I think, also, that when you talked about economic development in developing countries, there's an assumption that by ignoring climate risks and simply putting everything into kind of a standard development model, that will, in fact, promote the fastest development in developing countries and that will better position them to respond.

Again, I think there's literature that indicates that may not be the case. So you've been, I think, somewhat selective in your use of uncertainty, and I was a little surprised about that, simply because if one adopts a risk-management perspective in a problem like this, where there is uncertainty, I don't think the most robust strategies come from selectively using the uncertainty, but looking more at the full range of uncertainty and trying to design a strategy that's robust to that.

So I just offer that as a comment from someone who has worked a little bit on the science side. I certainly can't claim to be an economic expert, but it just strikes me that if we think about this as a risk-management problem, it's important to think about the full range of risk, not just part of it.

Thomas C. Schelling

Richard, I think you've misunderstood me. I never meant to hint that the market economy could possibly begin to take care of the problem. That's why I talked about how anybody who went to the Senate to look for confirmation would have to be prepared to talk about all the ways that government would augment what the private sector was doing to provide the incentives to shift to new energy sources, maybe to shift to sequestration of carbon out of stationary plants.

I felt sure that the Congress was going to ask what we do about gasoline mileage standards, and somebody was going to talk about building-code standards and all of that. I never for a moment thought that this would require anything other than very powerful government leadership in the provision of regulations and incentives.

On the costs of mitigation, I didn't mean to hint that they were great. In fact, I think all the costs of mitigation are going to be political costs. I think mitigation, at the outside, would be something like 3 or 4 percent of global GNP. And that's not much. We have about 30 trillion dollars of global GNP now. It'll probably double every 20, 25 years, maybe faster. Losing 3 percent out of something that is growing such that it'll double in 20 years, and double again in the next 20 years, it means that instead of doubling, you're down to only 195 percent of currently.

So I would say that the economic costs of mitigation are worth analyzing in order to minimize them and to do it efficiently. But I would say the only kind of cost is going to be the difficulty of getting the tax-paying public, or their representatives, to be willing to face the costs. And I think the costs can be greatly reduced by choosing highly efficient ways of imposing incentives. I don't think we will choose highly efficient ways. I think, for the United States, the most efficient way to do it, the way economists talk about efficiency, would be to have a tax on the carbon component of any energy that is used.

But I rather imagine that the Congress is going to want to listen to the farmers and the automobile workers and the electrical workers and the coal miners and all kinds of people, and we may be lucky if we end up with a gasoline tax that is different from a diesel tax, which is different from a kerosene tax, which is different from a tax on the coal that is used to produce electricity. It'll be different from any tax on methane, and it may be that methane will be taxed differently in the states that use a lot of it from the states that have alternative sources of heating in the winter time and so forth.

So I think the costs are entirely political costs. I don't think the economic costs, over the long run, are, in any sense, unmanageable. So if you thought that I wanted to do this without any government interference, and if you thought that I was afraid of the costs that would be imposed on the economy, I misspoke.