Transcript of Lecture
Moderator: Greg Keoleian= G
Introduction: Peter M. Wege = PW
Speakers: Rosina Bierbaum = RB
Stephen Director = SD
Jonathan Bulkley = J
Douglas S. Kelbaugh = DK
Carl P. Simon = CS
Questions from audience = Q
Date of Lecture: October 17, 2001

G: … CSS is the external advisory board. Peter entered the University of Michigan as a freshman in 1940. He left the University of Michigan in 1942 in order to join the Army Air Force. He qualified as a pilot and served throughout the Second War. Following his return from service, Peter rose through the ranks at Steelcase. And he stepped down last year as Vice Chairman of the Board.

Through the years, Peter has made many significant environmental contributions in addition to all that he's done for us here at the Center. He founded the Center for Environmental Studies in Grand Rapids, supported national parks and conservation programs in Costa Rica. He is the author of Economicology. Peter coined this word, a combination of economics and ecology. He is founder and organizer of the Economicology Collaborative Conferences, seven colleges and universities in Michigan and elsewhere in the country. He is a member of the National Wildlife Federation's Presidents Society and a major supporter of NWF's Environmental Education program for grade and middle school students throughout the country. He has been a major force behind the brand new Muskegon River Watershed Project that a number of faculty from this University are engaged in, and he is a generous supporter of many additional environmental activities in this country and overseas.

It is to recognize and honor Peter Wege for his sustained efforts to forward environmental knowledge and practice that the Center has established with this annual lecture series. So it's with special pleasure that we welcome Peter Wege this afternoon to introduce our first distinguished speaker in this series. Peter…

[applause]

PW: Well, go blue, think green.

[laughter, applause]

PW: That's my motto. There's twelve universities that we have in Economicology now. Every six months, we meet with the science and environmental people of each of these colleges.

There was three guys… I can tell this story because I've got the podium right now. Nobody is going to take it away from me.

[laughter]

PW: So there was three guys talking… my age… and one says, "Golly, I go to the refrigerator now and I forget what I was going to go there for." The other guy says, "Oh, that's nothing. I go out to the garage and get in my car and forget where I'm going." The other guy says, "Knock on wood [knocks]. I don't have any of those problems. By the way, who was at the door?"

[laughter]

PW: Well, that's my era. That's my era.

[laughter]

PW: I am pleased to introduce Dr. Rosina Bierbaum, the new Dean of the School of Natural Resources and Environment. In 1980, Dr. Bierbaum began her public service at the Congressional Office of Technology Assessment. She then served with great distinction as Associate Director for the Environment in the Office of Science and Technology Policy under the Clinton Administration, and was also Acting Director of the Office in the Bush Administration. That saved her. No, I'm just kidding.

[laughter]

PW: In 1999, Dr. Bierbaum received the EPA's Climate Protection Award for Scientific Leadership in Climate Protection. On June 2, 2000, she received the Waldo E. Smith Medal from the American Geophysical Union in recognition of her extraordinary services to geophysics. Please join me in welcoming Dr. Rosina Bierbaum, the new University of Michigan Dean for the School of Natural Resources and Environment.

[applause]

RB: Thank you very much. I'm so happy to be the new Dean of the School of Natural Resources and Environment and I'm very honored to give the first Wege Lecture, named after a man who believes, as Rene Dubois did, that to strive for environmental quality should be the 11th Commandment.

The global footprint of mankind, as depicted in the poster you see for today's event, can be seen in our alterations of our fundamental cycles of the planet. We have increased carbon dioxide by 30%, doubled nitrogen, transformed 40% of the terrestrial part of the planet, used 50% of the surface's fresh water, 70% of the major marine fisheries are going extinct, and we appear in general to be causing the 6th major extinction on the planet.

The subtitle for my talk, "A Matter of Degrees" is something that I really mean in three ways here: Degrees in terms of temperature, as much as total temperature will change. Degrees as in extent or the summation of environmental insults, the degrees of environmental insults. And degrees, finally, in terms of latitude or longitude as in where you live on the planet. A matter of temperature, I think, certainly will determine the kind of planet and the environmental challenges we face. The Earth has already warmed about 1° over the last 100 years in response to the 30% additional carbon dioxide in the atmosphere. And we're headed to somewhere between a doubled CO2 world, which would lead to a temperature increase for our part of the planet of the yellow area, somewhere between 5° and 10° or possibly to a quadrupled CO2 world, which would ultimately play out in the deep red colors of up to 20°, and this is in Fahrenheit, change for the planet. To give you an example of what that would mean, the doubled CO2 would lead to about a 10% to 30% decrease in soil moisture during the growing season, but we would be thinking of more like a 30% to 50% decrease in soil moisture in the growing season under quadruple CO2. Clearly, this would make a difference.

If we think about the middle picture, the extent or the sum of environmental insults. By that, I mean we need to think about how other stresses, such as ozone depletion or biodiversity loss, resources scarcity, urbanization, habitat fragmentation… how all these problems might interact on concert with climate change. Very little research has actually been devoted to try to analyze these interactions or for looking at the potential for systems to collapse under multiple environmental stresses.

Yet of course there are linkages among environmental issues. We've just seen a United National Environment Program announcement yesterday that the ozone hole is expected to close more slowly than we originally thought and that climate change is interacting with it. We know that climate change may enhance forest growth, but we know that forests hold carbon as they are growing and release carbon as they are dying. So that in turn can exacerbate or ameliorate climate change. Biodiversity loss is occurring at something like 10 to 1,000 times natural extinction levels and yet these relic populations may in fact not be able to move as fast as the climate map is shifting over them.

Similarly aerosols, which is in the yellow here, can either reflect incoming sunlight which will lessen climate change, lessen global warming. Or if they are dark aerosols they can absorb heat and enhance climate change. We really need to understand these interactions better. For example, a lot of people argue that climate change will bring a warmer, wetter world and it will be a greener world. Well, what if it's all kudzu [laughs]?

[laughter]

We already have an invasive species problem of several billion dollars a year in the United States. Currently, kudzu is limited in the North by the frost line and in the West by the moisture line. We expect the world to get warmer and wetter and we've spent very little money understanding how noxious weeds will change as climate changes.

Similarly, we need to understand what will happen. Fisheries are already in decline. We have 5 million data points that said the ocean is warming down to depths of 3,000 feet. We know that there is nutrient pollution and we have the emerging problem of [___isteria?]. How warmer temperatures, fisheries and coastal pollution will interact has been little understood. But clearly, the extent of this is something that we need to grasp and get a handle on to understand future environmental problems. It reminded me of a John Muir quote that, "When you tug at one thing in nature, you may find it attached to everything else in the rest of the world."

The third meaning of degrees is the latitude and longitude, or where one lives on the planet. You know, we talk a lot about the global average temperature change. Well, you're not going to feel the global average temperature change. It depends a great deal where you are. It depends on whether you live in the North or South and whether you have the technological capability to adapt the financial resources and education. The kind of environmental insults you might experience in different parts of the world depend on where you live and again, your response depends on all of your resources.

Very little work has been done to try to look at particular regions in the world and understand how climate change might affect them. But in this case, I show you two model results of how July might feel like… the heat index in the U. S. It may feel like 10° Fahrenheit warmer for us. And the models differ in exactly how that is going to be. But I think you sure don't want to move to Texas.

[laughter]

There are definitely going to be some places where the natural conditions, the current environmental stresses and the overlay of climate change will be a big problem.

This is the requisite picture of the greenhouse effect. I would like to say that climate change actually is the most dangerous environmental problem that faces us and the most intractable. I would say it's the most dangerous because it essentially affects all of our environmental conditions and processes, as well as all aspects of human well being. It's intractable because it's deeply rooted in the characteristics of the world's energy systems. They can only be changed with great difficulty and with enough time.

I would submit that nearly all countries are vulnerable. The Southern are constrained by their capacity to respond financially and institutionally, and the Northern countries because that's where you expect the climate change effects to be manifested the most, at the higher latitudes.

I would submit also that major disruptions in one will propagate to other regions because we're so linked by the flows of people and goods and money and crops and images and ideas and diseases and drugs and weapons.

The picture that I have here shows you the natural greenhouse effect and the blue blanket there are the greenhouse gasses that exist in the atmosphere, principally carbon dioxide and water vapor. Unfortunately for us, keep the world 60° warmer than it would be otherwise. The problem, of course, is that in addition to that blanket, we've added many more of these effectively bent arrows that are trapping the heat back into the planet and enhancing the natural greenhouse effect. In fact, the principal greenhouse gasses, carbon dioxide, and we add about 7 billion tons of carbon each year to the atmosphere. Most of that from fossil fuel burning. That's about 6 billion tons. But also one from land use change and deforestation.

There are other greenhouse gasses that are about 20% to 25% of the problem, nitrous oxide and methane, but you simply cannot get a handle on the greenhouse problem if you don't control carbon dioxide.

We have good records of what's happened in the atmosphere since the industrial era. You see starting from 1860 on the left through to the present day. The concentration of carbon dioxide in the atmosphere has risen from about 285 to 365. The blue part of the curve is taken by estimating carbon dioxide in air bubbles that we have from ice cores. And then the yellowed soft toothed area… It is the crown jewel, if you will, of climate science. This is the measured record starting in the international geophysical year of 1956 of the respiration of the planet. Here you see every Spring, as the leaves in the Northern Hemisphere leaf out, the atmosphere is drawn down about 7 parts per million and then it gives it off at the end when the leaves drop. But nonetheless a very clear increase since 1957.

The next picture should look sort of similar in curve to you. This is the same period of time and the growth in world energy use. I would like you to notice that the top three bars represent carbon-based fuel use: coal, oil and gas. And so for all the talk about biomass, hydro and nuclear, the world is 78% carbon-based and the emissions of these carbon-based fuels trap very closely with the emissions in the atmosphere.

But what has that 7 billion tons a year, in current terms, done to the temperature? This next chart shows you over the 140-year record an increase in the Earth's temperature of about a degree. That doesn't sound like very much, but the next graph puts it in the 1,000-year time frame. Here we've reconstructed the temperature in the Earth, using various proxies like coral and pollen and ice cores. In fact, some of it was done at this University. But I want you to notice how the 100-year record that I show you over here looks very anomalous, and 1998, at the very top, now appears to be the warmest in 1,000 years, a very clear p________ to the planet that we have caused in only about 100 years. Although if you've followed the climate treat negotiations at all, the issues of equity are right at the heart of it.

So who's to blame? Here's a pie chart of whose carbon dioxide is in the atmosphere? You can see that the U. S., with 4% of the world's population, has about a quarter, the rest of the OECD about the same, the former Soviet Union about the same and the rest of the world, where 80% of the population lives, has contributed only about 25% to what's in the atmosphere today. This is very clearly what led folks in Kyoto to say, "You caused the problem. You start to fix it."

Now clearly this picture will change and over time, instead of the developed world being three-quarters of what goes into the atmosphere. By the end of the next century, the developing countries will clearly be putting the bulk of emissions into the atmosphere. But carbon dioxide lives, if you will, for 100 years. So at the end of the century, the composition of the reservoir of the atmosphere will still be 50% due to the emissions of the developed world.

So I showed you how energy grew today and I show you here how energy is going to grow tomorrow. But let me put them on the same chart for you. I've never seen this before and here again you see fossil fuels dominating. Here are low, medium and high potential scenarios for emissions and energy use over the next century.

This says to me that, in many ways, maybe we haven't seen anything yet. The stark increase is nothing compared to the potential increase in the future. Let me just take that middle line and show you what that middle emission curve would do to temperature, again showing you the 1,000-year record anomalous temperature of 1998. That range of scenarios will take temperatures… this is in Celsius over here… the equivalent of 3° to 10° Fahrenheit by the end of the next century. And you can see on this long time frame how very dramatic a p________ that is. That rate of change is faster than has been observed in human systems in the last 10,000 years, essentially taking the rate of change outside the time when humanity has flourished or outside of human ken.

This temperature increase will do a couple of things. As you warm up the planet, you will increase evaporation which will mean there's more water available to come down as either rain or snow. And you see both blamed on climate change. You will also melt glaciers and, through thermal expansion, raise sea levels. That change in temperature and water patterns and sea level rise will essentially change the ideal range for everything we know. From where disease organisms will live, for where crops can grow, from where forests can grow. It will effect the quality and quantity of water. It will inundate coastal areas and we have a very real question of how will species keep up with this kind of rate of change?

We are already seeing some changes. The one degree temperature increase over the last 100 years hasn't been distributed evenly across the planet. Some areas, shown by the bigger red circles, have seen more than a degree. Some areas downwind of cities or biomass burning. We actually have seen some cooling, so again your place makes a big difference.

We're also seeing signs that the hydrologic cycle may be speeding up and this is transient precipitation over the last 100 years where the bigger the green circle, the greater increase in rainfall. But you see in the interior of continents, some areas have actually gotten drier. Nonetheless, over the last century, globally precipitation has increased about 1% to 2%. We have better data for the U. S. and over the same 100-year period on average, U. S. precipitation has increased 8%. This ends up being the equivalent of adding an extra Mississippi River-worth of water on the U. S. every year. Quite a significant change. In addition to just total rainfall increasing, the way in which the rain is delivered appears to be changing. On this graph, gentle rains are on the left of each graph and severe rains are on the right. What you see over the 100-year period is that there has been an increase in the highest percentile rainfall events. So these are not Shakespeare's gentle rains from heaven that are so conducive to crops. These are more the erosive rains that cause problems as we saw yesterday.

[laughter]

Now if you continue this trend… I pulled out a figure from the Midwest Assessment, which was actually done with about ten people from this University. Over the next century, here's what two models predict will happen for our region. That is, a continuation of this trend. Very little increase or even a decrease in the light rainfalls, but an increase in the heaviest rainfalls.

Water, I think, can safely be said to be the linchpin of climate change because we already have problems with supply, quality and competition. These are only going to increase as the water cycle of the planet is speeded up. While this one is sort of hard to read, the point of this is mainly to tell you there will be additional water problems in each region.

Eleven out of twelve models suggest that the Great Lakes will actually drop, even though there will be an increase in precipitation. Evaporation from the Summer would actually lead to a drop of somewhere between… here it says 2 to 8 feet or 1 to 6, somewhere in that range. By 2050, that could mean a 15% reduction in hydro, an increase of 5% to 40% in navigation costs.

If you look at the Chesapeake and Louisiana, the main issues for water there are going to be sea level rise, loss of coastal communities. You get to Louisiana where the land is subsiding as the sea level is rising, and you will loose several thousand square miles of wetlands.

You come to the Great Plains and issues of irrigation, runoff during floods, erosion become more of a problem. The water problems that we're already seeing in California and the San Francisco Bay will be increased.

The timing that water is available is expected to change too. So let me show you over the last 50 years. Here is what's happened to the last day of snow on the ground. The areas in red are losing snow a couple weeks earlier than they did in 1950. So the snow is melting sooner. Unfortunately, we are in this band. We're only losing it one day.

[laughter]

So when we had people from Seattle and the Columbia River Basin sit down together, they produced a model that said, "Well, our flow in the 2050's is going to come a few weeks earlier than it does now, which is the dotted line. So we had planners from the City of Seattle talking to the hydro people, talking to the salmon experts. And they said, "We're not going to be able to supply to hydro needs. We won't have fish… we won't have water for the fish at the time we need them and we won't be able to add three Seattles in the time period of 2050.

So sitting down and kind of doing these sort of "what if?" experiments, where different aspects of the environmental issues are brought into play can actually help you begin to think whether there is adaptation potential for you.

Another area very important for us is combined waste water systems. There are these combined storm drains, sewage and industrial waste. They are mainly used in about 950 communities in the Northeast and Midwest. So when high volumes of water exceed the amount that can be discharged easily, it ends up in the surface water. And of course, with increased precipitation events, the potential for public health problems will increase.

This next chart shows you Lake Ontario. It's a bit complicated, but basically the shaded area are the water levels within which we regulate and can regulate easily Lake Ontario today. You see the darkest line from 1954 to 1995. We've done pretty well. We've stayed within that shaded area. Then we ran two models and one model represented by the red, yellow and blue suggested that lake levels will be very low for much of the time and well below what we planned for. And the other model, which is the highest line, said about half the time the lakes are going to be too high for what you planned for. And some in Congress have kind of used this information to say, "We know nothing." I would submit that, in fact, [chuckles] what this is saying to us is that we may need to prepare for increasing uncertainty. We really don't know on a regional level, which is right. But we do know that there will be more extreme events of droughts and floods and that water will become more of a problem and that maybe the systems, the infrastructural systems that we have planned based on the previous century may in fact be inappropriate for the next century. We should, in fact, be considering how we can build in resiliency or flexibility to increasing uncertainty. We know it is, of course, the extreme events, the droughts and floods, that end up causing so much human misery and socioeconomic damage. And both of those are handled not particularly well by us and are things that we could do better on. So contingency planning, I think, would be one way to build in some adaptive capacity for climate change.

Let's look at agriculture. We already talked about the potential for more floods and droughts, a potential shift in ag pests, reduced food in vulnerable regions. A lot of people say, "If climate change has a good news story, it's going to be in agriculture because carbon dioxide is a fertilizer if nothing else is limiting. And if ever you're really managing a system, it should be agriculture."

So here's a picture of expected grain yields in a 2 X CO2 world. The first picture of temperatures that I showed you earlier. And here green is more productive and yellow and red is less productive. It looks like the U. S. makes out pretty well. The U. S. would experience about a 10% increase overall, although within individual crops this 10% increase would be plus or minus 10% to 30% for particular regions and particular crops. But it is the poorest countries of the world that will lose as climate changes and in fact decrease their productivity. Technically, there is enough food in this scenario to feed all the people of the world in the 21st Century, but of course, this will be something that our socioeconomic systems will have to handle and we'll have to be able to handle distributional systems to get the food to the right folks.

Then as I mentioned extreme events, I would just point out that even today, as corn has increased productivity over the last 50 years when there is something that takes it out in a big way, it's a blight or a drought or a flood. So learning how to handle these extreme events better can only help us in the face of climate change tomorrow.

In terms of human health, we worry about weather-related mortality, whether it be from floods or heat stress. You all remember the Chicago events of 1995 that resulted in more than 700 deaths. In today's climate, that event was a 1 in a 150-year event, but in a doubled CO2 world… if carbon dioxide doubles, that becomes 6 times more frequent, or a 1 in 25-year event.

Warmer temperatures can also facilitate smog formation, reduce air quality and something that's just beginning to be uncovered, lead to more pollen of allergenic substances. A very interesting paper published this year to show that ragweed spores have increased as carbon dioxide has increased as carbon dioxide has increased and in a doubled CO2 world expected to increase again. Very interesting tentacles into human health here that we've barely explored.

In the case of coastal areas, obviously rising sea level and the potential infrastructure loss, as well as beach erosion. When we did a little case study of Manhattan, for example, looking at sea level rise and meeting with the city planners, the best guess at sea level rise over the next century, 20 inches, during high tide and storm surges, will lead to inundation of LaGuardia and to the subways… a very big infrastructure issue that of course has not been planned for at all. But at least they can begin to think about what steps might be able to be taken.

U. S.-wide, this 20-inch sea level rise would lead to a loss of about 9,000 square miles total. You see it here as wetlands and dry lands. Again, Louisiana, which is subsiding, has the most to lose out of this.

If you look at a place like Florida and think of the fact that we're spending $8 billion to bring back The Everglades, about a third of it could be underwater, under the upper end of sea level rise in the next century. This obviously would be a great cost to the U. S. That same type of sea level rise would take out 18% of Bangladesh and produce 13,000,000 environmental refugees. A quite serious problem as the Nobel Prize winner Henry Kendall said, "You can't have half of a ship floating while the other half is sinking. What affects one part of the world will impact the rest.

For natural ecosystems, here we worry about this shifting climate map, changing too fast. So what will happen to our parks and refuges? We pay about $3 billion a year to maintain our parks. We like them the way they are. We put fences around them because we hope they'll stay that way. And yet the climate map will be shifting. There will obviously be impacts on forestry and tourism.

And let me show you what might happen in our region to forest type. It looks like most ecosystem models project for the U. S. as a whole that there will be an increase in forest growth for several decades as trees actually respond to the CO_2 fertilization effect. We might be seeing signs of this already. Already from satellites we see that there is an earlier greening of the planet. Measurements from 75 reference gardens around the world have said, "It looks like Spring is coming about a week earlier and Autumn is coming about 5 days later than 30 years ago. When this hit Washington, we actually changed the date of the Cherry Blossom Festival. It had missed it for 12 years running.

[laughter]

By building this new schedule in, they were able to make it.

So we expect forest growth is going to increase over about 4 or 5 decades. But then, larger scale processes may kick in, such as fire, insects, droughts and disease and may decrease productivity. In the Northern forests, where climate change is expected to be the most, two-thirds of the current area may undergo a change in vegetation type. So for our region, if you can read the color scheme there, some of the most important timber trees, which are quaking aspen, yellow birch, jack pine, red pine and white pine, are going to be retreating Northward.

You see there we have a much simpler forest. From an economic point of view, the greatest loss may be the wood fiber industry which a shift towards this oak/hickory forest you're seeing would certainly eliminate.

Sugar maples, essentially moving out… This had a great impact on New England and as it would, on us for both foliage and pancake reasons [chuckles] and is one of the examples that did resonate most strongly with the Congress.

[laughter]

A lot of people assume that a transition from one state to another is going to be very smooth. This is some Canadian work that was done on how fire might change as climate changes. Obviously, the more red there is, the more fire risk there is. And this has been very little studied. You may know that there is a lot of discussion about how much carbon trees can hold and how many forests you can plant and how much more you can have plants suck up. But these erratic and potentially events like fire need to be factored in. In the recent climate negotiations in The Hague, the Canadians actually asked if there was a big fire, could they not get a carbon penalty in their accounting system, knowing that in fact this research works. So there's a lot of details. The devil is in the details in a lot of these things.

In terms of endangered species, this map just shows you sort of some hot spots of rare species. Many species are confined to very small regions. If you think of a shifting climate now the potential for biodiversity losses to increase becomes greater.

This is a picture of Grinnell Glacier of 1910, where the glacier extended. In 1997 when I climbed it, just barely. By 2030, all the glaciers in Glacier National Park will be gone. It will be the Park Formerly Known as Glacier.

[many low voices]

This obviously means something to us for tourism, but when the mountain glaciers of Peru go, that serve whole cities, this will mean much more than just a tourism loss.

Finally, I put this together also for the Congress [chuckles] because to me, as an ecologist, knowing that two-thirds of the boreal species might change type was just a statistic that moved me. Mark Twain said, "The sign of an educated person is if you are moved by statistics."

[laughter]

So that one moved me. But it didn't move the Congress.

[louder laughter]

So I put this chart together to show that in today's world, here's where the Baltimore Oriole is. And in tomorrow's world, it will be the Ontario Oriole. Somehow that clicked [laughs].

So to recap, the impacts of climate change essentially I think every system is vulnerable to climate change and exactly how vulnerable it is depends on the overlay of other environmental stresses, how warm the temperature actually gets and exactly what else is happening in your region, thereby making you adaptable or not.

I started by saying that climate change is the most dangerous and intractable problem, so let me go back and finish with some slides on that aspect. Again, looking at the developed world versus the developing world, here's our population in yellow. Here's their expected median population in blue. It took all of time, until 1800, to establish the first billion people on the planet and it took what… 14 years to get the 4th billion in 1974. Clearly the quality of life is going to be dependent on how many people are on the planet.

If you look at energy use per person, all these people… this represents the population of the developing world, and you see that they use somewhere between one-tenth and one-twentieth of the energy of the average U. S. citizen. So all these people at one-tenth or one-twentieth, well if they start using energy at the rate we are, you'll see why… you can understand immediately why those energy growth curves are so dramatic.

Not only will the ecological world look very different, but the built world is going to look very different too. In 1970, here are the world's largest cities. The blue are essentially the developed world and the shades of pink the developing world. And we recognize Los Angeles, New York, Paris, London and over here we have two in Japan. So we have six of the biggest cities out of the top 15 in 1970. By 2015, none in Europe, New York, L. A.'s gone. We've got … so we have 2 out of 15… one in Japan. It will be a very different world. Again, as I said, if they develop as we develop the energy use will skyrocket. There's an old adage: "If you don't change direction, you're going to end up where we're headed."

[laughter]

And we are headed to a very high level. The intractability comes from the time constants. Here, I just put together a few examples for you. Politics doesn't move very fast, as you know. The corporate average fuel efficiency standards took somewhere between 3 and 20 years to get in place. It took us 10 years to reauthorize the Clean Air Act. R & D for the Clean Car Partnership for a New Generation vehicle takes about 10 years. Then it takes about 10 years to penetrate the markets. There is natural turnover times for stock, depending on whether it's a car or a city it's very different. And then juxtaposed with that, you have the lifetime of greenhouse gasses or the reversal of extinctions.

If you wanted to stop the world at that very first picture I showed you, the 2 X CO2 world instead of the 4 X CO2 world, let me tell you what you'd have to do.

Here's the business as usual curve we're on for admissions. We're at about 7 billion tons today and we're headed out to somewhere between 30 and 40. If you wanted to stop the world at a doubled CO2, you would have to be on this green line emission path. It shows you a couple of things. One, you would have to peak at about 9 or 10 billion tons. There's about 9 or 10 billion people coming in the world. That means a ton a person. The U. S. emits 5 tons per person. So we'd have to drop by 80% if that were in some sense a global average.

In looking at this chart, if you're a technological optimist, we have plenty of time to act. If you're a pessimist, we have no time to act because it means the whole world has to be veering off this business as usual sometime in roughly the next 20 years. The whole world. Not just the rich countries of the world. And eventually emissions have to drop below today's levels.

Kyoto, which was essentially a 5% emission reduction from the developed world, would have barely been noticeable on this curve. Nothing like the task that is before us. Of course, a journey of a thousand steps has to start with the first step. But it was merely the beginning of a solution, not a solution. Ok, so the task is enormous. What tools do we have in our arsenal? Energy R & D funding is declining in every country except Japan. You see from '85 to '95 what is happening. So the task is getting bigger and the dollars are getting smaller.

If you look at the total pool of funding, the whole world spends about $12 billion on energy research and here's how it is split up across the various fields. If you look at some of the really new and emerging ways that you might be able to capture carbon or fuel cells, biomass, methane hydrate. We spend much less than a billion dollars on some of these very exciting possibilities.

Wallace [Stegner?] used to say that, "The Americans had an amputated sense of the present; that we live kind of in the here and now and really can't place ourselves in the longer history of the planet. Well, here's the really long history of the planet. This is the 420,000-year record of the [Vlostok?] ice core. Again, they measured the air bubbles and the concentrations. And from that they get temperature and they get carbon dioxide. And you see 4 glacial/interglacial periods here. Carbon dioxide and temperature move relatively together.

A couple of points to know: Here's where CO2 was in 1800. Here's where it is today. So it's already higher than a half a million years. And if you follow those emission trajectories I showed you, by the end of the next century, we'll be at 700 parts per million, well on our way to a tripled CO2 world between the two pictures that I showed you at the beginning.

When you look at the planet by day, you know you don't see any signs of humans. This is the Apollo blue marble picture that they brought home for us of Spaceship Earth. When you look at the planet at night, all you see *are* the signs of humans. And here you have the lights of the cities, some incredible fires in Africa and in this particular season some methane burning and some biomass burning in South America.

But the other thing that's really so vivid to me is that there are so many places there that still don't have any life at all and over the next several decades, while the students in this room become the CEO's and cabinet members of tomorrow, lights will go on in all of those dark places. And the fuels that we use to turn them on will make a big difference between whether we live in a doubled CO2 world or a quadrupled CO2 world, and whether we can cope with the environmental damages to the planet.

Thank you very much.

[applause]

G: Thank you for an inspiring lecture. I think for the students in the audience, I think you could automatically get one credit in climate change 400 by just attending today, with all the information packed in there.

Now we'd like to invite our panelists to provide remarks. We will start with the Steve Director, Dean of the College of Engineering.

[applause]

SD: Thanks, Greg. I've been frantically trying to write things down since we have… none of the panelists had seen anything ahead of time.

?: Oh!

SD: (laughs) Thank you.

[laughter]

SD: First of all, let me say that I truly am honored to have been asked to participate in this and I'd like to welcome Rosina as a fellow dean. I do look forward to working with her in the future. It was an inspiring talk. I think it was kind of a scary talk, actually. It raised a number of really, really important issues that we're going to have to deal with. And I think that we're going to have to find solutions to some of these issues. Rosina didn't really talk about solutions in a big way. And I think that the University of Michigan, with its very broad excellence in a wide variety of relevant fields, is a good place to start working on some of these.

Since I am Dean of the College of Engineering, I thought that I would use my allotted six minutes to focus briefly on some of the technological things that we've been working on in the college. Clearly, I can't cover everything. There's just a lot, but let me just mention a few that I think go some ways towards addressing some of this.

Technology, I think, can play an important role in a number of ways. One is it can help us to better understand some of the sources of the problems that Rosina talked about in climate change and therefore helped us better address how to solve them. Technology can also play a role in helping to undo some of the harmful effects of industrialization and urbanization. And technology, I think, can also help avoid some of the future environmental problems.

So let me just talk about each of those briefly and give some examples. In terms of a better understanding of climate change, we have work going on in our department of atmospheric, oceanic and space science in atmospheric, chemistry and climate modeling. The goal here is to develop models to help describe the chemistry and climate interactions, and to validate these models through comparison with observations. This is very important because radiative and chemical processes in the atmosphere are affected by the emissions of various trace species, and these emissions can lead to the formation of aerosols, which can then _________ clouds and effect radiative transport in the atmosphere and changes in the radiative process and turn feedback to alter atmospheric chemistry. So we need to understand these complex processes and how they relate to climate and chemistry changes.

We also have work going on in our department of Naval Architecture and Marine Engineering in trying to model the coastal environment, especially the Great Lakes coasts, in order to maintain the integrity of that. And we have work going on in several of our departments in remote sensing that can help us get a better handle on this as well. In terms of trying to undo some of the harmful effects of industrialization and urbanization, we have work going on in civil and environmental engineering in trying to fix some of our water supplies. We know that water supplies are going to increasingly be hurt by pollution due to growth of urban areas and it's going to be increasingly difficult to maintain water quality.

The water quality of the Great Lakes Watershed in particular is greatly impacted by contaminant loadings resulting from chlorinated solvents. We're trying to address that in two ways. Work in surfactant enhanced aquifer remediation which takes advantage of the properties of surfactants to either soluabilize or mobilize non-dissolved source materials which is trapped in the soil matrix. We're also working in de-chlorinating [biocurtains?] which takes advantage of a biodegradation process whereby anaerobic microorganisms are used to convert chlorinated compounds into harmless by-products.

In order to avoid future problems, we have a number of activities, including development of new ways to handle nuclear waste in order to make perhaps nuclear energy a more acceptable form of the generation of energy and to reduce the harmful effect, or the fear, at least, that nuclear waste currently has. We have a significant amount of work going on in the mechanical engineering department and other departments in trying to improve our manufacturing techniques to make the manufacturing process more green and less harmful to the environment.

Two very new programs that we recently got significant funding for are in the area of trying to make more efficient or create more efficient conversion of energy. One of these in is the area of better fuel cell technology. The other is in the area of internal combustion engines, to try and make… create an engine that has the same kind of efficiency that diesel engines have, but do not in any way have the same kind of negative environmental impacts.

I might point out that the issues with the environment was the reason that the Department of Energy recently decided to sponsor the solar car race, an activity that our students have participated in for the last 12 years. As you know, or if you don't you should know, that our team came in 1st place. It's the 3rd time in the 6 races that our solar car team came in in first place. They are currently in Australia preparing for the world solar car challenge.

At any rate, I just want to highlight a few of the things that are currently going on in the College of Engineering. Many of these will be greatly enhanced by collaboration with other units in the University. Thank you.

[applause]

G: We'll now have Doug Kelbaugh from the College of Architecture and Urban Planning.

DK: I thought Rosina did a very good job of talking about the consequences of our actions on the natural environment. I'd like to shift the gears in two ways to talk a bit about the built environment and more about the causes and maybe a little bit about the solutions. We're headed into the urban century, folks. For thousands of years, the planet's been overwhelmingly rural and for hundreds of years, it's been predominantly rural. In about two years, it's going to be equally urban and rural and our kids will grow up in a predominantly urban world. It's a major, major shift… certainly as big a revolution as the IT, as the information technology or life sciences. And as Rosina's charts vividly point out, most of that urban population is in gigantic global cities, primarily in the developing world. Only 3 or 4 of the cities that we think of as the big world capitals will be among the 30 or 40 largest cities before long.

Ironically, American cities are thinning out. As you know, the cores are hollowing out and our suburban sprawl is smearing itself in a giant monoculture across the countryside. We are in fact getting less urban in an ironic sort of way. We're spreading out at a much faster rate than our population is growing… 5, 6, 7 times as fast as a matter of fact. So that now a typical suburban household takes about 11 automobile trips per day with their car. There are more cars owned. We are driving them further. We are driving them more often and we're driving them more often alone. If Mark Twain liked statistics, or could be moved by them, here's an interesting one. There are so few people now that commute in carpools… it's down from about 20% to 13%, that we could fit the entire… everyone in Western Europe into our cars along with us…

[interruption on tape]

… the world's population are consuming 40% of the energy, 40% of the water, 40% of the material flows. It's just not sustainable. It's about 10 times our share. So all of a sudden, maybe we don't look so generous. We look sort of greedy. Maybe we aren't so productive. We're in fact pretty sloppy.

What can we do about it? I'm going to mention 5 points. Others could certainly add equally valid ones. One would be to make in-fill development of existing cities, including Ann Arbor, our number one priority. As long as land is artificially cheap on the periphery, we'll continue to spread out. And as long as gas is artificially cheap, we'll continue to spread out. Not only in terms of driving all those vehicles all those miles, but in terms of heating and cooling all those big houses that have gone up from 1,500 square feet to 2,200 square feet, while our households have gone *down* in size for the last 15 years.

The other would be to get transit on track. Let's face it, transit is a joke is this country. We, as some pundits say… "You might as well put signs over the doors on the buses that say 'Losers Enter Here.' " I mean, that is in fact what it is. It is not a mode of transportation of choice. It's one of last resort. In Europe, it's actually fashionable to take transit to work. If we could get walking and biking more… Europeans, who are not exactly impoverished, bike about 10 times as much as we do. And walking, in the end, is the cleanest, the safest, the cheapest, the healthiest, *the* best way to move around. And that's what cities allow in great ways, particularly if there's transit which allows the pedestrian to move around the whole region.

Lastly, we need to make the built environment beautiful. There is a connection between the aesthetic preoccupations of all the people in my building and the scientific preoccupations… the people at SNRE. And that is that if something is not beautiful, we don't love it. And if we don't love it, we don't care for it. And if we don't care for it we don't maintain it and it is not sustained. Things that are beautiful are the things that we take care of. And our buildings and our cities need to be beautiful.

We've done this before, actually. At the end of the 19th Century, the American city was full of squalor and disease and noise and overcrowding and conflict. But in two short decades, the City Beautiful movement turned them into glorious, green civic places that were the pride and envy of the world for a long time until the automobile sort of undid it all. We could do this again. It's a big, exciting project to bring the built environment, the habitat for humans, into a greater harmony with the natural environment. Thank you.

[applause]

CS: Thank you, Greg and Jonathan, for this invitation. On behalf of Dean Rebecca Blank and the faculty and students of the Gerald R. Ford School of Public Policy, welcome Rosina to the University of Michigan and to the Directorship of the School of Natural Resources and the Environment.

The Gerald R. Ford School feels a true affinity with the School of Natural Resources and the Environment. Let me say a few words about that. First of all, clearly we both have new Deans, both of whom were influential policy makers in the Clinton Administration. Both care a lot about guiding their schools with a mixture of both academic and professional predilections into making a difference in the world, both inside and outside academia.

Let me give a little background on how I think we see the School of Public Policy and the School of Natural Resources can work together, and particularly what the School of Public Policy can add to this interaction. Our academics are rooted deeply in especially economics and political science. But we care deeply about policy, about implementing it and researching it. From an economics point of view we care more than most groups do about opportunity costs, about costs and benefits. They apply, of course, to questions of sustained ability, whether it's saving an endangered species or protecting a threatened environment, or discouraging pollution. We try to quantify the economic impact in a wide sense and not just in money terms, but in lives and in health. And certainly in comparing and contrasting the many policies that deal with climate change. These cost benefit concerns, I think, will play a big role.

We also care about turning these recommendations into policy. We teach courses about how legislators work, how to take advantage of these workings, and how to structure organizations to get things done. Finally, the School of Public Policy is a special niche among public policy schools around the world. We demand a higher level of quantitative thinking. All our students have to take calculus, statistics, probability. Many of them take the operations research course and decision-theory course that I teach. And almost all of them who aren't about advanced econometrics, so they can take this data and understand the strengths and weaknesses, and make sure that it's fine-tuned and correct.

Finally, we include faculty from 10 different departments so that we can really take an interdisciplinary approach to the issues we face. One of our newest faculty being, of course, outgoing Dean Barry Rabe, who I think will play a major role in the interactions between our two schools.

Let me close with a minute about my other hat. As Greg said, the Center for the Study of Complex Systems is a sister organization to the Sector for Sustainable Systems.

Dean Bierbaum talked about the results of many models relative to sustainability issues. The models we teach in our basic courses in economics, mathematics, political science, environmental science, have to be pretty simple. Usually everyone is the same. No one changes. The world is in simple equilibrium. However, to attract the attention of policy makers and people who make a difference, we often have to add realism to these models… diversity, dynamics, learning, feedback, networks, organization. And it's exactly those aspects that the Center tries to encourage and foster with its many faculty around the University.

Much of this begins with ancient-based models, models like School of Natural Resources and Environment Prof. Dan Brown's recent one and a half million dollar National Science Foundation grant that centers on a grant working very much to understand urban/rural interactions.

So finally, we at the Gerald R. Ford School of Public Policy look forward to tackling issues of climate change and sustainability issues together with you, Dean Bierbaum and the School of Natural Resources and the Environment.

[applause]

G: I'd like now to invite Dean Bierbaum and the other two panelists to come forward and I think we can take questions at this time from the audience. If you'd like to ask a question please raise your hand and we'll bring a mic to your side. [pause]

J: Well, I'll ask a question.

[laughter]

Just to get things started, Dean Bierbaum you emphasized interactions and systems interactions as being a crucial point. Do you have any sense of how the University should be doing things differently, looking ahead? We're in the 21st Century, but in our education of students that would be different from what those others of us who are here experienced in our educational opportunities.

RB: Sure, yeah. The way that, at least I suspect you were trained, Jonathan, the way I was trained is that I learned biology and I learned economics and I learned chemistry, but I didn't really understand how they worked together or how they could work together to help solve problems that had science dimensions, but solutions that were simply technical potential, as opposed to having some human feasibility or societal acceptance weren't really solutions at all. And so I think that the student of today has to learn to interact with folks of other disciplines and to understand the parameters of those other disciplines because I don't think there are any right solutions to these complex problems. It has to be weighed given what the science says, what's technologically possible and what society is willing to do. So yes, I think we do need to be trained in an interdisciplinary way.

You asked something about the multiple stress aspects. I do think that that whole general area… I think folks who study biodiversity loss for the most part haven't thought too much about climate change. Or people who study traditional local and regional air pollution problems haven't necessarily thought about the interaction. I think modeling begins to pull it all together, but a lot more hard work has to go into those kind of "what if?" scenarios that I suggested for places like Manhattan and for places like Seattle when you just put the overlay of possibilities together, you can gain additional knowledge about what options might exist or what options you might want to develop and what are foreclosed to you. And I think wise decision-making can proceed in the face of uncertainty, but I think you need to have as many cards laid out as you can.

Q: A question for Dean Bierbaum: So during the latter part of the Summer we were hearing a lot in the news about the U. S. rejecting the Kyoto Protocol and the United States struggling to redefine its position. The present administration struggling to redefine its position on climate change. They seem to be making progress towards that and then of course, the terrible events of September 11th occurred and we're not talking about that issue anymore at all. What do you see as the next steps that the present government is likely to take on climate change and how soon are we likely to get back to that being something that's actually on the agenda?

RB: You're quite right that it's taken a much back burner. The President, in the wake of the National Academy Report that reaffirmed that the issue was one to be taken seriously commissioned two things: Climate change technology initiative which was supposed to look at where we should put investments into the broad technological realm from buildings to industry to automobiles, and a climate change research initiative that was supposed to look for very important research holes that need to be filled. There are groups at sort of midlevels of the bureaucracies working on those. Those were intended to be produced in time for Marrakesh, the next negotiating session which starts roughly Halloween. Some of you may have seen that the European Union is going to announce at Marrakesh that it wants to start a carbon trading system for those countries in the world who are still participating in Kyoto. The U. S. of course, hasn't.

I think it's really hard to predict, but I think in this case Congress is more likely to hold the Administration's feet to the fire than the Administration to take any steps. I mean, in particular the Senate. If I were a betting person, I would bet that we would make some modest increase in research in technology and in research. Unfortunately, I think we'll put more into the physical climate system than we will into beginning to understand the impacts and adaptation measures. But it's really hard to predict. I mean, it's quite clear this Administration didn't want to act quickly and I'm sure we won't, but I think they will make a down payment on the research side, but probably not in SNRE areas.

Q: Thank you for an interesting and articulate presentation. I have a related question. Do you think, given the magnitude of the challenge facing the world in terms of reducing greenhouse gas emissions that it's a good thing to ratify the Kyoto Protocol? Secondly, is it useful in a symbolic, supportive way for places like the University of Michigan to make a commitment to a Kyoto reduction?

RB: This is Day 16, so I'm not sure I can speak about what the University should do…

[laughter]

I mean, I went to Kyoto. I was part of those negotiations, and I guess I would say that, you know, the Treaty isn't maybe what everyone would want. But I said that path of a… a journey of 1,000 miles has to start with a single step, and I really believe that's what it was. It was to begin to try to change people's thinking about the cost of carbon and that carbon had a value. So I think that was important. What I think isn't widely appreciated is that the architecture of the Kyoto Protocol was very much the United States. You know, the Clinton Administration was considered very brown, as opposed to green, in wanting maximum training, in wanting averaging years… 5-year averages. And many of the things that were built into Kyoto were because of the United States. And were the current Administration to agree to anything, I think they would want some of those flexibility measures before they would ever sign on.

So I think the architecture of Kyoto was very good in terms of the U. S. as a country, and I think some first step is necessary. Having lived through Kyoto, my feeling is that if Kyoto gets thrown out, you probably couldn't negotiate anything again for another 10 years. So to me, the effort to begin thinking about the costs of these things and how you would design a training system and how much carbon you can store in forests and how fast those pools shift and what El Nina is doing to it, and all of that missing kind of information will be very important for truly global accounting. I think we just have to get on with it. So I see if as a very important mechanism for that.

Q: I think this is a question that sort of transcends different schools. Unfortunately, Bob Dolan couldn't be here for the other panel member, but one of the constants I guess to start off with one of your slides and then just a question to the whole panel is that you said, "One of the constants in time was market penetration of technologies to ameliorate or dealing with whatever issues are up." Does any of the panelists… do you want to comment on whether there would be a benefit at a university level or elsewhere to have some sort of a platform or an interface that that links up technology and technology development with policy, with business opportunities in a more formalized way than the ad hoc way in which it is currently being done to address the environmental issues.

DK: Obviously, the answer is "yes" and unfortunately, I don't think we've quite figured out how to do it effectively, so it's a challenge for us. But unlike some of the problems that Rosina has posed, I think we can solve that problem and it's incumbent on all of us to address that. I think industries understand, of course, in the long run, that the solution to these problems is in their benefit. For example, a complex system center is starting a working relationship with Ford Motor Company to look at the question they call "sustainable mobility" and they would really like to know where is… what's transportation going to look like 10 years from now relative to some of the issues we've seen? We hope to have a big seminar… a world-wide seminar on that next Summer.

PW: I'd like to make a suggestion that all of the Deans of the Colleges of Education, Law and our Natural Resources and so forth collaborate on a monthly basis on all the things they could do to take the leadership in alternative sources of energy, such as solar, get our transportation system going half as good as Europe or Japan. We don't have a transportation system except for freight in this country. We need a high-speed, safe transportation system in this country and we don't have it. I'd like to see you get the auto industry to come up with SUVs that will do 30 miles to the gallon instead of 12, you know? Those kind of things I think the leadership of this school can do and take the leadership in this whole country, and go blue, think green.

[end]

Transcribed by Kathleen Peabody
Ann Arbor, Michigan
November, 2001