COUNCIL on FOREIGN RELATIONS

Transcript

Developing an International Framework for Geoengineering

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Video Audio

RUTH GREENSPAN BELL: Okay. The microphone works -- (laughs) -- okay.

I'm Ruth Greenspan Bell from World Resources Institute, and it's my pleasure to invite -- to welcome you here this evening. I've been on the other side of this, so I remember the ritual Council warnings, which are: would you please turn off your cell phone, even if it vibrates, because sometimes it interferes with the speaker system, and this meeting is on the record.

So our subject this evening is geoengineering, and in some parts of the environmental community, just saying the word "geoengineering" is a fighting word. It can be very contentious. In part, I think this represents some fear in some parts of the community that if you start talking about geoengineering you give up on mitigation, you give up on adaptation, and just start trying to -- try to change the environment.

There is, I think, some fear of the impression that there's a magic bullet involved. And I think -- my own personal concern is that, I'm kind of worried that when the current climate deniers kind of wake up at some point and realize something is serious happening here, that they'll be seeking easy fixes. So I'm really, really pleased that the Council has chosen to have this conversation today, and particularly with these two speakers who I think are the perfect people to be talking about this.

So we will start. We will have a conversation for about a half hour, and then we'll open it up to questions at that point. I'm not going to repeat the bios that are in the handout that you have. Needless to say, we have two very distinguished speakers.

John Steinbruner is professor of public policy at the University of Maryland, and director of the Center for International and Security Studies, and he's been a leading figure for many, many years in arms control and global security. Granger Morgan is professor and head of the Department of Engineering and Public Policy at Carnegie Mellon University, and also, for many years, has been a leader in helping finding ways to describe scientific uncertainty and

incorporate risk into public policy decisionmaking. So we have totally the perfect people here to be talking about this issue.

So I wanted to first ask Granger to sort of set the stage for us and to tell us -- to start from almost a definitional point of view: What is geoengineering? And why is this set of issues starting, really, to be discussed with some degree of seriousness at this point? What is it in the state of play of climate science and carbon regulation that might be stimulating this discussion?

M. GRANGER MORGAN: Okay, and we're running the experiment tonight to see if an engineer is capable of talking without slides. (Laughter.) Both John and I have slides that are out there on the table if you want copies of them. But I thought actually I should start just a few steps even back from what you described and make sure we're all sort of up to speed on the climate problem.

The sun shines on the earth, of course, and about 30 percent of that light is immediately reflected back into space, and the other 70 percent is absorbed by clouds, by the surface, by the oceans and so on. And, of course, if that was all that happened, the earth would rapidly heat up and we'd all fry. Somehow we've got to get the same amount of energy back out into space as got absorbed. But once it's absorbed it, can't be reradiated as light; it has to be reradiated as heat, as infrared -- you know, like a radiator radiates.

And there's the rub, because the atmosphere, while it's transparent to the visible, is not transparent in the infrared. And so what happens is that the whole temperature of the planet warms a bit, and then finally it gets to a warm enough point that the amount of heat energy radiated off the top of the atmosphere is just equal to the amount that's being absorbed, and so the planet runs in equilibrium. And that's good thing for us -- this is the so-called "greenhouse effect," and if it weren't for that, it would not -- planet Earth would not be a terribly pleasant place to be.

The two principal constituents in the atmosphere that absorb infrared are water vapor and carbon dioxide. And we have for several hundred years now been gradually increasing the concentration of carbon dioxide, and as a consequence, the mean temperature -- or the average temperature at which the planet operates goes up.

So that's all kind of theoretical. And in the slides, one of the things you will see is a picture of a couple thousand-megawatt coal-fired power plant, just west of where I live, called the "Bruce Mansfield Power Station." A plant that size uses a couple hundred of these large 100-ton hopper cars of coal every day. And so to give it sort of a more concrete sense, a plant like that takes a couple hundred -- you know, a train of 200 cars turns it into a invisible gas; puts it into the atmosphere every day, and we're doing that in hundreds of facilities like that all around the world. So though it's invisible, the mass volumes are quite large.

The -- one other thing I should say about the physics, or the science, is that unlike conventional pollutants -- unlike, say, sulfur dioxide, oxides of nitrogen, which, when you put them in the atmosphere only stay there for a few hours or days. So if I stopped emitting sulfur dioxide, it would rapidly disappear, or if I stabilized emissions, concentrations would stabilize -- CO2 and other greenhouse gasses aren't like that.

They live in the atmosphere, many of them, for 100 years or more, with the result that -- it's kind of like a big bathtub. If I had a bathtub with a small drain and a big faucet, you know, unless I really closed down the faucet, the bathtub will continue to fill up. So think of the

atmosphere as like that bathtub, and unless I dramatically reduce emissions, by 80 percent or so, globally, the level of concentration -- or the concentration of CO2 in the atmosphere will continue to rise.

All right, that's all the science. But since it turns out many people do not understand this cumulative effect, and the fact that one really does need to dramatically reduce emissions in order to stabilize concentration, I've started making a point of talking about this whenever I talk about climate issues.

At Carnegie Mellon we've been doing a variety of things on climate impact assessment and integrated assessment of climate problems for many years. When we first got started we looked, sort of, systematically across the whole space. And one of the things we did was get a young post-doc, David Keyes, to do quite an extensive review of geoengineering -- by which I mainly mean changing the albedo, that is, the fraction of sunlight that's reflected back to space. I told you it was about 30 percent.

So this is not a new idea. People have been talking about it sort of on the fringes of the science community for many, many years. And we did a review, and then we set it aside. Like many others, we were rather reluctant to work too seriously on the problem, in part, because, you know, you're sort of concerned that knowledge might drive intention. That is, that if you get to the point you really know how to do this, and you know what it would cost, and so on, that that might raise the likelihood that somebody would do it.

So for, I don't know, 15 years or more, having done a set of fairly comprehensive reviews, we didn't work on it anymore. But then about three years ago, given the really abysmal progress that the rest of the -- you know, the U.S. and all the rest of the world are making, in terms of reducing emissions, I began to get concerned, among other things, that somebody might wake up one day and say, 'Oh, my God, we've got a problem.' I mean, the Chinese, for example, might conclude, because of changes in precipitation, 'we can't feed our people;' or Russia might conclude that all of Siberia is turning -- with the permafrost thawing, is turning into an impenetrable bog.

And so I got worried a bit about the prospect that somebody might -- or some small group of folks might go off and unilaterally just start doing this, having concluded, 'We've got a problem, we've got to fix it.' And at that stage, I decided maybe the foreign policy community should start thinking about this issue.

So three of us at Carnegie Mellon on the technical side, and John and David Victor on the political science side, got together and -- I guess it was about two years ago now, ran an event in the old building up the street, in which a -- day-long event in which a good cross-section of leading people on the technical side of climate science sat down with a number of experts in the foreign policy community to think seriously about this.

The participation in that group was all North Americans, and we decided we needed to broaden the discourse. And so, at the invitation of the government of Portugal, we ran a similar event in Lisbon last April, in which, in addition to North Americans, we had a fair cross-section of folks from across the EU, from Russia, China, India and elsewhere around the world. And both of these had as their objective to try to get the foreign policy community at least aware of this issue and beginning to think about it.

Now, I want to talk about two other things before I turn things over to John. First of all, the word "geoengineering" turns out to be, sort of, all-inclusive. I mean, to different people it seems to mean all kinds of different stuff. The Royal Society in London did an assessment recently -- actually, the discussion in the back of that assessment, on governance, builds directly on the results of the two workshops we ran, because two of the key authors had been participants in both of those workshops.

And they did a very useful thing. They introduced two words, "solar radiation management," for stuff that involved changing the albedo -- and, actually, in a piece that we published in "Nature" about a month-and-a-half ago, "Nature" used some phrase about sunscreens, or "sun shades," which is perhaps maybe even better -- and then all the other stuff was termed "carbon dioxide removal."

And, among other things on that side -- I mean, you can actually build devices to scrub carbon dioxide directly out of the atmosphere and then sequester it, that is, put it deep under ground in appropriate strata -- those sorts of processes are inherently slow. They could be as cheap as 100 (dollars) to $200 a ton. So they're important. They set an upper bound on what the cost of controlling CO2 might be. But they're inherently slow, and you could do them within the confines of a particular nation. I don't view them as posing significant governance issues.

On the other hand, the stuff that involves changing the albedo by, for example, putting very fine particles in the stratosphere -- and we can talk a bit more about how you would go about doing that -- could be done at relatively low cost, perhaps a hundredth or less the cost of abating emissions, and could be done by a single state operating within the confines of its national borders.

I have a doctoral student right now who, in collaboration with groups at Oxford, is doing climate modeling. And while you can, indeed, reduce the average temperature of the planet, it's imperfect, and the effects are different in different parts of the world. And, over time -- for example, she has looked at how China and India's climate might (have) evolved. And while they're both closer to today's climate than they would be, say, 80 or hundred years from now, over time they -- in a space of temperature and precip, they move away from each other.

Last comment. I think that it would be a real -- well, I've published in several places recently an argument that says the time has come to mount a serious research program here. I'm not talking about an enormous amount of money, I'm just saying that, to date, there's been hardly any serious research, and for two reasons we need to get serious and understand what could be done and what it might cost.

The first reason is that there's some possibility that somebody else would do it. And then, if we thought that was a terrible idea -- because, for example, it does nothing about the ongoing acidification of the oceans, which will probably leave us without coral reefs by the end of this century, or any of a number of other impacts from rising CO2 -- if we thought it was a bad idea, we need to know enough to be able to mount coherent counterarguments.

And the other reason we need to do research is to, in the event that we have a climate disaster, we know what we're getting into if we suddenly decided we had to do this -- if we had a billion people at risk around the world, for example.

And so, in the back few slides of this thing that I've passed out is an argument that says one of the things that climate science community should start doing fairly quickly is figuring out a

space in which they could do field experiments without any sort of international oversight or overview. I think if you -- I mean, we do stuff in the stratosphere all the time, of course, and so it's not as though the stratosphere is absolutely pristine. But you don't want to have people going off and doing things that involve large radiative forcings; or go on for extended periods; or, for that matter, provide lots of reactive surfaces that could result in significant ozone destruction.

So I think that one of the early requirements for the science community is to figure out: Can you define a sort of space within which -- as long as you're behaving inside that space, issues of governance are not a big deal, but doing anything outside that space requires some collective agreement that it would be appropriate to do that?

And, at that point, I'm going to stop, and John -- (laughs) -- pick up.

JOHN STEINBRUNER: (Laughs.)

BELL: Yeah, sure. Obviously, the questions then turn to governance issues, and that's what I'd like you to address. But I just -- a special question is: The U.N. negotiations have demonstrated the difficulty of getting a mutually-acceptable agreement in place on the climate issues. I'm curious whether you would also address what this tells us about getting rules into place for geoengineering?

MORGAN: And maybe before John talks about that, I should say I think that putting something in place quickly, that made it really hard to do research on modest scales, would be a disaster. But John and I may disagree.

STEINBRUNER: Now, the role I've played is to try to anticipate what kind of rules would have to be applied in a situation where there is a technique that almost certainly would work and it is not very expensive, so it's not as if there's a lot of uncertainty about what to do. There's at least one technique that would reduce -- mimicking the volcanoes, would reduce average surface temperature on the order of a half a degree centigrade in a single year. But you'd have to keep doing it year after year.

So I am anticipating a situation in which the image of global consequence becomes globally distributed and people start to get concerned about their equity in this. And though I agree that it is desirable and probably feasible to set a limited space -- such that you could say, well, field experiments in this relatively modest range are okay, I'm not sure how limited that can be, because at some point the world is going to insist on having a collective stake in this, almost certainly, because you're dealing with a global commons. The atmosphere -- (laughs) -- which everybody breathes, is a global commons if anything is, and the basic rules say, nobody gets to appropriate for personal or sovereign use, and everybody's equity has to be taken into account.

So what I'm saying is that because you can imagine having very substantial global effects on the basis very small initiatives, anticipate the need for global rules which do not currently exist. There's no direct legal structure dealing with this question, not surprisingly, because it's just coming on the horizon.

Trying to be practical about it, what I'd say is it would be a very good idea for the National Academies of Sciences to have coordinating mechanisms among themselves to set guidelines for field experiments that might, in fact, set your limits and say: This is what you can do, and these are the limits you have to adhere to. And if you go beyond those limits, what are the guidelines for doing a, globally, sort of, credible review as to the relative merits. And I presume

that nobody's going to go off and try to do this with no research whatsoever, so there would be a period of time in which we are dealing with, basically, field trials.

But I don't think it's too early to anticipate the possibility of a situation arising in which suddenly there is a great deal more fear than there currently is, coming much more rapidly than the scientists anticipate clicking in. And at that point, we could have a real mess on our hands if there are no rules whatsoever. So what I'm saying is, anticipate the need for having a basic principle, which is, "Thou shalt not mess with the atmosphere unless everybody agrees in some globally representative way." And the criteria for judging this have to do with meeting a very heavy of burden of proof. You have to demonstrate that the benefit to be achieved decisively outweighs the negative consequence.

And, I would say, and this is the important point, you have to demonstrate that this is not a substitute for mitigation, because if it is, it's the equivalent of heroine addiction, basically -- once you start, you can't stop; and that you have not affected the underlying carbon build-up, acidification of the oceans, and all that just keep going.

MORGAN: You might explain why you can't stop.

BELL: Kind of, suggest --

STEINBRUNER: Why you can't stop? You cannot stop because the technique that will work, only works for a year or two. You put particles up and they come down within a year or two. The carbon dioxide stays for a century. So his bathtub analogy is --

MORGAN: But the bathtub has continued to fill. So if you stop, suddenly you get a whopping big temperature increase, which just raises --

STEINBRUNER: Right, right.

MORGAN: -- ecosystems.

STEINBRUNER: And we're messing around with the rate of temperature increase. I think it's fair to say we're projecting a rate of increase that the geological record has never seen. So we're messing around already with global balances that could conceivably put everyone at risk.

And if you want the nightmare scenario that might wake everybody up and suddenly make this a much bigger deal than it has been, it's the possibility of a surging release of frozen methane, gas hydrates that would produce a positive feedback cycle. And, you know, that could create an image of real catastrophe -- I mean, real catastrophe that would seize everybody's imagination, way out in front of what the scientists could really sort out.

And that's been hypothetical. I've been saying this for a couple of -- about a year since we've been talking about it, and people have been saying, 'Yeah, but it's, you know.' But they've just measured -- they just measured it in the Arctic Shelf. And it's the first observation, but I would say we ought to pay attention to that, because this is potentially a very big deal.

Bottom line of all this is we need to start talking about it in terms of the governance issues: What kind of rules do we need to put in place to provide adequate vetting for any initiative? And, unfortunately, it's not just big governments that could do this; it is small governments, it is billionaires, probably, could figure, "I'm going to save the world all by myself and I won't bother to mention it."

So you've got a problem -- a situation in which small initiatives could have a global effect, and we don't have any rules for dealing with that. And I'm saying it's time to start talking about the rules. I concede that on this subject, and in general, it's not popular to talk about global rules; so I'm telling you, however, we're looking at situations that's going to make it necessary, like it or not, and we ought to start thinking about it.

BELL: Can you mention what bodies you might have in mind? You mentioned an informal set of bodies through National Academies of Science that could work on these. Are there other bodies you think that would be well-suited, that you can imagine to take this responsibility?

STEINBRUNER: Well, you can imagine the coordinating mechanisms of the National Academy of Sciences working out some kind of understanding among them, and making themselves, kind of, maybe the global equivalent of an institutional review board for medical -- you know: If you do any experiment on human beings, you have to -- you have to justify yourself to the institutional (review boards, who do an ?) independent -- that they are not your, you're not subjecting the subjects to unnecessary risk.

I think they could -- using that analogy, they could set up a basic mechanism, an understanding the way Granger was talking, "Okay, if you're operating within these fairly narrow limits, where we don't think there's going to be any major global consequence, do it on your own;" or, "You can do it on your own, but there are disclosure rules, transparency rules. You got to publish what you're doing. You can't hide it." "If you go beyond these limits" -- and the limits need some agreement, then there has to be, I would say, some common vetting process that they would have to organize among themselves collectively. We all have a stake in that.

And I would say it's good to start talking about just that much. But what happens if tomorrow we get, sort of, somebody announced, 'Okay, we've got frozen gas hydrates coming out like crazy, and unless we stop this, we're all dead,' and people start believing that. What do we do?

At that point, if you're talking about real emergency things, I'm saying, well, if you're looking at the only mechanism we have at the moment for global vetting, you're talking about the U.N. Security Council. You're going to have to go through that. And if you don't like that, then think of something else, because don't think that you can do this on your own without triggering real, real reaction.

And this is something that if people think there's an (emergency), they're going to get excited about it. They're going to get really excited about it, and you're not going to be able to act unilaterally -- (inaudible) --

MORGAN: A couple more comments on, sort of, coordination, and who might do what.

As I mentioned, the Royal Society has done a study that, among other things, introduced this very useful distinction between solar radiation management and carbon dioxide removal. The Royal Society is getting geared up right now to do a second round of work on global governance issues. It'll be an informal kind of thing. In the paper that John and I and our co-authors published in "Foreign Affairs," we also raised the prospect that ICSU, the International Council on Scientific Unions, might be a candidate for coordinating at least research activities among different research groups around the world.

I want to reiterate what John said, which is I think that any research in this area needs to be open. I think it would be truly disastrous if, you know, we discovered a few years from now that

there was a "black program" that some government had stood-up to sort of learn on-the-quiet how to do this.

And I also think that we do need to get a serious research program going, because the sorts of events that John's talking about -- that is, that a climate catastrophe of one sort or another, are still way out in the probability -- in the tails of the probability distributions of our uncertainty.

I don't think there are very many scientists who would say they're high-probability events. But they are out there. There is some -- I mean, it's not zero. And you don't want to be in the position of suddenly deciding you got to do something dramatic quickly if you haven't studied it and you don't know what might happen.

STEINBRUNER: Just one little bit. The burden proof on the moment quite appropriately falls very heavily on anybody who wants to proclaim a catastrophe. You have to demonstrate to confidence that -- It will shift in public a lot sooner than it'll shift among the scientists. And if it did -- if some image of a catastrophe started to take hold, it would be very difficult to disprove it also.

When you're dealing with out-on-the-tail, low-probability events, whoever carries the burden of proof to say it might happen, loses. And so what you have to worry about is some image of catastrophe that takes -- seizes broad imagination, and the scientific community cannot disprove it.

And you could get that. This frozen gas hydrate thing has some potential in that regard.

MORGAN: So you started this session by saying, many people look at this and think it's a really awful idea. And I agree. And I think it's actually a good thing that many people look at this and think it's an awful idea. I mean, messing with the planet is not something one should do lightly.

And, actually it was very interesting, the Russian participant at this workshop we were in in Portugal reminded us about various Russian attempts to, you know, redirect rivers and otherwise engineer the landscape; and, you know, pointed out that there was a lot of hubris here and it didn't work out too well. You don't want to -- so if you do, as a last resort, have to engage in such activity, you don't want to do it without knowing quite a lot about it.

STEINBRUNER: Right.

BELL: I was going to actually ask a question about the flip of the rush-to-judgment, which is if, you know, if serious scientists at some point decide -- and governments even decide at some point intervention is necessary, and you think about, kind of, the normal NIMBY writ large problem that we see in other environmental and other areas, is there any active preparation going on at this stage to kind of introduce -- I mean, I realize the Royal Society and others have issued these, but I sort of suspect they're --

MORGAN: Well, there's a bunch of stuff going on. I mean, I spent the last two days at a workshop over at the Bipartisan Commission -- I forget exactly what it's called --

STEINBRUNER: (Inaudible) -- global task force on geoengineering.

MORGAN: Yeah, which has got a task force that it's putting together on this. In a couple of weeks there's a four- or five-day event out at a -- (inaudible) -- to be trying to start some

conversation on this. So there's a bunch of low-level things going on. There's this Royal Society event that I described.

But, you know, it's also politically reasonably touchy I think. I mean, John Holdren quite appropriately noted that we should not completely take this off the table. And Seth Borenstein, of course, turned it into a big article, implying that, you know, that the administration was about to embark on this; which is not, I mean -- So, you know, it's touchy. I mean, it is very pressworthy. So, you know, I'm not faulting either one of them in that case. But you can also understand why people might be a little reluctant publicly argue that we need a research program.

I don't think we need a big program at the moment. I think that some tens-of-millions of dollars, spent appropriately through places like NSF, and maybe NOAA and NASA at later stages, would be entirely appropriate at this point. I mean, it really is the case that we're almost dead in the water with respect to serious research on this problem. About the only thing that's been done has been some computer modeling using general circulation models. And it is pretty clear that one will have to do some small-scale field stuff to really understand some of the technology.

The other thing we ought to be doing is having some instrumented aircraft available, so if and when we get the next Mount Pinatubo we're all set up to go and study in detail the processes involved.

BELL: Too many earthquakes, not enough volcanos, right. (Laughs.) (Laughter.)

MORGAN: Yeah, although my suspicion is, if we had a volcano tomorrow, we wouldn't be in a position to do the --

BELL: (Laughs.) I'm not urging -- (inaudible) --

MORGAN: (Laughs.)

BELL: Okay, why don't we now actually invite the audience to join into this. We have microphones that we're going to pass around, and I would ask you to please speak directly into the microphone and state your name and affiliation.

Mr. Topping.

QUESTIONER: My name is John Topping, with the Climate Institute.

And Mike MacCracken, our chief scientist and, together with the Climate Response Fund, is essentially organizing the (Solemar ?) meeting. And, you know, the whole purpose of that is to really try to develop some guidelines that would be very useful. And, you know, both -- you know, I can't speak for, you know, exactly will come out of it. There will be about 150 experts from member countries there.

But what's interesting, I think, on -- just on this issue, is that there are a range of possibilities, some of which might be almost win-win. I mean, one idea that occurred, Russell Seitz, I think at Harvard, has essentially advanced the idea of --

STEINBRUNER: Microbubbles.

QUESTIONER: -- essentially microbubbles. Well, you know, they may or may not work. If it works -- what it does is -- presumably is to reduce evaporation, which is a huge problem in the reservoirs. So it's a kind of win-win strategy, and conceivably it's a way of -- a soft way of testing something that, you know, might work much more broadly.

You also have in the Arctic, you know -- I mean, when we talk about runaway or rapid climate change, I think the, you know, the greatest concern would be --

BELL: Can you hold the microphone up.

QUESTIONER: I'm sorry -- it would be melting, let's say, in Greenland, or obviously the, you know, the methane releases. Well, black carbon plays a very, very large role in some of that, and there's now a -- efforts under way, an ANSI study that ultimately might result in an ISO standard that essentially is looking at perhaps the possibility of establishing a regional warming -- you know, global warming potential looking at the Arctic.

What happens in the Arctic, that a large part of the black carbon essentially comes from forest fires in Alaska, Canada, you know, Siberia, open burning in Kazakhstan. Well, conceivably, better forestry practices are a way of addressing that.

And then you get into the other issues. Perhaps, rather than global geoengineering, what you might find -- if we got into the very difficult situations that, you know, we described, it might be that very localized, regional geoengineering over -- affecting Greenland or affecting the Antarctic might be feasible. At the same time, you go with an aggressive mitigation strategy.

And that's, you know, I think that's perhaps one of the things that might be on the table, but, you know, they all have to be vetted.

BELL: There are quite a few parts to that question.

Could I suggest one thing, as starting off this? A lot of this, I think, is a little bit "inside baseball." And because there's some people in the audience who've been focused on this for a really long time and some folks who are new to it, so maybe you can explain some of these things that John mentioned before we respond to it -- black carbon, you know, some of the other --

STEINBRUNER: Let me just comment on the microbubbles idea.

BELL: Yeah. Microbubbles, yeah. Can you explain what it is first?

STEINBRUNER: Microbubbles are very tiny bubbles, sort of, micro-scale bubbles that sustain themselves over very long periods of time at the right size in water. There's an issue of how much energy it takes to do it over a large scale, okay, but it's quite dramatic.

And I think Russell Seitz is now making a local, not a global claim that you can put them in lakes that are subject to evaporation; you could reduce the evaporation and have a beneficial local effect. I don't think he's -- and it's just at the laboratory basis so far, so I don't think he's ready to say, you know, we're going to put microbubbles all over the ocean and solve the problem.

If you did, though, it looks like it would have less consequence than the sulfates in the stratosphere. So one of the things that needs to be looked at is things that can be done, either locally or globally, that don't have dramatically bad side effects, or very uncertain ones.

BELL: Granger, did you want to talk about black carbon, or -- there was a second part to --

MORGAN: No, I think we should keep questioning.

BELL: Okay. Keep going, okay.

Any other questions?

Please.

QUESTIONER: Hi. I'm Cheryl Hogue, with Chemical and Engineering News.

I'd like for you all to talk a little bit about what you foresee as possible research by the U.S. government. I think there were a couple of agencies mentioned. I know that chairman of the House Science and Technology committee, Bart Gordon, is really hot for the Department of Energy to be involved in this, although that sounds more like carbon capture and sequestration rather than the, kind of, solar radiation management.

Could you talk a little bit more about that, and how you foresee the U.S. government's role in research?

MORGAN: Yeah. I think, first, that it probably is important that there be federally-supported research.

I'm troubled by the prospect of private-venture people getting into this business, because, among other things, suddenly there becomes then a, kind of, incentive to do it. And, I mean, on the one hand, I think it's terribly important that we understand what it would cost, how you would do it, what the intended and unintended consequences would be.

I think that in the early stages National Science Foundation might be actually quite a good venue because, you know, they are in the business of exploring a wide range of issues, opportunity for multiple investigators with different perspectives, opportunity for folks to work on some of the social science issues. We've actually been -- with some NSF money, doing some work in this space.

And, as I say, I don't think, at this stage, large amounts of money are needed. Later on, when you are actually trying to run some field campaigns, then NASA might be an interesting candidate, because, you know, they've got a strong capability to do things in the stratosphere. That's probably sufficient.

STEINBRUNER: Let me just say, though, that remember, the underlying situation is you don't want to do this without mitigation. And we are not -- one of the problems is we are not on course to do prudent mitigation, so part of the research effort has got to go into alternative technologies for mitigation. And that would --

MORGAN: Yeah, I'm certainly not proposing that this be "instead of," and the amount of money I'm talking about is pretty modest compared with the amounts we're now spending.

But, I mean, stop to think about it. We've been talking for a couple of decades about carbon capture and deep geologic sequestration in the context of coal-fired power plants. And we're beginning to do a few minor things, but we still haven't got the first commercial scale plant up and running. All the pieces have existed at commercial scale for quite a long time, but we just haven't spent the money to put the pieces together.

If you asked me to bet today on who will get the first commercial-scale plant up and running, I'd put more money on the Chinese than I would on the U.S. So John's absolutely right. I mean, it is really dismaying at the slow rate of progress.

And it's also dismaying that we got so many people playing "my technology is more virtuous than yours." I mean, if we're going to achieve an 80-percent reduction in emissions, it's literally going to take everything we've got, and even still, I think there are good questions about whether we'll make it.

STEINBRUNER: I was going to say I'm biting my tongue, (Steve ?), about the small reactor story -- (laughs) --

MORGAN: (Laughs.)

STEINBRUNER: -- but I'll give it -- It's very difficult to imagine how we're going to get a prudent standard without an expansion of nuclear power that is more broader than anything going on, or even imaginable, with current reactor designs.

So one of the conclusions you reach -- or current fuel cycle management practices, or current security relationship, so one of the things that you can say, I think, with some seriousness, is that one of the things we're going to have to do, in order to have any hope, is to develop small, inherently safe, sealed reactor designs that you can put around the world, and the that use them do not get at the fuel -- cannot get at the fuel.

But that's an entirely different industry from what we're currently talking about. So one of the things that absolutely needs to happen is to -- there are about there are about eight or 10 of these designs, which is too many -- there needs to be a runoff among them, and two or three of them brought to the point of commercial viability. And whatever else you do, you're not going to make it without that. But you're going to have to do a lot other things as well.

MORGAN: We got another -- yeah, over here.

BELL: Please.

QUESTIONER: Hi. Alex -- (inaudible) -- USAID.

First, I'd like to thank the Council for having something on science policy. It's very welcome. And I applaud you on, sort of, the scale of your vision and for how you're thinking about these problems.

I have a point and a question. The point is, in biological control -- whenever we've tried to use biocontrol to control certain types of pests that we want to get rid of, and we used other biological mechanisms to do so, we've failed -- (laughter) -- miserably many, many times.

And that leads to the second question, or the second -- the question that I have is, what effect, in terms of these microparticle shading? You have indicated that you've done modeling on your

-- your post-doc has done modeling on temperature, modeling on precipitation, but given that, you know, there's potential heterogene(ous) effects, what is the effect on photosynthesis, and how that photosynthesis feeds back within the process?

MORGAN: Well, first of all, we're not talking about more than a couple percent change in the -- (inaudible) --

Second, after some volcanic eruptions, though there has been direct reflection, the albedo has increased. The amount of diffuse sunlight has also increased. So there's actually been a bit of an uptick in photosynthesis, and you've seen some modest increase in forest growth, and that sort of thing.

I mean, when Kate Richi (sp) -- this doctoral student and I first started working this problem, we were quite concerned about the issue of photosynthetic effects, and went out and talked with a bunch of leading ecologists. So far, we haven't been able to find anybody who can make a case that there would be a serious issue.

And there might, indeed, as I said, be some short-term boost, which, of course, alone, doesn't mean it doesn't have impacts, because, you know, different plants have different abilities to engage in photosynthesis. So, just as a richer CO2 climate -- or atmosphere favors some plants over others, so too a changed light environment changes the relative competitive advantage of different plants.

I want to hit one more time the ocean acidification issue. If you're not aware of this topic, take a look at the slide on the bottom of page 15, which has the Keeling Curve that everybody has seen. This is the curve on Mauna Loa. There are the now similar curves all over the world that show the regular increase of CO2 modulated by the annual cycle of vegetation.

What you haven't perhaps seen is this lower curve, which is the pH of the oceans, and pH is a log metric. So what this is saying is that the oceans are today 30 percent more acidic than they were in preindustrial times. This is not caused by geoengineering, but the key point is that geoengineering, while it can offset warming, doesn't do anything about this. And so here are some pictures on the next slide. They are much more striking, in color, of what coral reefs look like.

Now, I must say that when we were publishing a piece a few years ago -- and for those in the press here, I'm off the record, my editor said, "Why do you care about coral reefs? They're pretty, but." But coral reefs are, in fact, of course, the base of multiple ocean ecosystems. I'm back on the record, but I don't want to get any editors in trouble. (Laughter.)

STEINBRUNER: You're messing with the bottom of the food chain.

MORGAN: Yeah, right. Exactly.

STEINBRUNER: Not a good idea.

QUESTIONER: I'm Eli Kintisch, with Science Magazine.

The first question is for John. You deal with lots of different countries in your work on nonproliferation. Do we know anything about what the other superpowers, or the biggest players think about this?

And the second question is: Your idea was we won't mess with the atmosphere unless we all come to an agreement. But we have lots of international laws in which some countries might disagree. Why is that -- if we were all in a, if we were all in a room, and one person was drowning or something, we might act in a way that would, you know, cause discomfort to help that person.

MORGAN: This gentleman, incidentally, you should know in full disclosure, was at our meeting in Portugal, and is -- I think you're writing a book, right?

QUESTIONER: (Off mike.) It comes out next month.

MORGAN: Yeah. (Laughter.)

BELL: On geoengineering --

STEINBRUNER: I was going to --

MORGAN: Yes, on geoengineering.

STEINBRUNER: -- I was going to ask you, for that reason, what your sense of the state of major-power discussion here. But I don't think -- to put it mildly, "not very far along" would be the answer.

And I'm not aware of any -- I've gone to the State Department and talked about it, and they were kind of, 'Oh, yeah, really?' I mean, they're not doing anything, that I can detect, that is attempting to engage broad discussion on this question.

MORGAN: (Off mike.) No. I'll leave it at that.

BELL: Well, it's kind of -- may I just add? To be more specific, are the Chinese engaging in some of these discussions? For example, in Lisbon, did you have --

MORGAN: Well, I mean, we had at this meeting in Lisbon someone from China, but they didn't talk about any active research program. I, frankly, do not know.

BELL: Get your microphones.

QUESTIONER: My name is Mike Morantz (sp).

My questions are two. One is on the bubbles. I keep thinking about the conflict of trying to put fluoride in water -- the politics of that, or using gene changes in meat. There's a huge part of the population that would oppose it.

And the second is, you keep focusing on catastrophe rather than a long-term problem, as if it's going to take a catastrophe to be reactive rather than proactive. Would you comment on that?

STEINBRUNER: Well, I would like to believe that "sweet reason" propagates itself, and that the world gradually comes to believe that we have to do something about this without any image of catastrophe needing to trigger it.

Human beings being what they are, though, and political processes being what they are, it's a lot easier to believe that we will suddenly get a lot more serious, and we do have to get a lot more serious. If there is -- now, obviously, my favorite scenario is that a generation comes of

age; realizes this problem; and gets a lot more serious about it spontaneously. We know enough about it to realize that we really ought to be taking prudent action.

Every time I say something like that, though, I run into -- like a friend, just a few weeks ago, who is working for somebody who I guess is going to run for governor of New York, and has done very extensive polling and asked people what do you care about? Didn't show up in New York -- didn't show up.

Now, you know, it's pretty obvious that people were worried about their jobs and that sort of thing, but it is literally not on the -- it doesn't get onto the list, never mind down the list. So if public reaction is to -- has got a long way to go before it will support the fairly dramatic changes required to really achieve mitigation. And that's why we all get driven into these catastrophe scenarios.

Plus -- you can comment on this -- (inaudible), the people watching the climate and its effects are getting nervous. I mean, they're seeing changes going a lot more rapidly than they anticipated. And although they can't come up and say, 'Now we proved that we're going over a cliff,' they're getting noticeably uneasy. And so I'm just -- I'm sensing, if you will, that we're going to have to go to a different state of public consciousness, and it's probably going to be an image of big trouble that is clearer than we currently have that would get us there.

MORGAN: So, just a quick elaboration:

First of all, of course, there is a lot of money getting spent to make sure that a very substantial portion of the public stays totally confused about this. And, I mean, it's been really quite pernicious. But there's been literally tens of millions of dollars spent on every little thing that comes along that might, you know, relate to some uncertainty. And while sure there's uncertainty about some of the details of the climate science, there isn't any uncertainty about whether we have a serious problem.

The other issue is that there are folks running around saying, 'This is going to be incredibly expensive. It's going to just totally wreck the economy.' Well, you can recall that many of those same people made precisely that same argument about the Clean Air Act. And the electricity industry met the requirements for the Clean Air Act at a cost of -- well, actually the economy met the requirements of the Clean Air Act at a price that was about a half a percent of GDP.

Now, if you were going to decarbonize the energy system on a gradual basis over the next 50 years or so -- by which I mean, for example, in electricity, roughly doubling the rate of new construction and never building anything that was not zero carbon -- you could probably decarbonize the entire system for something like 0.7 of 1 percent of GDP.

But you can make it as expensive as you want. I mean, if you hold off and hold off, and then suddenly decide, 'Oh my god, we got a real problem,' and you have to junk a lot of technology that's still got useful life, you can make it really expensive.

So the folks who say you could wreck the economy this way aren't wrong, they're just not telling you the whole story. I mean, it won't wreck the economy if you go about it in a systemic way. You will wreck the economy if you wait until the last minute and then suddenly discover that you got to junk 2,000-megawatt, relatively new coal-fired power plants.

STEINBRUNER: And to add to that, there's a lot of liquidity running around the financial system looking for the next bubble. (Laughter.) This is actually -- the energy transformation is

a very productive place to put your money. You can make money doing that. And it's a productive result.

So it doesn't appear to be, at least, hopeless to convince the markets that, rather than go create some speculative Ponzi scheme, put it in -- put money into a transformation we know we're going to need, and you can make a lot of money doing it -- whoever, sort of, gets the lead, sort of, items in this area. And, you know, I think, conceivably, you can convince the markets that this is a good place to invest.

And Granger is exactly right. The problem is to try to do it on a prudent schedule, not to wait until there's some kind of crash effort that has to be --

MORGAN: But you see, because, as John says, we are human, and there is a good possibility that that's the way it will play out, I mean, my concern is that we get into a mode where we wait, we wait, we wait; 'Oh my god, there's no way we can do it fast enough, we got to do geoengineering.' And so that's another --

STEINBRUNER: Forget the other.

MORGAN: Yeah, and that's another --

STEINBRUNER: That really is (heroine addiction ?)

MORGAN: -- reason why I think you really have to understand today not just what could be the direct consequences, but what might be the down sides; and, you know, is it really, indeed, as simple and straightforward as we -- many people think? I mean, for example, there's some recent results that suggest that sulfate may not be a terribly effective strategy, that you may want to use sulfuric acid.

One of the things, of course, that people worry about is what about acid rain? Well, I mean, it turns out that the amount of material that you have to put in the stratosphere to offset is really small, in comparative terms, and so the ecological impacts of fallout are not likely to be significant.

And there are people also talking about specially-engineered particles that would self-orient, self-levitate. I mean, there's all kinds of fairly wild possibilities, but nobody's working seriously on most of them.

BELL: I think I see another --

MORGAN: Yeah, we got three here now.

BELL: Yeah.

Please.

QUESTIONER: Thank you. I'm Jim Turner, from NOAA.

First of all, thank you very much for talking about ocean acidification. But I do have a question about some of the field-scale -- the experiments that you were talking about doing. What are some of the parameters that you would need, because you certainly need something that's big enough so that you can detect an effect, and also, something that is large enough so that you could learn enough to extrapolate from it?

So can you talk about some of the parameters that -- you know, when you talk about a limited scale, you know, field test, can you talk about the kind of size you're talking about?

MORGAN: So not everything you do --

BELL: (Off mike.) Can I just?

MORGAN: Yeah, please.

BELL: Let's do this: I see two more hands, so let's cumulate the questions and then -- because we're sort of, almost at the end of the time.

MORGAN: All right, fine.

QUESTIONER: This is a general question, but besides Al Gore and the three of you, where is the leadership going to come from -- (laughter) -- to engage these projects and move forward?

BELL: And there was another, or was I mistaken?

Okay.

QUESTIONER: (Inaudible.)

I just wanted to ask whether -- a proposal I've heard, that it would be useful to paint all roofs, parking lots and roads white so the light would be reflected directly out. If that was suddenly done, would that make a measurable effect, or would it be irrelevant in the larger scheme of things?

MORGAN: I'll take the first and the last -- (laughter) -- and John can get the middle one. (Laughter.)

MORGAN: He is, after all, the political scientist up here.

Not every experiment that you'd want to do in the atmosphere needs to be a long-term measurement of changes in forcing. I mean, for example, there are serious questions about how would you introduce the material. You may want to introduce it as a -- in a gaseous or liquid form; you may -- and so you need to look at how spray technology works.

And so there are a bunch of things that you could do on a really quite small scale. There are folks talking about trying to do synchronous detection studies. So far, the numbers I've seen suggest that the forcing levels you require may be fairly high. But the notion of synchronous detection is that if you put stuff in at a phase that's not in-sync with the diurnal -- or, I mean, with the annual cycle, that you might be able to pull a signal out from the noise. But it's precisely thinking seriously about some of this stuff that needs to happen, and so far it hasn't.

On the parking lots, I've never run the numbers, but I know somebody who claims to have run the numbers that says white roofs and white parking lots don't appear to have a big effect. But I should run the numbers myself.

STEINBRUNER: As for leadership -- (laughter) -- I wish I knew. It's a little hard to see.

But, you know, you could say, if you want to be on the upside, when there really are emergency situations, usually leaders do emerge. I don't think they're out there in any -- and if you're talking about globally credible leadership on this question, it ain't there at the moment.

MORGAN: Yeah, I wrote an editorial in "Science" -- gee, a long time ago now, over a decade ago, called "Managing Carbon from the Bottom Up," that argued that we were putting altogether too much effort into global -- into trying to negotiate a global regime to which everyone would salute and sign up; that a far more plausible route forward was to get various parts of the world to each decide -- to decide, 'This is a serious problem; we got to do something about it,' and then gradually to coalesce these different regimes.

And so, you know, in this country we see California trying to do reasonably serious stuff, and we have a few others around the world who are trying to do reasonably serious stuff. I think that maybe a little less attention on trying to negotiate a single, all-encompassing agreement that has real teeth and impact, and a little more work here at home on, sort of, getting out front would be a good place to start.

And so, for example, getting a half-dozen 800-megawatt coal-fired power plants built with carbon sequestration, doing a much bigger program of nuclear rejuvenation and renewal than we have, and a whole variety of -- really going, in a serious way, after energy efficiency. You'll notice that we're looking at a whole slew of incandescent lights here, in a new LEEDS building. (Laughter.) Working on a bunch of those things would be probably very desirable.

BELL: We need to wrap this up, unfortunately.

Let me just -- two points: Some people think that the Copenhagen Accord actually represents the beginning of that bottom-up that you're suggesting, this putting commitments on the table. Who knows, I mean, it's another hour debate which we won't -- (laughs) -- go into here.

I wanted to thank you both for this. It's the beginning of a really important conversation that we all need to be having on this issue.

And I want to thank the audience for some really good questions.

And good night -- and I'm supposed to also remind everybody that this was on the record. That's what my cheat-sheet here says.

MORGAN: Except for my crack about an editor.

BELL: Except for that one, yes. (Laughter.) (Applause.) Do not record that. (Laughs.) (Applause.)