Social Science:
What we know, and what we ought to know

LIZZIE BURNS: Welcome. Thank you all very much for coming to the Forum on US Solar Geoengineering Research. My name is Lizzie Burns. I'm a Fellow at Harvard School of Engineering and Applied Sciences. I'm joined here by my colleague, Gernot Wagner, David Keith in the audience, as well as some of our other staff members, as well as Ted Parson from UCLA School of Law.

We, at Harvard's Solar Geoengineering Research Program are really thrilled to be co-organizing this event with the Emmett Institute on Climate Change and the Environment, where Ted is the co-director. Ted has been fantastic. The background paper that you have in your hands today, he really helped lead the development of that introduction. And there's amazing contributions from our speakers in there today. A lot of diverse thinking. So we encourage you to read it, if you haven't done so already.

But first and foremost, we'd really like to thank that Alfred P. Sloan Foundation for funding this event. Evan Michelsen, program director, is here, as well as Bob Litterman, a board member, and we just really thank you all for your support. We'd also really like to thank the Carnegie Endowment for International Peace for hosting us in their amazing space here today.

So as you'll see in your agendas, the day is set up with four great panel discussions. The morning is largely focused on the sciences. You'll see me start out with a social science panel, which is then followed by a natural science panel, where the discussion will largely focus on what research is helping us start to learn about solar geoengineering, as well as what still remains as great uncertainties.

The afternoon is, then, largely focused on policy. Solar geoengineering is, of course, global in context, so there will certainly be discussions about international politics. This event, though, today, for the most part, is focused on US policy. However, of course, though, in this international context.

With that in mind, we really want to thank our speakers, who are incredible for being here today. And we also want to thank our amazing guests. We are really thrilled, because there is so much experience in this room. A lot of diverse backgrounds. A lot of diverse perspectives on solar geoengineering. So we're really excited for a really rich discussion today.

And because of that, we've intentionally structured the panels, so, at their core, there's going to be time for Q&A with the audience. So if you have questions, by all means, there will be a chance hopefully for you all to ask them, and we encourage you to engage in these discussions.

The other thing we just wanted to let you all know is that this event is going to be Livestreamed. Actually, I think we're live right now. This Livestream footage will also be stored on our web site afterwards for people who aren't able to view it live. And the hope was that people who aren't able to be with us here in person today can still engage and watch the discussions that take place.

So for any reason you aren't comfortable being on film, there is an area in the back of the room. You'll see signs on the table that say "No Filming." Simply sit there, if you don't wish to be on the camera. And with that said, if you don't wish to be filmed, but still want to ask a question during Q&A, simply write

your question down on a name card, find a staff member like me, and we'll try to ask the question for you.

The last thing I'll mention is that we also have an independent documentary filmmaker here. His name is Ben Kalina. He's right there in the back. Ben is entirely separate from Harvard, UCLA, or this event. He's just putting together a documentary on solar geoengineering. So he asked to film segments of the events today, where he receives permission. Ben has his own permissions form. If you are interested in being on his film, by all means, please sign his permissions forms. If you don't sign the forms, you won't be on film. So if you have questions, just find Ben or me.

In the meantime, thank you very much for being here. And I'll turn things over to Gernot.

GERNOT WAGNER: You all know the definition of solar geoengineering. Yes, there are important actions between solar geoengineering and mitigation. Often they come under the heading of moral hazard. In fact, that, in itself, is one of the crucial research questions discussed today.

Yes, it is solar geoengineering, as opposed to carbon geoengineering, deliberate interventions in the carbon cycle. They are two very important interactions. We are focusing on the solar aspect of that. And crucially, it is about research. Now, that does include governance, of course, both research into governance and, for that matter, governance of research itself, and the interactions.

And yes, there is the US as well, which, in some sense, is limiting, in the sense that climate change, of course, is a global problem, global solution. Solar geoengineering itself, of course, has very much global implications. That said, we are, in fact, focused on US researchers, US research on this topic. And there, too, of course, context matters, which is precisely where Ted comes in—Ted Parson—and the very first panel, both context overall and, of course, also how that context, in fact, has changed recently.

EDWARD A. (TED) PARSON: Thank you.

When we first planned this event about a year ago, we had a fairly clear expectation of what was happening and why it was a timely event. We expected that it would be quite likely that there would soon be movement toward establishment of US federally funded research programs, including solar geoengineering, and that these would probably include federal funding for small field experiments.

And we imagined that, in that context, we would be having a discussion today about how to do that. You know, what research is likely to be federally funded, what should be—what the boundaries of such a program might be, and, in particular, how to do it responsibly, in terms of program management, independent advice for decision making, transparency, public consultation, and other governance issues. We weren't unmindful of the international dimension of this, but we were centered on US, thinking about federal funding, because, however international the linkages and the collaboration, each national jurisdiction has particular programmatic and institutional and governance needs.

Now, a fair amount has changed since then. Some changes have been obvious, some have been less obvious. And those changes have, in important ways, inflected the aims for what we can do here today. I think they've not made the discussion any less important, but they've unavoidably changed its character. And we think it's important to at least sketch out and frame some of those changes and their

possible implications at the start to help us kind of think and discuss clearly through them as we proceed through the day.

So it seems clear that there is now less near-term prospect of US federal research program, either a new dedicated program, or of significant support for solar geoengineering within current ones, given budget constraints. At the same time, there's been a substantial increase in interest and support for funding of solar geoengineering research from other sources—governmental programs and other nations, and also foundation and other private philanthropic funding. With these new resources, there have developed some significant new projects.

So among our co-organizers, my three colleague co-organizers are all involved in the new Harvard Solar Geoengineering Research Program that you've heard about, and will hear a little more about. There's a new geoengineering governance project at UCLA that I'm going to be leading. Perhaps the most important new initiative is the Carnegie Climate Geoengineering Governance Initiative, led by Janos Pasztor, who's here with us today and will be speaking a little later.

In addition, several proposed outdoor filed experiments that have been discussed in the scientific literature, and thought about for some time, are moving step by step toward realization. And we will hear more about those over the course of the day.

Now, what are the implications of this for what we do today? There are some important senses in which the change of political context doesn't actually change anything. It doesn't change anything about the reality of climate change, and the magnitude and time, costs, and severity of risks that it poses. It doesn't change anything about the suite of available options and what we know about how to put them together, in terms of coherent, effective responses to reduce risks. It doesn't change anything about the large scale reasons that support the potential value of research into solar geoengineering options.

But at the same time, it changes all of the details, all of the particulars, within that. So to be a little speculative and personal, I would suggest that both the need for solar geoengineering research and the associated risks of doing that research have both increased. That's a tension. At the same time, concerns about governance of research, they've decentralized. They've distributed. There's more actors involved than we expected there would be when we thought of this a year ago. So as the sources of potential support distribute, there's more need to understand, and speak openly, about the associated risks and what they imply for governance, and perhaps more need for explicit coordination and joint development of approaches to governance.

The shift in the political context may also, in all frankness, inflect the big questions of how we think about doing solar geo research. The prudence of doing it in particular institutional settings, perhaps the prudence of doing it at all. Although, there is this tension, where both need and risks appear to have sharpened. Maybe a US federal program is not just less likely, but also less advisable. What does that mean? The research is best done elsewhere. It's best done in more distributed, coordinated networks.

We allude to some of these issues near the end of our background paper. My sense is these are likely to be, and ought to be, front and center in our discussions as we move toward specific governance issues over the course of the day's discussions.

So with those brief remarks about how it's changed, why it's still really valuable for us to be here today talking about mostly the same things, but with different context and different details, I think that's all we have to say for opening. And now, we should just move directly on to the first of the four panels.

The first panel is on social science issues. I will be moderating that panel. May I invite the three of the panelists who are here to come up and join me.

OK, now I speak to you in my capacity as moderator of the first panel. So the first panel is on social science research issues related to solar geoengineering research. We put the social science panel first, partly just to shake up the conventional kind of step by step, supposedly rational ordering, where, first, you hear about the science, and then the social science, and then the policy.

But also, more centrally, out of a sense that the most important concerns and risks, and the most important issues, posed by solar geoengineering are in the domain of the social sciences more than they are in the domains of physical and environmental sciences and technology. And also, the biggest risks that have been raised related to solar geoengineering and its potential development and use.

I'm going to make a couple of really brief sort of framing remarks to give some context for the comments from our panels. Then, we'll follow the process we hope to do for the whole day, which is the initial presentations from the panelists will be very brief—no more than five minutes each. Then, that will leave time within the session, first, for some discussion among the panel, where I will throw some questions and comments and things out to them, and then for a lot of time for interaction and conversation with you folks.

So a couple of preliminary observations. First, when people speak about social science issues related to geoengineering, there is often an ambiguity or an overlap between social science issues, policy issues, and sometimes policy advocacy. This is unavoidable, to some degree, because it is of the very essence of social sciences that they're about how do societies react to this, what are the impacts, and what does that mean you do about it. We'll have a lot of explicit policy discussions later on. The whole afternoon is basically dedicated to it.

I had a wonderful discussion with a bunch of my students a couple of evenings ago about Kim Stanley Robinson's Mars trilogy, and what it means for environmental law and constitutional issues. They steered asteroids all the time.

I'd like to steer this panel to focus principally on issues that are closer to social science research questions.

Now, it's been clear, since the first re-emergence of debates over solar geoengineering about a decade ago, that solar geo, including research, posed crucial societal and political and policy questions, and that the social and political domains mediate the most serious risks. They are more about how the technologies are developed and used by whom to serve what ends than they are necessarily about direct environmental consequences, or particular modes of intervention, not that those questions aren't also very important. Many concerns and questions and speculations have been raised in the space of socioeconomic aspects of these technologies, including some very colorful and extreme, but kind of hard to bound speculations, like the prospect of these technological interventions being so readily available that they might be deployed even by small non-state actors in a completely unregulated way.

But it strikes me, as we suggested in the opening framing document, that there's actually three questions related to socioeconomic aspects of solar geoengineering that are the most important ones. They're pretty broad, but they seem to emerge as the big ones.

First, the interactions of solar geo with the rest of, or with a complete, strategic climate policy response. These issues have mostly, and most prominently, been raised in terms of the risk of displacing mitigation effort, the concerns that have often, although ineptly, been called moral hazard concerns. Will it happen? What causes it? What particular activities in the solar geo space might be the triggers of such displacement? There have been studies done at the level of individual surveys and experiments, individual responses, asking people how the knowledge of solar geo inflects their willingness to support mitigation. There are some questions about what those studies tell us about the real question, which is the likely response of political systems to the perceived availability of these.

At the same time, there have been many analogies offered for the role solar geo might play in the complete climate response, and some suggestions posed that there might be ways of influencing these interactions in a way that's actually constructive, rather than destructive. So there's a set of questions clearly in the domain of social and political sciences about interactions that I would argue are the first of the three biggies.

The second of the three biggies are the questions broadly related to images, or analogies, often called slippery slope, or lock-in. The concern that, even if doing a little early research on this is much more good than ill, somehow those steps might put in place forces that push toward continuance and expansion of the endeavor, even if it turns out on balance not to be a good thing. Again, these are clearly a set of questions that are related to research absolutely in the social, political, and economic domain, and they raise all kinds of interesting questions—do such processes operate? By what mechanisms? How severe are they likely to be? Are there ways they could be mitigated? What steps might trigger them? So that's the second biggie.

First biggie is interactions with the rest of the climate agenda, second is lock-in, or slippery slope, and then the third is the broader question of citizen understandings, perceptions, preferences that would contribute to the question of the societal acceptability of the endeavor in its early research stages, as well as in broader, longer term questions of whether nations, or other actors, move toward operational deployment. What would be the conditions for a social license to proceed with certain kinds of research? What are the conditions that would mediate that? Is this even a correct way to pose it, or is the very framing of this question somehow tendentious or manipulative? That is the third biggie.

Now, I'm almost done, and I'm going to turn to our panelists in a moment. I'm going to ask our panelists to consider these things or related questions within their expertise. And I'm going to ask them to do so with two other exhortations.

First, in considering these questions, let's try, as best we can, to avoid the risk of considering solar geoengineering in isolation. In effect, let's not fall into the trap that is described by the first of my biggies. When the context is severe climate risks, and the aim to reduce them, that sort of defines the frame for debates about geoengineering. It's easy to forget this. It's also hard to understand how to precisely, or accurately, consider this.

So for example, one might argue for an application of precautionary reasoning that is one-sided, if you think only of precautionary reasoning about geoengineering interventions, leaving you with the question of how you think about precaution in the sense of risk issues.

The other final exhortation I would give to the panel is, to the extent possible, in addressing your topics and your areas of expertise, see if you can highlight for us the following kind of procedural questions—what relevant social science research has been done on the questions you're interested in? What has been learned from this, and with what confidence do we know it? And what does this suggest for further research, further socioeconomic political research, that might be of high value?

That's all I have to say for opening. Let me just conclude. I'm going to introduce all four of our panelists in turn, in advance, and then we can move smoothly from one to the next. So our first speaker is Professor Kate Ricke, who has recently moved from research positions at the Carnegie Institution and at Cornell University to take an assistant professorship at the University of California, San Diego in the School of Global Policy and Strategy, where she also holds a joint appointment at the Scripps Institution of Oceanography. Kate holds a PhD in engineering and public policy from Carnegie Mellon. She is a climate change scientist, who integrates tools from the physical and social sciences to analyze climate policy problems, with particular emphasis on uncertainty and heterogeneity.

Scott Barrett, who will go second, is the Lenfest Professor of Natural Resource Economics at Columbia University in the School of International and Public Affairs, and the Earth Institute. Scott is originally an economist, but the breadth of his interest really transcends that discipline. He is a leading scholar on global challenges, ranging from climate change to disease eradication, and he's interested in how institutions and norms can promote and sustain international cooperation.

Holy Buck is completing a PhD in developmental sociology at Cornell University and, in the coming year, will hold a Nature Conservancy postdoc at UCLA. She holds a master's degree in human ecology from Lund University in Sweden, and she previously worked in the geospatial industry. She has wide ranging interests, mostly related to climate change, energy system transformation, and human environment interactions. She has a bunch of exciting field studies underway related to albedo modification in the Arctic, climate change impacts in the Imperial Valley of California, and the Blue Revolution, in relation of human societies and enterprises to the ocean.

Now, our fourth panelist, whom you cannot yet see, is Rose Cairns. Rose is the only speaker of the day who will be joining us remotely via teleconference. She is a Research Fellow at the Science and Technology Policy Research Unit at the University of Sussex in the UK. At Sussex, she is the coordinator of the Nexus Network, which is an interdisciplinary initiative to bring together research, service, and leaders in policy, business, and civil society on collaborative projects on environmental issues broadly. She is also a participant in the Climate Geoengineering Governance Research Project, which is a collaboration between the Universities of Sussex, Oxford, and University College, London. Rose holds a PhD in conservation politics, where she studied the Galapagos, from Leeds University, and she previously worked in the environmental NGO sector.

So that is the end of my part. May I invite Kate to lead us off. Five minutes each, please. Kate, the floor is yours.

KATE RICKE: All right, I'll try and stay on track. So I mean, I might be abusing my position as the first speaker a little bit, because I'm mostly going to talk about mitigation. But my point, hopefully, will come across that it's really impossible to talk about social system risks from solar geoengineering without talking about contingencies that are associated with mitigation.

And so I wanted to show some figures from work that I did with Doug MacMartin, who is going to be speaking later, where we looked at mitigation scenario constraints on temperature target overshoot. And so this is a period of time in which global temperature increase exceeds some sort of temperature target that's been set. And so, in this project, we decomposed into two categories mitigation technologies. We looked at decarbonization, so technologies that reduce the carbon intensity of the energy system. And we looked at negative emission technologies, so things that capture carbon dioxide from the atmosphere that's already there, something that the geoengineering community might call CDR, or Carbon Dioxide Removal.

And so we benchmarked our scenarios against the policy groupings in the IPCC Working Group III scenario database. This is this 1,000-plus scenarios that were generated from integrated assessment models, economic models, of climate change for the last IPCC Assessment Report.

And so what we did in this work that hadn't been done before, we de-coupled decarbonization and negative emissions of these technology portfolios, and then extrapolated them beyond 2300. And so these figures, they show global temperature through the year 2300, and the time series are decarbonization scenarios in blue, decarbonization plus negative emissions in red, and this is relative to the two temperature targets that are named in the Paris agreement—two degrees Celsius above pre-industrial, and 1.5 degrees above pre-industrial. And so I'm showing here scenarios that are employing, relative to the database, aggressive, moderate, and weak deployments of decarbonization and negative emissions.

So in the least aggressive combination here, global temperature still hasn't peaked in 2300.

By the way, this star is the estimate from the literature right now of where the INDC commitments under the Paris Agreement put us in 2100. So right there on the line with our weakest decarbonization scenario, weakest relative to the database. So you can anchor a little bit what weak means compared to what weak means in the real world, right?

On the opposite end of the spectrum is the most aggressive scenarios, most aggressive decarbonization in the scenario database plus, with some geoengineering optimism, a negative emission scenario that's even more aggressive than what's in the scenario database. And this gives us, in our analysis, our lone scenario that hits 1.5 degrees without any overshoot.

So I think those two figures, for me, represent the sort of either/or futures that most geoengineering experiments and models are compared against. So there's obviously this whole range of potential futures that's between these two extremes. And I think the implications for risks from things like moral hazard, lock-in, termination, they're all quite different under these different mitigation pathways.

So all these scenarios I showed you, except for these, have a significant amount of negative emissions baked into them. And in the Working Group III database, that's mostly coming from bioenergy with carbon capture and storage, or BECCS. And so, while BECCS and these other negative emissions

technologies are not completely untested, for the most part they haven't really progressed past the pilot project stage yet.

Whereas, decarbonizing technologies already produce a substantial amount of electricity, and they're a lot more of a known quantity in terms of economics, policy, regulation. And we talk a lot about catastrophic failure, or termination scenarios, with solar geoengineering, but I think it's worth, too, thinking about all of this in terms of contingencies associated with failure of viable negative emissions technologies to emerge. Because there's huge uncertainties associated with this.

On the other hand, if some significant capability for negative emissions ends up becoming viable, there's a range of potential futures that at least somewhat have limited overshoot. And I think the implications for social risks associated with geoengineering here are also quite different. So there's these two extremes that are often presented in this physical climate modeling, one in which everything goes perfectly and we meet the target without any solar geoengineering, and one in which we implement solar geoengineering to counteract rising greenhouse gases endlessly, basically.

And I think, at this point, it's led to the sort of unhelpful false dichotomy in risk-risk discussion, in terms of social science. And these characterizations of high risk solar geoengineering are contingent upon certain implementation scenarios.

Let me see what I really want to say. I'm really not sure whether the physical climate model and community is going to move past the dichotomy, or how much they even need to for their purposes, but I think, social scientists, we really need to stop taking cues from the physical sciences in this regard. Because this either/or really doesn't make sense.

EDWARD A. (TED) PARSON: Wonderful. Thank you, Kate. Scott.

SCOTT BARRETT: Thank you. Thank you very much.

So I want to talk about three things. The first is the international dimension. If the United States conducts some geoengineering research, that is basically an invitation for other countries to carry out the same research. If the United States does not undertake research in some areas, that is not limiting the ability of other countries to take research in those areas. To the extent that there is concern about the research that might be done, not just by the United States, but by anyone, there needs to be some kind of—I'll use the word agreement, but I mean it in quotation marks. It needn't be explicit, necessarily. But there needs to be some kind of agreement, possibly about what should be done, but probably more importantly what should not be done.

There will be a tendency for a lot of people to want to restrict dramatically what countries should be permitted to do. This would be a mistake. Because if you pursue a regime—I'll use that word in quotation marks as well—but if you pursue a regime that is strict, from the perspective of individual states, they will simply opt out of that regime. And you, then, have no limitation at all on their freedom of action.

So this is a regime for mutual restraint, and if you're looking for an analogy, it would probably be something like the nuclear testing regime, which is imperfect. But it's wrong to think of things in some kind of ideal sense when you're dealing with a world of 200 sovereign states.

The second thing I wanted to discuss is errors. The one error the world might make is for one country, let's say, or a coalition of countries, even more likely, to use geoengineering when it shouldn't be used, in the sense that it would make other countries, and all countries in total maybe, worse off. That's the concern that I think a lot of people have.

But there's another risk, and that is that no one does geoengineering, when we'd be better off if it were done. I don't think many people are very worried about that. But—and this gets to Ted's issue of social acceptability, and it's also noted in Kerry Emanuel's comments—there's a tendency for people to treat very differently two different situations, one in which an intervention is deliberate, and one in which the intervention is inadvertent. It just happens. But we're not trying to do it. It's not intentional. And we have an emotional, instinctive negative reaction to a deliberate interference.

We need to understand that the most important thing, or the only important thing, I would say, are the consequences of what we do. And whether those actions come about deliberately or inadvertently—and we are now masking climate change because of the release of sulfur dioxide, sulfates, in the troposphere. We're already doing it, and I don't hear any great outcry against that. So I think this is an area for social science research. There has been some done, particularly in the area of moral philosophy, but I think more work needs to be done on this.

And the third issue I wanted to touch on was about interactions that Ted mentioned. So there are four things we can do about climate change. The first is to reduce emissions. Now, that's the obvious thing, because that means not putting something in the atmosphere that isn't already there. That's as conservative as you can get. The second thing we can do is adapt. The third thing we can do is solar geoengineering. And the fourth thing we can do, tied to what Kate was saying, we could have another engineering intervention to remove carbon dioxide from the atmosphere.

Now, there have been negotiations going on for over 25 years to get countries to do the first thing—to limit their emissions. These efforts, which are the greatest diplomatic efforts in all of human history—so no one can complain that no one has tried. People have been trying. And the reason that we have failed—and we have failed—the reason is not that everyone's waiting for geoengineering. It's the other way around. The reason we're talking about geoengineering today—solar geoengineering today—is because those efforts have failed. And the reason they failed is because you have a massive collective action problem, where it's in our collective interest to act to limit emissions. That's absolutely clear. But it's in the interests of individual states to hold back and let others do more, and the consequence is that everyone does too little.

Adaptation is the opposite. There's a very powerful incentive to adapt. And it's going to take place all over the planet. And it's pretty uncontroversial, because if one country adapts, no one else is affected adversely by that, generally speaking.

The third area—solar geoengineering—now, that's more provocative. It's like adaptation, actually, because it can be done unilaterally. It's unlike adaptation, in that other countries would be affected, and that's why a governance regime is so important for solar geoengineering.

But the fourth intervention of removing carbon dioxide from the atmosphere, which is, by the way, the only true backstop technology for addressing climate change, it does not require a behavioral change. This is the key point I want to make. It does not require a behavioral change, as does the reduction in

greenhouse gas emissions, which we're very bad at doing. What it requires is the raising of finance. And I think, because the collective action problem is not as severe for the carbon dioxide removal, even though it would be expensive—and by the way, because it would be expensive, it won't be done unilaterally, and, therefore, it won't have the governance issues.

The solar geoengineering, as everyone's going to say here today, and it's permeated throughout all the different notes that were produced, you don't want to rely exclusively on that at all. But you can't, you know, at the same time, say, well, we should do a little solar geoengineering and then expect all this emission reductions to come along with it, because it hasn't happened so far. So I think we need to also look at a research program on carbon dioxide removal, and I'm not talking about there bioenergy. You need to do this at such a scale that we need to be thinking of this as an industrial process. Thank you.

HOLLY BUCK: So we have about 10 years, at least, of social science research on solar geoengineering. I don't think we have a lot of actionable knowledge from that research. So I'd like to talk about why, and I'd like to background my comments with this deceptively simple question—what is solar geoengineering?

Many of the 30 or so empirical social science studies understand it as an emerging technology. And they've been inspired by similar work on biotech or nano. But solar geoengineering is very different, because there's not the same type of commercial motivation to develop it, and the research trajectory is going to be a bit different. So these are some other lenses that are applicable, to some degree or another. And many of these are more people-centered. And the lens you use matters, because it takes you towards different research and governance questions.

So a concrete example. A few months ago, there was a paper that came out by a team at Arizona State that garnered a lot of press attention. And they suggested that you could re-freeze arctic ice using 10 million wind-powered pumps. So if you're thinking of this geoengineering scheme as infrastructure, you're thinking, well, how will it be financed? What country is the steel coming from? If it's a development project, who's going to benefit? Is it going to be maintained by technicians who live in the Arctic and create regional jobs, or built up by foreign contractors? And how are the new settlements for creating it going to be organized, as resource boom towns or permanent communities?

Alternatively, if you're thinking of this idea as an idea, or an imaginary, what priority does the imaginary have to make us re-think our choices? Clearly, re-freezing the Arctic would be an expensive proposition. But the authors note that it's comparable in scope to the US automotive industry, or the Iraq War. So it's expensive, but economically achievable. And the money spent on manufacturing would encourage economic growth.

So this matter of lenses, or frames, is one reason that we don't have knowledge that is fully actionable. I think we need to be using more of these social, or people-centered, ways of thinking about the problem.

Another main reason we don't have more usable social science research is the methodological challenge of this topic. Next slide, please.

So social science methods generally lend themselves to investigating things which already exist. And because this is a speculative future activity, and one which people don't know much about, studying it brings two major methodological limitations. One, people's perspectives may shift over time as they

learn more, and two, when the researcher is the one informing participants about the subject, their framing biases the results.

There's also practical reasons that we don't know more. One, cost. Two, it can be tough to build international collaborations, because people in other countries are focusing limited resources on more immediate issues. And three, socially, things can change rapidly, so the knowledge you generate in one social context might not be as relevant in five or 10 years. For example, people are concerned about the integrity of democratic institutions in a way they weren't just a year ago. Things like that are going to be very influential on perceptions of the feasibility of social solar geoengineering.

So what we need is a mix of messages that speak to the varying questions and rationales of different studies pictured here. But getting the kind of social science we would need for a best case scenario of governing solar geoengineering is going to be an uphill battle.

I've stated in the written submissions here that I don't think the US has legitimacy to take a leading role on solar geoengineering right now. Where I think we should focus our attention is on what's less speculative, and also necessary—carbon dioxide removal, as my colleagues have mentioned. I think that the two-part description of [INAUDIBLE] concept of climate engineering has misled us. And you see this in the early social research, where you had respondents talking about choosing CDR strategies versus SRM ones, which is a misplaced question, when what we're looking at is an SRM-CDR system.

So we need social science looking at how to scale up negative emissions practices, things like migration from land use change, technology adoption, introducing new agricultural practices, citing and financing new facilities. We studied all of this already, and we should be doing it in a more mission-driven way.

So in summary, I'm calling this the CDR-first strategy of geoengineering. Emphasize CDR within development discussions, try to build it up, and then, if research shows a sign to be promising, already have relationships in place, and knowledgeable, well-educated, multinational professionals, who can help guide it to be deployed in a way that maximizes benefit to vulnerable peoples and other species.

EDWARD A. (TED) PARSON: Thank you. So now, we get to turn to our remote panelist, Rose, who we see in still photograph up there on the screen. Rose, are you in contact with us on audio?

ROSE CAIRNS: Hi, yes. Can you hear me?

EDWARD A. (TED) PARSON: Hello. Yes, we can hear you very well. Welcome. Thank you for joining us. Please proceed. You have the floor for approximately five minutes for your opening remarks.

ROSE CAIRNS: Great. Thanks so much for the opportunity to speak, and apologies for not being able to be physically there with you today.

My written submission outline argued that many of the future, social, and political, and indeed physical implications of a future solar geoengineering program are radically unknowable, as well as being endlessly contestable. And many are not, therefore, amenable to empirical study. And I question the wisdom of pursuing a research agenda in this area.

I went on to suggest that an important role for social scientists should involve facilitating spaces for critical societal reflection, or whether this direction for research, among the many other approaches to climate change that exist or could be researched, is desirable or acceptable. So I won't rehearse these arguments to you much more here.

Instead, I'd like to take a couple of minutes, at this point, to highlight what I see as problematically partisan framing of this event in favor of solar geoengineering research, and to outline the ways in which this matters for ongoing discussions, not just about geoengineering, but about humanity deals with climate change.

EDWARD A. (TED) PARSON: Excuse me, Rose. I can sense from the puzzle looks in the room, I think you're speaking a little too quickly for clear hearing in the room over the Skype connection. So I wonder if I can ask you to slow down your words per minute by 10% to 20%?

ROSE CAIRNS: I think I'm worried about hitting the five minute mark, so OK, apologies.

EDWARD A. (TED) PARSON: Yeah, you know, you can go to seven.

[LAUGHTER]

ROSE CAIRNS: Thanks. So I'll just repeat the last sentence that I made, then. So I'm not going to talk over what I put in my background document, but I do want to talk a little bit, and perhaps to critique, what I see is quite a problematically partisan framing of this event in favor of solar geoengineering research, and to outline the ways in which I think this matters for ongoing discussions, not just about geoengineering, but about how humanity deals with climate change.

So the introductory document to this event suggested that, even if one is opposed to eventual deployment, one should be generally supportive of research, as it is crucial to inform any future decisions, including a decision to reject geoengineering—on page six. Indeed, the document goes so far as to characterize critics of research in this area as holding an extreme position, which seems to be a somewhat unhelpful rhetorical maneuver.

However, the way the background document is itself written seems to undermine the claim that there would ever be enough known to outright reject geoengineering—solar geoengineering. In this document, every problem, concern, or even fundamental objection raised is simply framed as an area for more research. It is difficult, therefore, to imagine a moment in a future research program when, collectively, the proponents of this approach would say, we know enough, this seems like a bad idea. Rather, the dominant dynamic at play appears to be one of what you might call an engineering mindset.

Obviously, no offense to any engineers in the room. This isn't bad in itself, of course. But it is problematic in this context, as it appears that all problems or objections are understood as practical challenges to be overcome, rather than fundamental obstacles or indications that this is not a viable option for dealing with climate change. Given the apparent dominance of this mindset in this field, it is more plausible to imagine that, whatever issues or problems might be revealed by an increasingly scaled up research program, these would simply be re-framed as technical challenges, rather than reasons for abandoning the endeavor. This dynamic, combined with the framing of opponents or critics of research

as extreme, makes it feel like the space for real critical reflection on the desirability of this direction of development seems limited by the terms of debate.

Compounding this issue, and it's something that's been talked about by others here, is the fact that this discussion is solely about solar geoengineering research, rather than being a broader discussion about research into climate change strategies in general. This seems to constrain the parameters of what can be brought to the table as a relevant topic for discussion. Given that resources for research are finite, the question is to where we, as a society, should allocate these funds, and hence where societal attention should be directed. It means that geoengineering needs to be considered among all the many other approaches for dealing with climate change. Rather than simply asking, research on solar geoengineering, yes or no, the question should be, how do we respond to climate change? What are our options?

Another problematic issue in the framing of this discussion is the attempt, I believe, to separate discussion of the governance of research from governance of deployment. The well recognized experimental nature of any ultimate deployment at global scale mean that, while it is true that not all small scale experiments can be said to constitute deployment as such, on the other hand, essentially, deployment would be research. Furthermore, given the impossibility of extrapolating from small scales to global scale, and the drive for evermore certainty around impact, it would seem inherent to research in this area that there would be a tendency towards scaling up of research to ever greater geographical and temporal scales, meaning that a consideration of the issues raised by these larger scale interventions is, I would argue, crucial to discussions of whether to embark on this research trajectory in the first place.

In addition, the very existence of significant research programs, whatever their impact on the physical environment, will fundamentally alter in unpredictable ways the social and political context, in which climate governance of the future will be conducted. Thus, on multiple levels, research and deployment are inextricable from one another, and I believe that discussions of the governance issues raised by the prospect of full deployment of solar geoengineering need to be a fundamental part of discussions about research.

Following from this, I would like to suggest, perhaps controversially, that the onus at this stage of development should be on proponents of research in this area to outline plausible scenarios under which these technologies might be governed in acceptable ways. I have yet to hear any description of a future solar geoengineered world that sounds to me anything other than dystopian, or highly unrealistic.

For example, in terms of the social assumptions made about the feasibility of collective international agreement on temperature targets, or the idea that issues around attribution and causality, particularly as extreme weather events, would not be a perennial problem, or the idea that trust, or lack of it, amongst the international community would not hamper deployment, or that costly and potentially destabilizing militarization would not be associated with the technology.

As a result of all this, I do not think that this, among many of the other possible directions for research on climate change solutions, is where we, as humanity collectively, should be allocating scarce resources, academic time, and policy attention. Thanks.

EDWARD A. (TED) PARSON: Thank you, Rose.

I want to make sure we have lots of time for discussion and engagement with the floor participants. But before we do that, I'm going to pose one question to each of our panelists. It's just so hard to choose. The material is so rich. I'll go in order.

Kate, your work suggested that the model-based studies of the role of climate engineering have suffered from a false dichotomy, in part driven by the technical needs of climate modelers to have simple, standardized scenarios. But I don't think I clearly heard what the research program was that you would advocate, in order to transcend that false dichotomy and help inform a more realistic set of decisions.

Can you sketch for us, one, what that might be? Or, if I'm misunderstanding or posing the question incorrectly, or tendentiously, then push back and tell me what it should be instead.

KATE RICKE: Do you mean from the physical side or from the social science side, in terms of modeling research?

EDWARD A. (TED) PARSON: Your choice. Whichever is most important and valuable.

KATE RICKE: Right, so I mean, from the physical modeling side, I said that there's often this false dichotomy in the studies. And because of that, and because, to an extent, social sciences have taken it up and run with it, we get sort of these extrapolations about risks, and about our social science impacts that are based on implementing these extreme scenarios. I don't think that, necessarily, physical science has to change, because it makes sense from a climate modeling perspective to model extreme scenarios. Because you're always having a signal to noise problem in the climate models, you want to be able to tease out mechanisms, and so you kind of want to hit things with a hammer in order to be able to do that. In my experience, at least. And I mean, I've run these scenarios, so I'm to blame as much as anyone else.

However, like I said, I just think that the risks associated with the either/or scenarios are not representative of the whole risk space that would exist when we think about actually implementing geoengineering. And I mean, I think just to start is to think, when we're talking about impacts, models, when where we're talking about strategic economic models, to think about all of the scenario space that occurs between those two. And that's not hard to do, necessarily, from a modeling standpoint. It just requires setting out on our own as social scientists to take ownership of a broader set of scenarios. And I think the tools to support us from the physical sciences are there, in terms of emulators and being able to use the output from the physical sciences to support, from a physical climate standpoint, what the outcomes associated with this broader range of scenarios would be.

EDWARD A. (TED) PARSON: Thank you.

Scott, in your remarks and background paper today, and really, in much of your prior work, you've done a wonderful job at abstracting very cogently the essential structural characteristics of the collective action problems among nations that exist on different aspects of potential climate response. So mitigation—a severe collective action problem, as evinced by the sustained failure. Adaptations—strong incentives to do it at the national level. Carbon—still a collective action problem, but in a sense, an easier one, less pernicious, because it's in the domain of just investing in solutions, rather than policy changes going against existing political constituencies and behavior change.

I don't think I clearly heard, in your remarks, a similarly compact characterization of your view of what this essential structure of the strategic problem among nations is regarding solar geoengineering, and how that fits into the whole thing. Can you briefly speculate on that?

SCOTT BARRETT: Speculation is the right word, because we don't even know what geoengineering is going to be. We talk about it as if we know what it's going to be, and I think we don't. I mean, I agree with Rose that there's this intimate connection between deployment and R&D, and you can't really separate them.

For example, if you were never going to deploy, there's no point in doing the research. By the way, the research may show you that deployment is a bad idea. So I think for people to think that, if you do research, it's some kind of slippery slope, I don't buy that argument at all. But as I said, for research, you would have a—call it a regime, I'll be a little nonspecific about the form it might take—but you would have a regime about mutual restraint. That's where you have some leverage in the international system. One country agrees not to pursue something in exchange for other countries agreeing not to pursue something.

And this is a very important motive for why countries would engage in a regime like this. Because otherwise, what countries want is a free hand. They want to be able to act on their own. So you would need that in any kind of deployment regime. You would need it any kind of R&D regime.

The default is there is none. There is no regime at all, which means pretty much that countries can act as they please. And it's tempting to want to, again, constrain what countries can do, but you have to be very careful about that, because they'll just simply move outside the system that you're trying to constrain.

Now, one area that I think—again, I've been thinking about this. You're looking for analogies, and you're thinking about how this is going to unfold, it is about speculation. So the view we've had, up until this point, I would characterize, is there's some—if you'll forgive this description—but there's a man with a long white beard, who is standing next to a switch. And the geoengineering is this man pulls the switch, particles are emitted, and temperature is altered. I don't think that's how it's going to happen at all.

I think, instead, there will be lots of different kinds of intervention. There will be tendencies for states to want to target individual problems, to the extent that's possible, to want to limit the side effects, because that would allow them to get permission to go forward. These are very early days, when we think about this technology, and I know there are severe limitations, and David Keith and others will explain what they are, about how much you can compartmentalize things. But I think there will be a tendency in that direction.

And an analogy—and I think it's helpful to use analogies, although, generally speaking, everything we're talking about here is unprecedented—but an analogy is with, funny enough, I think global positioning. The United States has a GPS system, which is made available to the world for free. So that's like doing geoengineering and helping the world for free. But the United States also reserves the right to pull this at any moment. And because of that, Europe is developing its own system. Not surprisingly, China has assisted. Russia, India's developing something. Not all these are at the same—the European one is at the same scale as the US one.

So now what we're talking about is a very different world, in which these different technologies—it's not so much that they're competing, but they're having to coordinate their actions. Dan Schrag also, he and I were the two that I noticed mentioned this in our little notes, that probably what we need to be thinking of is a multiple of interventions. And I would say they're also going to be tied to multiple different kinds of adaptation interventions.

So the geoengineering I think we're talking about for this planet is going to be much more extensive than a simple single operation. And again, you would have a regime that, in this case, would coordinate. The world is very effective at coordination. We're very good at that. The one thing that we should always remember is that what we're bad at is voluntary cooperation, which is the effort we've led to try to address climate change. We should continue with that. But you have to understand, the tendency of the global system is, when that fails, to do these other things.

EDWARD A. (TED) PARSON: Thank you.

Holly, in your remarks in your background paper, you did a very cogent job of outlining the social and psychological conditions that would support a geoengineering initiative, initially concentrating strongly, perhaps exclusively, upon the carbon side rather than the solar geoengineering side. I'm going to ask you to speculate, too, and kind of think about second steps.

When, and how, if at all, can you see an acceptable movement toward consideration of solar geoengineering in the framework that you've identified? And I think, you don't have to think about deployment or stuff like that. I mean, if you want to limit it just to the research space, and say kind of when, or under what conditions, can you see sufficient societal license support for a research program that includes a solar component, or not at all?

HOLLY BUCK: I think that the way things are now—I mean, as you know—everybody probably knows—that the US doesn't have a federal research program on this. And a lot of funding is done by private sources, philanthropic sources. That has a lot of problems, in that, ideally, you'd want an open call for proposals, so bright, young people with different ideas can put them in. You'd want peer review with certain criteria, all the things that you have to do if you want to get an NSF grant. I would really like their standards to be applied to all the new philanthropic initiatives.

And I think it's appropriate to be doing solar geoengineering research like that. I just don't think that, right now, the US should be federally funding this. Because if you go talk to citizens in other countries—since I have—about this, and they'll say, oh, it's this kind of American idea. Part of that is probably because I'm an American talking to them about it. But part of it is that they mean that it's bold and it's technological.

And a year ago, they were associating American values like pragmatism optimism—those qualities that we represent around the world. And now, if you go have that conversation—and I'd like to empirically test this, I'm not sure, but I hypothesize that this solar geoengineering is an American idea, and it means egotism and bullying and doing what you want, and not considering other countries.

EDWARD A. (TED) PARSON: And recklessness.

HOLLY BUCK: Yeah. So I mean, all of those things have been America to different people in different times in history. And now we have this old facet of them coming back up, and I don't think we can legitimately put federal money into this right now.

EDWARD A. (TED) PARSON: Thank you.

OK, Rose, your remarks and your written presentation both advance a very cogent case suggesting a kind of tendentiousness, or bias, or a prejudging of the conclusion, among those who think it's important, or valuable, or, on balance, advantageous, to proceed with solar geoengineering research. You argue quite forcefully for that, and you, in effect, pose a completely fair challenge, which is of the form of asking, to those who think we should proceed with this research program, what conditions would lead you to change your mind?

Now, one of my wonderful, old colleagues at a prior job, who worked in empirical research in the domain of social and health and individual welfare policy, was fond of saying, in policy debates, whoever owns the null hypothesis wins. So it seems to me there's a fair way to interpret that thrust of your remarks as basically saying, you don't own the null hypothesis, I do.

Well, fair enough. We can move to the level of fighting over who owns the null hypothesis. But the completely fair question you pose to those who think research should proceed, I think, can be posed back to you and those who argue that it should not, on the same basis as you argue. What conditions, if any, would lead you to conclude that proceeding—now, you can make the question easier by limiting it to with a solar geoengineering research program, or if you want to make it even harder for yourself, you can say, with operational deployment of solar geoengineering—what conditions would lead you to conclude that it was OK?

And I've actually got two for you. That's one. You can think about it for a moment.

And the other one is there's a sense in which your remarks suggest an enhanced humility leading to even the complete retreat from the stage of a research-oriented perspective. You argue about sort of deep uncertainties, an unknowability about implications in social aspects of solar geoengineering. And I think you actually come to the point of saying research about this cannot be done and, therefore, the only proper or legitimate role for social science researchers is to, in effect, be engaged participants in a process of social deliberation coming to kind of acceptable, legitimate decisions about how to proceed on climate change comprehensively.

Is this really correct? And are you really asserting that there is, in effect, no role for social science research, understood as research? So two of them. I acknowledge they're both hard. You can partly punt, but you can't completely punt.

ROSE CAIRNS: Thanks. And I think it's a nice tactic to return the question back in that way.

I mean, it is—my question, as you as you rightly said, was about the conditions under which people would change their mind. I mean, I have yet to hear anything resembling a description of a future, as I mentioned in my remarks, that comes close to a description of the world that we live in. It appears to me that people are describing an imaginary world, in which things that we know about the way in which

politics works, and the ways in which societies interact with one another, and the role indeed of different kinds of knowledges, it isn't the world that we know, the world that their describing.

So what would need to happen for me to think that solar geoengineering could go ahead? I would have to fundamentally change my understanding of the world that we live in. It would have to be other than the world that we live in. And understanding the moment at which solar geoengineering research could go ahead, as I say, I don't think you can distinguish between research and deployment.

I think you need to consider, if you're going to prioritize this direction for research, you need to look at the endpoint. If you cannot see an endpoint that is anything other than dystopian, why would you continue down that trajectory?

So I don't know if there are conditions under which I would change my mind. I genuinely don't. But I'm very willing to have anyone who would like to attempt to change my mind. I think that would be a nice, productive thing to happen in this space.

In terms of your other question about my suggestion about a more humble role for research, and particularly the role that social scientists might play, well, I think, look, the bigger question is, what do we broadly think that social science knowledge, and other kinds of knowledge, does?

I mean, there's a lot of talk about using social science knowledge, for example, to construct a governance arrangement, and this assumption that governance is something that one can construct, and that knowledge is used in these ways to actively construct something, rather than being more of an emergent process by which power is distributed and decisions made within society, in which different kinds of knowledges vie for some kind of dominance within that system. I'm not saying that social science is irrelevant. My contention, though, is that there is a tendency towards seeing social sciences in an extremely instrumental way.

So when you look at the range of perspectives, saying, well, how do we change those perspectives, under which conditions might make people let go of their fundamental objections, and how can we tweak the situation in our favor? And I find that view, that very narrow, instrumental view, of social scientific knowledge to be extremely limiting. And I think that we need to have a broader understanding of social sciences—sociopolitical sciences, humanities—of looking to society for that collective wisdom, and actually listening to what people are saying about this, rather than trying to change their minds. It's just a different way of understanding who's knowledge is relevant in this space.

EDWARD A. (TED) PARSON: Thank you very much.

Now, while I'd love to continue a discussion just among myself and the four panelists—I think that would be really fun—we have a lot of expert knowledge of people in the room. Let me turn it over and invite comments from the floor. Let me just ask, we have roughly 20 more minutes to this session, so may I ask that both the questions and any responses from the panel be brief and cogent. And I will collect a few comments at a time, and then, as seems appropriate, distribute them among the panel.

TED HALSTEAD: Good morning. Ted Halstead, Climate Leadership Council. Thank you for a very rich first panel.

I want to pick up on Scott's point of the collection action problem being at the heart of where we are today, otherwise known as a free rider problem. And I just want to suggest that, aside from geoengineering, there is another path for reaching climate solutions. If we think very simply of Kyoto as an effort to get everybody on the same page, and Paris as an effort to get everybody to the same table with their own piece of paper, there is an alternative. And that is focusing on border carbon adjustments, which could create a first-mover advantage to act unilaterally and compel other countries to follow suit. My group is coming out with a paper on that within the next month.

Bringing this to geoengineering, though, I think that the biggest priority for the field should be to focus on that collective action side, meaning the governance structures necessary to move forward on research and potential deployment someday.

And then, finally, since it's fun to comment on everything, regarding Rose's final comments about the world we live in and the world we want to live in, I mean, look, we live in a world where we're heading towards four degrees of warming. And if we did not have to be here at this session talking about these—I mean, I find it—it's with great reluctance that a lot of us are here.

But given that we're headed towards four degrees, we have no choice than to put geoengineering on the table, and to at least think through the governance structures, so that, if we get to the point where we need it, we're ready for it.

Thank you.

EDWARD A. (TED) PARSON: Thank you. May I collect maybe two or three more comments before I pass them on to the panels?

JESSICA MATHEWS: Jessica Mathews, from the Carnegie Endowment. I was really puzzled by the list of the three key questions, because you left out governance. There is a rich body of experience for social science to mine, to ask the question whether there is anything in the human experience that suggests that such a governance structure could be created. The example that Scott Barrett cited of nuclear testing is weird as a moderate example, because, although it's only de facto, and not de jure, the regime is a ban.

But the questions of how you create a governance structure for a technology that you don't know what it is, or what it will do, seems, to me, to be the core of what social science could offer. And so I'm asking the question, why wasn't that the first of the key questions?

SYLVIA RIBEIRO: Thank you. Hello, my name is Sylvia Ribeiro. I am with the ETC Group. And I have a very similar question to that. It's that I think that, in the same sense that Rose was suggesting, I think the discussion is already biased in the questions, in the sense that, for instance, is it possible to have geoengineering in one country? Because geoengineering, by definition, is to affect global climate. So I think there are fundamental social concerns and questions we have to tackle to be able to see if we, at all, want to have any program on geoengineering. And I think that should be a prior question to the others.

PETER FIEKOWSKY: Peter Fiekowsky, with the Healthy Climate Project. And geoengineering sounds like sort of an engineering project. And my question is, if it were successful, what would the goal be?

Normally, when we do a project, we set a goal—specific goal. For me, for the climate, I want to give a healthy climate to our children. If we're successful in geoengineering, what would the outcome be?

EDWARD A. (TED) PARSON: OK, let's get one more on queue.

KELLY WANSER: Thanks for the question, Peter. It was a little bit related to the perspective I wanted to provide looking at the Earth system as a complex system. It undergoes changes in nonlinear ways, and we're increasing the risks of the trajectory that we're on. And so I liked Scott's comment about risk management, and looking at things in the context of relative risk.

And the question is, if our options are the status quo, more investment in mitigation, adaptation, or something we call geoengineering, what information do we have to evaluate the relative risk against the goal that we're trying to achieve, and if a healthy climate for our children is the goal that we're trying to achieve? And we might translate that into a stable equilibrium system—some way that we define where the system is not undergoing such permanent state shifts that the environment, as we know it, is fundamentally different.

And so I think, going back to Rose's points about the case for research today, is, if we look at it as a risk management problem, what is the level of information that we have about the portfolio of options that we have to address it, in an environment where the political and social system is not necessarily controlled? And so in that context, I'm arguing the case a bit like a medical situation, where we have an earth system and we have 19th century medicine. And so we're operating in a decision environment, where we have imperfect information. This one form of treatment is experimental, and we know very little about it.

And so I would, I guess, to Rose's point, say that there is a case for information in the context of relative risk reduction, and if we're able to pursue policies in a rational way, in a risk managed way, then we would be able to make decisions that don't automatically lead to deployment, if the risk of deployment outweigh the risks of other courses of action.

EDWARD A. (TED) PARSON: I think that's a rich enough collection to turn back to the panel. So let's see, we have Ted—consider the context headed to four degree heating, have no choice. I'm going to give that one to Rose, because it is most directly a kind of an inquiry toward her argument.

Jessica—actually, I'm going to take that one and sort of take it off the table, because, in a sense, your question is, why do you say it this way? The answer, as one of the drafters of the background papers, is all three of those big questions were intended to be governance questions, in the sense that each of them was a challenge to a governance response. So the question, how could you govern this technology is a question, how could it be governed in a way that would address these as priorities among the other collection of challenges? So we are not unmindful of governance as the primary challenge. It's so big, it's beyond the questions. But if you wanted to propose other challenges that should be equally central to considering governance, we could talk about that.

Sylvia—should there be a program at all, given kind of the existing political conditions and, in particular, critically, should there be one in one country?

Peter—what's the goal, what's the outcome?

Kelly—if there were a rational basis for considering risk management, wouldn't it be obvious that we should pursue research into this, to which there's sort of the unstated, other side question, well, if we don't have a strong political social basis for rational risk management, in that case, how do we think about it? Or that's the way I'm going to take that.

So let's go in order for the others. Rose, Ted Halstead says we're headed for four degrees heating. You didn't say anything about the severity of climate change risks independent of solar geoengineering. So how do you consider that in your argumentation that the basis for ever doing it, and thus for researching it, is invalid, and, doing so, likely to lead to a risk of dystopic futures, given the state of political and social conditions?

ROSE CAIRNS: Hi. Yes, no, I mean, I agree. We're not in a great situation. I'm not denying that a four degree future doesn't look like a great future either.

But I would like to just come back and say that this particular framing that we have no choice but to put geoengineering on the table is quite a dangerous framing. And I think it slightly belies the argument that has come out before that, if a research reveals that this is difficult or dangerous or risky, that we'll just be able to, then, say, well, it doesn't work, then.

It seems to me, if you're saying, we have no choice as a framing, that, again, this leads to that dynamic of, then, well, we'll just have to figure out a way. Whatever kinds of obstacles or risks or problems get revealed by the research, we'll just frame them as challenges—engineering problems, if you like—to be overcome, rather than reasons to stop going down this path. So I think that that framing really needs questioning.

And again, the we, the problematic we, that is often used, that we need geoengineering. It will have to be there if we need it, if we want to use it ultimately. And who is this we? Again, it's this imaginary idea of an international community acting in kind of beautiful harmony to suddenly set a temperature target, and go ahead with geoengineering. And I don't think that that is realistic. And I think putting geoengineering on the table, as was suggested, is actually very dangerous, and will cause all kinds of unforeseen consequences.

EDWARD A. (TED) PARSON: Thank you. OK, the other questions, I'm going to offer panelists' choice who takes them on. So we have Kelly on kind of the premise of the social political conditions justifying a research program or not. Panel, does that suggest researchable questions about those social and political conditions, and are those, in some sense, prior even to a decision to pursue research, let alone any future hypothetical deployment?

SCOTT BARRETT: Well, in my case, I'm more interested in addressing another point. So I do want to use up my time.

[LAUGHTER]

EDWARD A. (TED) PARSON: OK, actually, the panel is allowed to punt. That's one of the benefits of gathering multiple questions. OK, what's the goal, what's the outcome?

HOLLY BUCK: I can do that.

EDWARD A. (TED) PARSON: Please, Holly.

HOLLY BUCK: Yes. Well, I mean, obviously, that's not for me personally to answer. It's for the people, however you construct them. And one interesting thing was citizens really do want to talk about this more broadly.

So we had a project, the idea is that you'd want to incorporate public engagement early into the research process, because it could make the research better. You could focus on what people want to know about, and what their questions are. So we tried to gather up what people's questions, ideas, and concerns were about solar geoengineering, in order to do some science in response to that. And people were interested in that, but they wanted to talk about all these other things—you know, consumerism, ways to cut carbon, just the whole range of things you might imagine.

And we really need to be a social scientist, thinking of spaces to have kind of those broader conversations. And then there's the tension with also hopefully making it usable to scientific research.

I would say one thing that, in terms of societal goals, the one process that has been done collectively would be the Sustainable Development Goals. And it would be interesting to analyze how they could be furthered by geoengineering, and how to use that. That's one lens to get at that question.

EDWARD A. (TED) PARSON: Interesting. Anybody want to take on, should there be a research—actually, Scott, what was the question you wanted to take on?

SCOTT BARRETT: Well, actually I'm interested in all of them. But Ted asked the first one that I have a particular interest in.

EDWARD A. (TED) PARSON: Go ahead.

SCOTT BARRETT: But I am interested in all of them.

So Ted's basic point, if I'm interpreting it correctly, was, well, you know, we're looking at geoengineering because of the difficulties of addressing the fundamental problem, which is not to put things in the atmosphere that aren't already there. That's the key point. And we have had this whole—years of attempts to do this.

Kyoto, you mentioned. Paris. I've done research on all of these. There are deep weaknesses to all of them. And so then, there is the question, well, who would do better? That was your point. And this, I think, should be a major research priority. I spend almost all my time doing this.

Now, your idea was about—you called it border carbon adjustment. So you have the basic free rider problem, but on top of that, you're doing all this in this world of globalization. So when you go to intervene, you're going to be changing market prices, which is going to cause—so one idea is you want to impose border tax adjustments to correct for that.

That will not, however, correct at all for free-riding. That standard border tax adjustment, intended to address the trade leakage issue would not do that. Also, it would not address the leakage in the fossil fuel market, which would be a major issue. Ultimately, what I'm quite sure you care about, is actually

reducing global emissions. And that means, could you use something like a tariff to enforce an agreement to limit emissions?

So the world does agree. And there is a goal—two degrees C. Funny enough, people say we should avoid 2 degrees C, but those same people don't say we should do it through means like this. Now, William Nordhaus of Yale University, a very distinguished economist who's been working on climate change since the late 1970s, has a provocative paper called Climate Clubs, in which he's looking into the question about whether a subgroup of countries would adopt, in his language, a carbon tax, and then impose generalized tariffs against nonmembers to see if that would create incentives for the nonmembers to join the club.

I do think that, in terms of addressing free-riding, trade has to be brought in. It's inconceivable how we could address it without that, except for the miracle technology arriving. Now, I'm doing some research on this myself. Now, for Bill's work, what he basically shows is that, if the carbon tax is in the neighborhood of $50 per ton, the system won't work. So it only would work if you had a very small carbon tax.

So I don't think this is any kind of solution. I mean, David Keith and Dan Schrag and others will tell you to stabilize the climate by limiting concentrations, you have to bring emissions to zero. We should all be filled in complete awe of what this actually implies. Now, he's—

EDWARD A. (TED) PARSON: And you're on mitigation, and although it's the important envelope around all of this—

SCOTT BARRETT: Yes, but it's very important. It's very important because, first of all, we should pursue every effort we can on this. And also, the case for geoengineering, and this goes a little bit to what Rose is saying—I don't agree with what she's saying, but it goes a little bit to what she's saying—if we don't pursue every possible avenue to address the fundamental problem of concentrations in the atmosphere, then there's always going to be this concern about geoengineering as some kind of quick fix or something.

But the last part I want to make is that he's, in your analyst's model, he's assuming that there's no retaliation. Well, I can tell you, you remove that and, all of a sudden, the instances in which that approach would work start to really shrink. And then there are some other things I can tell you. I think this is the way we should be thinking about it.

But really, I've spent over 25 years working on this, at least I cannot see any kind of global regime on climate change that can address the problem at this fundamental level. And frankly, that's the only reason I'm sitting up here right now.

EDWARD A. (TED) PARSON: OK. We're going to maintain a larger scale time discipline, and there will not be another round of questions and comments. So every topic addressed here will be revisited repeatedly over the course of the day. So hold your questions and comments.

Please join me in thanking our panelists, the three here in the flesh and the one remotely.

[APPLAUSE]

Thank you all. Thanks for your excellent questions. Thank you.