Hacking the Climate

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Greg Dalton: I'm Greg Dalton. And today on Climate One, we're discussing painting the sky. Imagine Superman flying into the earth's atmosphere, and spraying a mist that reflects the sun and cools the earth. Today, we'll talk with four humans about doing that with machines from a cartoon or from a science fiction novel. Scientists studying the possibility of altering the atmosphere to fight global warming call it geoengineering. Others call it hacking the sky. Whatever you call it, the U.S. military, Bill Gates and researchers around the country are looking into intentionally changing the heavens to an unprecedented extent in human history.

Over the next hour, we will talk about the scientific, technological, moral and political dimensions of geoengineering. Joining our live audience at the Commonwealth Club in San Francisco, we're pleased to have with us four people involved with this cutting edge research. Ken Caldeira is an atmospheric scientist at the Carnegie Institution for Science at Stanford and a leading expert on geoengineering; Al Lin is a professor at U.C. Davis School of Law, who studies the governance of geoengineering research; Jane Long is co-chair of the Task Force on Geoengineering at the Bipartisan Policy Center in Washington, a former associate director for energy and environment at Lawrence Livermore National Lab; and Armand Neukermans is a physicist and inventor involved in geoengineering. Please welcome them to Climate One.

[Applause]

Greg Dalton: Welcome everyone. Ken Caldeira, let's begin in 1998. You're sitting in Aspen, hearing a very conservative scientist talk about changing the atmosphere in a way that you thought was crazy.

Ken Caldeira: Yes, I was at a meeting in Aspen in 1998 on how to address the climate problem, and Lowell Wood who was a protégé of Edward Teller who was instrumental in creating the hydrogen bomb said that one way to solve the climate problem would be to put small particles high in the atmosphere and that these particles would reflect sunlight back to space.

And the sun is what warms the earth and greenhouse gases prevents that heat from escaping back to space. And so his idea was to offset the effects of increased greenhouse gas concentrations by reflecting some of the sun's warming rays back to space. And I thought that this would make no sense and wouldn't work because even if you could cool down the earth, on average, I would expect that since the sun warms in the daytime and not at night and at the equator not at the poles, where greenhouse gases block sunlight going out all over the earth more or less uniformly. And so I thought these things would never cancel and you'd wind up with big regional or seasonal effects. And we came back and did some computer model simulations using climate models, and it turned out much to our surprise that it worked quite well.

Greg Dalton: And another person in that audience that day, David Keith, also was changed and now he's one of the primary advocates for doing this, right?

Ken Caldeira: I would say so.

Greg Dalton: Jane Long, how did you come to discover the sort of fantasy or science fiction of

geoengineering?

Jane Long: Well, I came to Livermore not knowing very much about climate science, I had been working a lot in energy and I taught myself - I was commuting from Oakland to Livermore, and took a course in climate science and then ran into people like Lowell and Ken at Livermore where we began to talk about it. And then I got asked by a government official to put together a panel, which we did, because they wanted to hear from scientists about whether or not this was a good idea. And we put this panel together and lo and behold it wasn't just scientists actually. We had people that were diplomats. We had political scientists. We had ethicists on this panel and a unanimous conclusion that we needed to start looking into this technology.

Greg Dalton: And we'll talk more about that in this hour. Armand Neukermans, you were involved, there's a group of people involved in developing the inkjet printer at HP. How does that relate to geoengineering? The inkjet printers that many of us have in our homes and offices, how does that relate to painting the sky?

Armand Neukermans: Well, the real story is that Ken and Steve Schneider and Jim Lovelock came together at our house and saying, "Well, don't these two guys in Scotland that's sort of trying to get some idea going about spraying and smoke particles?" "Yes, I worked on that four years ago." And so they invited me to Scotland and say, "You know I'm not going, this is too much carbon and all that kind of stuff." Anyway, they twisted my arm and I ended up going. And then I decided I'm going to go there to help the guy. Well, they handed me the project and because they wanted the project in Silicon Valley --

Greg Dalton: How much scotch in the afternoon?

Armand Neukermans: I don't need very much scotch.

Greg Dalton: Okay.

Armand Neukermans: One glass is enough. It was very comfortable. So they twisted my arm and so -- I mean, basically it changed my life so that's what I've been doing the last six years.

Greg Dalton: And so explain this --

Armand Neukermans: So let me just first make clear that you understand. None of us really advocates geoengineering. We're saying, "Look, the research should be done." None of us reasonably defend that you're going to deploy this.

Greg Dalton: So let's use that inkjet printer or a glass of milk and explain first simply what we're talking about, spraying mist into the air that reflects the sun back?

Armand Neukermans: Well, this is a relatively simple idea that basically use the clouds like a mirror. And this particular one which we called marine cloud brightening was invented by John Latham who was an atmospheric scientist in England.

He was walking with his son in Wales and that came part of the cloud and sunset, "Wow, look at that. This is like a mirror." And so John started thinking about this and then wrote something in 1990 or something. He wrote an article about this and who's writing about geoengineering or climate change at the time? And so it sat there for ten years and then things go on and people start saying, "Maybe we have to look into this." But this is a relatively simple idea and I'm not an atmospheric scientist, so there's room for some discussion here. But anyway, so if you look at here at California, when you go to the coast, most of the time the clouds there are gray. And clouds are white and just

like a glass of milk, right?

So if I take milk, it looks like a white. And if I dilute it, then it gets gray. And there's nothing white or gray in that whole milk, they're just little droplets and there's water and there's little droplets of fat in it, and the combination of multiple scattering gives you that color. So what happens in the clouds that are sort of gray, they don't have very many droplets, or they're quite big. And so the idea is that if you would help by a natural means to bring more droplets in there, nuclei as they call it, they will become droplets too and you will have more scattering so it will look lighter. The clouds will lighten.

Greg Dalton: So clouds are mirrors. You can make the mirror stronger and reflect more heat up into, bounce it back into the atmosphere and it won't warm up.

Jane Long: Into space.

Greg Dalton: Into space. Al Lin, this sounds like playing God. Who gets to play God?

Albert Lin: Well, this is a very interesting question raised by these various techniques that fall within the rubric of geoengineering. I mean, one of the reasons why geoengineering is a controversial topic is because it's talking about potentially trying to affect, influence the climate at this very broad scale akin to perhaps you could say playing God.

And the question is, of course, who would do this? And ultimately, ideally, this decision would be made by the international community, by humanity as a whole. How would that be made though, there's all sorts of questions regarding could one country do it on its own or even an individual who had the financial means to try to do this. So all sorts of difficult questions regarding how you would actually manage a scheme like this even if you could somehow agree to go forward.

Greg Dalton: Ken Caldeira, how much research is happening now today? Who is tinkering with the atmosphere?

Ken Caldeira: We're all tinkering with the atmosphere with our greenhouse gas emissions.

Greg Dalton: Anyone who drove here driving their car now is tinkering with our atmosphere. Fair enough.

Ken Caldeira: But nobody is intentionally trying to alter the atmosphere and nobody is now engaged in any outdoor experimentation with geoengineering. There are a couple of projects ongoing in Europe, in Germany and in the United Kingdom. And there are a few projects here in the U.S., but they're all indoors, laboratory and paper studies.

Greg Dalton: Okay. How do we know that the Chinese or the U.S. government isn't doing it in secret? Jane Long? I mean --

Jane Long: Well, I'm fairly certain that the U.S. government is not doing it because we've been trying for years to get them to start research and they are very reluctant to do that. So I don't think they are. I think the Chinese government is doing a lot of weather modification which is very different. So I don't think anyone has gotten to the place where there has been a global perturbation and I think we would know. You would be able to detect it from observations of the earth.

Greg Dalton: So if Russia or China launches an ICBM, U.S. Military knows right away and you're saying that if Russia or China --

Jane Long: Yeah, I mean --

Greg Dalton: -- tried to do the same.

Jane Long: This is a big operation. It would take lots and lots of airplanes, lots and lots of balloons, or whatever delivery mechanism you chose, so you would know. But I think the issue is that Al brought up the idea that we have a problem with trying to decide who would do it and that moral or governance issue. But we also have an opportunity here because the thinking about geoengineering is such an anathema to people; it's so hard to believe that we should do this intentionally. There's much more moral baggage associated with harming the earth intentionally than all of us drove our cars and did various things to emit carbon dioxide.

And as Ken points out, we all changed the climate a little bit today in our activities, but we did it unintentionally. It's the intention that makes this really very difficult. But the fact is that we are entering a time in the earth's history where we can't avoid that intentionality. We know now that we're changing the climate. And so the idea of thinking about this and thinking about the governance concerns of how we would do this may bring us to a place where we actually do a better job of that intentional, of managing this planet. It's the only planet that we have so far to live on.

Greg Dalton: Al Lin, you say that researchers are waiting for a social license. What does that mean to get a social license to go forward?

Albert Lin: Well, as Ken described, there hasn't been.

I mean, there have been very small scale kind of marginal field experiments, but there are these researchers who would like to go forward in a very transparent way with further experiments to try to develop geoengineering techniques or to see whether they might be feasible. But at this point, they've held off on going forward because of the sense that they don't have yet a social license. And the idea behind the social license is that they're concerned about the reactions that might take place and they also want to, I think, have a sense that whatever researchers produced, the research results are legitimate and will be accepted as legitimate. So at this point and we're kind of at a standoff is my sense of it, where we have a growing number of researchers who are interested in doing some field experiments, but a bit hesitant and hesitant partly because of the social license issue and connected to the social license issue of reluctance of various government entities to fund the research.

Jane Long: So I see that a little --

Greg Dalton: Jane Long.

Jane Long: I see that a little differently. I think there's quite a few people who are ready to do small scale, very low risk experiments that are looking at actually how the chemistry and the physics actually occurs. These are relatively small and they try to look at the mechanisms by which particles form and how they reflect and whether or not they impact the ozone or other things that would be deleterious. They're ready to go but there's no money. There is no funding for these projects. It's the government that is holding back on the social license. And I think what's happened in the last few months is that the National Academy of Sciences, for the first time, was asked by the government to produce a report and that report on geoengineering recommends research and this has begun to open the door to thinking about funding.

I mean, the first act of governance is funding. If you don't get funding for the project, then the government has basically governed you out. You're not going to do it. So I think we have

catalogued a number of very important experiments which happen to also be very important for climate science. And one of the ironies of most of the geoengineering technologies that are out there is that they involve either aerosols or clouds, and those are two of the things that have most of the -- a lot of the uncertainty in climate models. And understanding how the climate works comes from not having a very good understanding of how aerosols behave and how clouds behave. So there's now a body of research that's been defined which would go out in a very small scale and put a few particles in the atmosphere, and try to understand what it does to -- what it actually does on a very small scale that would help us understand if these technologies would be effective or advisable. And I think those are the two first things that really have to go forward at small scale and at low risk. I think there are quite a few scientists that are ready to go, I don't think they're waiting for a social license. I think they believe in this. What we need is funding to move forward.

Greg Dalton: Ken Caldeira, you're a part of a group that's funded by Bill Gates. There is money there. So what is Bill Gates' motivation and what's going on with his money in this area?

Ken Caldeira: Bill Gates has created a small fund known as the Fund for Innovative Climate and Energy Research and I can't speak for him, but I think he feels that this is an area that the government should be funding. But because the government is not funding, he stepped in to support some small amount of work doing computer modeling and laboratory experiments. And I think he just sees this as a research area that's underfunded and he's trying to step in to fill the gap.

Greg Dalton: Jane Long, what do you think about for-profit or private funding of this type of research?

Jane Long: I think it's really important that the government fund the actual physical experiments, the kinds of thought experiments and workshops and things that are being done through private funding, I have no problem. But once we get to any kind of an outdoor research project, you very quickly want to see that become programmatic and become strategic. Because as we move from very, very small-scale research with literally no physical risks associated with it, and if you ever move to something that's maybe still very low risk. But large scale, say over 1,000 kilometers or something like that, 1000 miles, you wouldn't want that kind of research to be done unless it was publicly available, publicly governed and was totally transparent to everyone in the public about what was being done and why it was being done. And you wouldn't want to take any risk at all unless it was somehow strategic research.

Greg Dalton: Jane Long is a former associate director at Lawrence Livermore National Lab. This is Climate One. If you're just joining us, we're talking about geoengineering or painting the sky to fight climate change. Al Lin, what do you think about private funding and sort of for-profit motivation, and how this could be governed and should something that's only funded by the government?

Albert Lin: Well, I think private funding is a concern. I generally agree with what Jane said about the need for whatever field research activities take place to be subject to a public accountability and transparency, and that's much harder to do when you have private funding going on.

Some of you may be familiar with an incident a couple of years ago where an American businessman undertook an ocean iron fertilization project on the Pacific. There is some disclaimer on his part as to whether that was a geoengineering experiment or not. Many people perceived it as a geoengineering experiment, given the background of that particular person involved. And that was essentially privately funded. It was funded by a Native American tribe in Canada which was actually seeking enhanced salmon runs, but arguably it was also a type of geoengineering research which was done without public oversight and public accountability. And there is a lot of concerns about

what that could lead to because of the possibly that ultimately some of these activities could be undertaken privately without public say, without say by government over what goes on.

Greg Dalton: Ken Caldeira?

Ken Caldeira: No sensible person would invest in solar geoengineering with the intent of making money. It's thought that it will be very cheap; if it does get deployed, it's likely many decades away. There's all these other controversies associated with it. So I do not believe that there's any sensible person today investing in solar geoengineering with the intent of making money.

Greg Dalton: Could they do it for ego or power? You get a couple of billion, you get kind of bored, what are you gonna do with your money?

Jane Long: Those are real issues. I think there are all different kinds of vested interests, not just making money. And protecting society against that vested interest is very important.

Greg Dalton: Armand Neukermans?

Armand Neukermans: But there is a difference essentially. Look, quite frankly, our society couldn't operate anymore and people would be dying on the street without the private support of NGOs and all that kind of stuff.

And if you now see what's going on in science, it's not very different. A lot of the science, even academic, is already funded by private. Look at the Moore Foundation. The stuff that comes there, I mean I don't understand it what they're funding. What is at essence here is that if you're going to do an experiment, you'll need the approval of a very confident body. Whoever is going to fund it, that's something else, but you need the approval from who is confident enough to judge that. That's really what's certain. And so let me give you an example.

We sort of worked on this for six years. What we're making is sort of like a snow blower, but the particles, the droplets that come out are a thousand times more, okay? So we thought it was right, ready for, but it isn't quite ready yet. So the University of Washington, as was always the plan, is taking this over and they have two intentions essentially. One is to study the clouds for this because it would make and shape new clouds with this, and study them like they never done before, and then look at geoengineering. So we're looking for wherever the money comes from at this point. And what it really comes down to is that we take each one of these sprayers, sprays a half of glass of seawater, okay? That's what it does. All right.

Would you need permission to do that normally? I mean, you spray this and that. We dump thirty [unintelligible] in the atmosphere or 35 every year and no one ask for permission. But in the interest of the controversy, we will seek permission and say, "This is the test. You have to have total transparency because of what's happened in the past." People did these tests then they say, "You know, we're going to get carbon credits out of this." Well, sure, you got to get carbon turn around very quickly. So you have to have the moral ground to say, "Look, this is the experiment that they're going to do and we would like to have approval from a confident body."

Greg Dalton: That makes sense, though a lot of this backdrop came out of, as Ken Caldeira mentioned in the beginning, some of the people involved in the nuclear age. What if this technology, Al Lin, gets in the hands of a rogue state or a group that is not as well-intentioned as governed as Armand Neukermans just said? Could this technology spread like nuclear technology and get in the wrong hands?

Jane Long: So I think it's really different than nuclear technology, right? Nuclear technology,

when you wanted to learn how to make a bomb, the technology was extremely sophisticated and difficult. Here, the technology is actually kind of simple. Spraying things up in the air is kind of simple. And so the real issue is whether or not you can really mount the campaign, and I don't see how you mount the campaign without being noticed. So I don't really think that analogy --

Greg Dalton: Could ISIL get a bunch of sprayers and spray it over the Middle East? I don't know, right?

Jane Long: Yeah. But the idea that we're unloosing a technology, I mean we've known -- people have known for a long time that when volcanoes erupt, they put sulfur in the stratosphere and that cools the earth. It's like, it's not that difficult to understand that that technology works, though it's not like the sophistication of trying to figure out how to make a bomb.

Greg Dalton: Albert Lin?

Albert Lin: There are some parallels with nuclear technology. I mean, I agree it's very different in certain ways, but there is the possibility of dual use, that is, just as nuclear could be as peacefully for energy and then for weapons purposes similarly. You could see some of the technology that's being developed here potentially being used in a military way or at least in a way to disadvantage one's neighbors, whom one disagrees with. So there's the possibility of that dual use or the possibility of misuse. And I think the key seems to be that, if you ultimately did want to go forward with geoengineering, you want to do it well.

But with kind of the evil use, you don't necessarily have to do it well. You may not care about the side effects that we might be caring about, or the negative environmental impacts that might follow from one of these techniques. Whereas, if you really want to deploy it to deal with climate change, you also want to make sure that the negative implications are.

Greg Dalton: If you're just joining us --

Albert Lin: -- are dealt with.

Greg Dalton: Albert Lin is a professor of law at U.C. Davis. I'm Greg Dalton. This is Climate One. It's now time for our speed round where we're going to ask a yes or no question to each of our guests, and this is intended to be fun and pick up the pace a little bit. So Ken Caldeira, yes or no, humanity is doomed?

Jane Long: That's easy.

Ken Caldeira: No.

Greg Dalton: You waited kind of a little bit.

Ken Caldeira: Well, I thought I could. I once wrote a paper about in 1.5 billion years, the sun will eventually swallow the earth’s orbit --

Greg Dalton: Okay. All right.

Ken Caldeira: So --

Greg Dalton: We'll give you -- yeah, in the next billion years, humanity is doomed.

Greg Dalton: Jane Long, for-profit research into geoengineering makes you very nervous?

Jane Long: Yes.

Greg Dalton: Albert Lin, if geoengineering goes wrong, lawyers will survive the catastrophe better than other humans.

[Laughter]

No one said cockroach so --

Albert Lin: Yes. Well, I would say there would be survivors.

Greg Dalton: Armand Neukermans, the CIA is working on geoengineering and the NSA is listening to us right now.

Armand Neukermans: Is there another option for it? It's sort of gray.

Greg Dalton: Gray like the clouds?

Armand Neukermans: Yeah.

Greg Dalton: Jane Long, if North Korea can hack Sony, they can hack the sky.

Jane Long: Yes.

Greg Dalton: Albert Lin, U.S. courts are unprepared to handle the oversight of geoengineering.

Albert Lin: Yes.

Greg Dalton: Ken Caldeira, if Stanford scientists hack the sky, they will do it with cardinal red particles.

Ken Caldeira: No.

Greg Dalton: Armand Neukermans, people in Silicon Valley think their money will protect them from the worst impacts of climate disruption.

Armand Neukermans: No.

Greg Dalton: Thanks. That's the end of our speed round. I want to pick up on earlier, we talked of, the morality of this was mentioned. Jane Long, is it moral to do this research into changing the sky in a hubris kind of God-like way or maybe it's immoral not to do it?

Jane Long: I think it's immoral not to do it. I think that we have created a situation for our offspring and my grandchildren and your grandchildren, there are people that will come after us that could be untenable and it's part of taking responsibility. I think we have to take responsibility for the earth because that's where we all live and because that's where our children and their children are going to live. And so the need to learn how to take responsibility is paramount in our survival. You asked, are we doomed? We're not doomed if we take responsibility.

Greg Dalton: Okay.

Jane Long: And we need to do that.

Greg Dalton: Ken Caldeira?

Ken Caldeira: One of the main reasons why I'm working on this is that climate models project that with business as usual, carbon dioxide emissions every summer in the tropics will be -- nearly every summer in the tropics will be hotter than any summer yet experienced. And in these extreme heat events, there's often widespread crop failures, so there's some potential for widespread famines and it's possible that these technologies can save hundreds of millions of lives. We don't know if that's true but there's a possibility. And so I think we would be remiss not to study these things. I think that concern comes with our ideas about our relationship with nature. We like to think, and maybe we would like for the world to be basically a natural place where we carve out a little man-made part in this natural world. And this idea that humans are managing the entire planet and there's fundamentally no more nature is a concept that we need to grapple with and I think is disturbing to people and rightfully so.

Greg Dalton: Man's dominion. Albert Lin?

Albert Lin: I think we have to be careful about research. I'm not opposed to research in principle. I think when we think about what research generally produces knowledge and knowledge is a good thing. We want to know more about these things to know what to do whether to move forward with these technologies. But there are concerns regarding what the net effect of research is, that is, what role does any individual project play. You might say, "Well, a particular experiment doesn't produce much risk, but is it part of this larger scheme?" Whereby, ultimately, we move down this road where we've invested so much where we've created vested constituencies, whether it's companies or scientific communities, that are interested in going forward because they have a personal or financial or professional stake in moving forward with the actual deployment and not just the research. I think that's a very real danger we have to be aware of and be concerned with, assuming that field research does go forward.

Greg Dalton: So as I was preparing for this, I was thinking kind of like Botox. You start with a little Botox and then you start doing more and more. Then, pretty soon, you can't stop. You got to keep doing it or you'll look bad, right? So is there a point of lock-in, Ken Caldeira, where once it starts, we're down a slippery slope, you got to keep shooting that stuff in your skin?

Ken Caldeira: I basically oppose the development of institutions that would do this research, in that I think it's really good when there's a cloud physicist at University of Washington who are mostly doing other things who spend some fraction of their time on this.

Because I don't think we want to create a cadre of people who have a vested interest in seeing all of this go forward. I would feel much more comfortable to have scientists who are working on other topics spend 20% of their time working on this, which is the kind of level of involvement that I'm really at.

Greg Dalton: Jane Long, once funding starts flowing to universities and labs, they want to keep that money flowing.

Jane Long: That's right.

Greg Dalton: They want to see their papers published and they have their careers staked on that success.

Jane Long: That's right. And I think these are real problems and these are some of the more difficult vested interest problems we have. We also have people that just really want to save the world and I'm really glad they do. They want to come up with good ideas, but they need to be checked. So I think there, eventually, Ken's model for getting started makes some sense. But

eventually, if you keep pursuing this, you're going to have to have some institutional controls and you're going to have to reward people for saying, "This is a really bad idea and we shouldn't do it."

Greg Dalton: And Ken Caldeira, if we'd started this geoengineering -- again, we're at Climate one today. We're talking about painting the sky and putting aerosols and making clouds brighter so they reflect heat up into the atmosphere and cool the earth. Once that started, if it's stopped, what happens?

Ken Caldeira: If a system were deployed full-scale and then stopped right away, it would be a lot like a volcanic eruption which puts material into the sky and then it falls out. If you kept doing it for a few decades and then it was masking lots of warming, as soon as you stop, all that masked warming would come at you pretty rapidly and so you'd see very rapid warming. And so there would be incentives to try to phase it out slowly if it wasn't working. You wouldn't want to turn it off all at once.

Greg Dalton: Let's talk about some of the regional impacts. Ken Caldeira, we've been talking at a global scale, what are some of the ways that this could be done at a regional scale in California or Southwestern U.S.?

Ken Caldeira: Most of the research so far has been at a pretty global level. And one of the things that I would like to research, but haven't gotten around to and there's no funding for anybody else to do it really, is to look at this idea that Armand is working on of making the clouds whiter. It's possible that whitening the clouds in the Pacific off of Los Angeles or San Francisco could help bring moist, cool air into the desert Southwest, or this coastal fog is going away with global warming and that's threatening the coastal redwoods. And it's possible that these approaches could bring more clouds and fog into the coastal redwoods. And so this cloud brightening idea has potential for regional scale alterations of climate, but nobody has yet even begun investigating that.

Jane Long: I really want to second that.

Greg Dalton: Jane Long?

Jane Long: Yeah. I think what's happened here is because there hasn't been a coherent program, very few people have begun to think about this. And the governance issues for the global ideas that came up very early on are going to put stratospheric sulfur everywhere it's going to reflect, and the whole world is going to become a lower temperature. The governance that goes along with that is just totally nonexistent. But the idea that we're going to get specific local regional climate problems and people are going to push very hard to deal with these heat waves or we're losing our crops or we're losing our redwoods, these things, I think, are going to become very probable and I think they will drive a need for a technology that really hasn't been invented. And there's no body of science, Ken is quite right, there is no program now that looks at what you might call extreme adaptation, and yet the governance of that type of activity is probably a lot easier. So if you've had a heat wave for a month, and every year you get a heat wave and it's a little longer and it's a little hotter, somebody is going to want you to do something about it and there's going to be a huge amount of pressure.

Greg Dalton: There's going to be a ballot initiative in San Francisco, do we want more fog? And then that you got to vote, right? More fog, more --

Jane Long: I think --

Greg Dalton: Can you imagine, right?

Jane Long: That's way more likely than having the whole world vote to have solar radiation management at a global scale.

Greg Dalton: Ken Caldeira?

Ken Caldeira: I think there's often an assumption that deployment of these technologies will be widely unpopular. But if you're in Phoenix and it's getting to be 120 degrees and there is no rain, and somebody spraying some seawater off of Los Angeles can make you have cooler weather and moister weather or if you can preserve the redwoods -- I was at a meeting where there was a fellow there from Ghana who stood up and said, "If we're having crop failures and we think that putting aerosols in the stratosphere can cool the weather and allow us to grow our crops, we would be all in favor of it."

So I think the question is how -- we don't really know how bad climate change will get and maybe it's something we just adapt to and it's not really so bad after all. But if it really does turn out to be catastrophic, there could be real demand to do something quickly and these kinds of approaches are the only things that politicians can do that will cause the earth to start cooling within their term in office, within their political careers. Energy system transitions take half a century or more. And energy system transitions don't cool the climate, they prevent it from warming further, or warming so fast. And so the only thing that we can do to cool the planet or that society can do to cool the planet is deploy these sorts of technologies.

Greg Dalton: So does the possibility, Jane Long, of a quick technological fix mean that we can go about our carbon-intensive lives and keep driving big cars and flying around and eating steak and like, "Oh, well, I can take a pill later, I don't have to diet. I can get gastric bypass surgery or whatever it is and live happily."

Jane Long: There's just no silver bullet here. And basically, these technologies are not going to work if we keep emitting. I think one of the most important things about climate science that most people don't understand is that all of that carbon dioxide that we put in the atmosphere stays there for a really, really long time like 1,000 years before it decays. And so if we stop tomorrow, if we stop emitting tomorrow, we still have everything that we have put up there to deal with which is continuing to warm the earth. So if you keep emitting and you keep emitting, you can't keep up with it with any of these technologies. The only thing that we can think about is, this might take the edge off for a while, while we finish this energy transition that we have to make. And maybe we have to go farther. Maybe we find that not only is that energy transition not enough, but we have to take some of that carbon dioxide that's up in the atmosphere now and take it out. But the first thing and the most important thing is the energy transition. If you don't do that, nothing else is going to work.

[Applause]

Greg Dalton: Albert Lin, does this create a moral hazard? The possibility of even thinking about this means that there is a pain-free way out, that we don't have to do all these hard changes here on earth?

Albert Lin: Well, I think it's important that geoengineering ideas and whatever research that's done is done openly, it's done in a way if it's done then it's done in way that is explained for what it is, that the flaws are made clearly apparent. I mean, even if you could develop these technologies fully, as Jane says, there is no silver bullet. All of these proposed techniques have their limitations. And in particular, the ones that seek to deflect radiation do nothing about greenhouse gas concentrations in the atmosphere, and therefore wouldn't deal with the problems of increasing acidification of the oceans.

I think probably the most significant piece of the moral hazard problem is with respect to the politicians. That is, as Ken referred to, there is a need to the extent you need to show you're doing something about climate change is to show you're doing it in the near term. And it's very easy to say, "Well, we are working on this thing, this geoengineering. We're doing more research. And when the research comes, we'll fix the problem." And it's much easier to say that than to say, "Well, we need to do this energy transition much sooner and we need to invest the money upfront. Yes, it will cost money now, but later it will pay off and we really need to make a little bit of short-term sacrifice."

Greg Dalton: Ken Caldeira, I mean Washington can't even agree to pave roads and do some simple things. How are they going to agree on anything as complex as this?

Ken Caldeira: Well --

Greg Dalton: You don't want to touch that one?

Ken Caldeira: Yeah. Well, trying to turn our government from a dysfunctional government to a functional government is beyond me. But now I forgot what I was going to say.

Greg Dalton: The moral hazard with the idea of --

Ken Caldeira: There's been a few small focus group studies where they told people about this solar geoengineering.

First, they asked people, "How much are you willing to work towards developing an energy system that doesn't dump its waste into the sky?" And then they talked about this solar geoengineering ideas and then asked them again at the end, "Are you willing to -- how much are you willing to work towards an energy system transition?" And people, after hearing these crazy solar geoengineering ideas, were more willing to put a greater effort into changing our energy system. And I think part of the idea is that if the scientists are so worried about climate change that they are thinking of these crazy ideas, maybe we should take it seriously.

Also, I have spoken with people who think that climate science is garbage in, garbage out, and they just make the models to give whatever answer they wanted. And if the climate scientists were doing that, we wouldn't create climate models that said these solar geoengineering things would work. And so I think it shows that the scientists are being honest brokers and saying that this is what the physics says. And so I think it adds to the credibility of the climate science.

Greg Dalton: Ken Caldeira, you put out a tweet today that's linked to a climate geoengineering article and someone tweeted back, "Don't do it." You said, "Don't talk about it." But the fact is, even having this conversation is controversial in some quarters some people think, "Don't talk about it. Because if you talk about it, it might happen. That would be bad, so shut up."

Ken Caldeira: There are people who think that this conversation is a distraction away from the more important conversation about how do we change our energy system. But I think it really motivates the discussion about changing our energy system. Because if you think about this solar geoengineering options, you recognize that if we continue dumping our greenhouse gases into the atmosphere and forever put more and more aerosols in the sky that that's an ugly, ugly endgame. And so these things don't get you out of the need to change our energy system. And I think that once everybody recognizes that we need to change our energy system, maybe that we might actually do it.

Greg Dalton: Ken Caldeira is a climate scientist at the Carnegie Institution for Science at Stanford.

If you're just joining us at Climate One, we're talking about geoengineering, increasing the brightness of clouds and other interventions in the atmosphere to reflect heat up into the atmosphere and cool the earth. Also joining us here are Albert Lin from U.C. Davis School of Law; Jane Long from the Task Force on Geoengineering at the Bipartisan Policy Center; and Armand Neukermans, a physicist and inventor. I'm Greg Dalton.

[CLIMATE ONE MINUTE]

Announcer: *And now, here's a Climate One Minute.*

Spray painting clouds to deflect sunlight may sound like science fiction. But many of the fantastic ideas dreamed up by science fiction writers have come true, from robots to space travel. Kim Stanley Robinson, author of The Mars Trilogy, says that immersing ourselves in fantasy can be more than an escape. It can also be a useful tool for change.

Kim Stanley Robinson: *So you read a fiction in which the climate is changed in the future, you might find it reassuring; well I'll be dead before that happens, so that's their problem not my problem. On the other hand, you could take it as a warning, you could think, well I want a decent life for my grandchildren. and I rate my grandchildren's lives as importantly as my own as a philosophical or moral position. So at that point, imagining what it would be like can be vivid. You spend time living in that world because that's what fiction does. You are in a different world. It's telepathy, it's time travel. Reading fiction is a very powerful experience. So I believe that if it's done right it can change one's view. You come back to reality and you have a kind of double vision. You have your normal daily vision and then you have your science-fiction vision, the future, interposed on it or behind it, so you get a kind of 3D in time. And it helps you to make decisions about what do I do today to help the situation for my grandchildren? So the science-fiction double vision, the temporal 3D, the 4D vision is really a useful tool for figuring out what to do now. It's a philosophical tool.*

Announcer: *That was writer Kim Stanley Robinson, discussing the merits of science fiction at Climate One. Now, back to Greg Dalton and his guests at The Commonwealth Club.*

[END CLIMATE ONE MINUTE]

Greg Dalton: This is Climate One. We're talking about painting the sky and reflecting heat back into the atmosphere to cool the earth. I'm Greg Dalton.

We've been talking a lot about the sky, Ken Caldeira, let's talk briefly about the oceans. There's a lot going on in the oceans. It's absorbing a lot of the carbon pollution and there are some discussions about tinkering with the oceans too as a way to buy some time or address climate change. So what's going on there?

Ken Caldeira: Well, there are a number of things that people suggested doing with the oceans. One is this idea of fertilizing the ocean to have it drawn in more carbon. Another idea is to put big pipes in the ocean to mix cold water up to the surface and cool the earth that way. Or people, as far back as 1965, have suggested putting white particles on top of the ocean to send more sunlight back to space. And my own view is that none of these are particularly good ideas. I think they're worth investigating a little bit more, but none of them seemed particularly wise to me.

Greg Dalton: We're talking about painting the sky at Climate One. Let's go to our audience questions. Welcome.

Stanhope Gould: My name is Stanhope Gould. I was a member of that CBS News Team in 1971

that began a year-long series called Can the World be Saved? For all the good it did. My question is about timing. In the book Quest, it says that coal use worldwide is increasing because of poor people who are looking for the good life.

Lester Brown says the melting of glaciers and depletion of aquifers is the greatest threat to human food security in history. All of the scientists say that it's happening much faster than they thought. My question is, can anything be done with the people you're talking about? Can this be a factor?

Greg Dalton: Jane Long, you looked into the energy mix. Briefly tell us -- coal is cheap, it's available --

Jane Long: Yeah. So I mean I think that there is a lot of tools that have to be put on the table to solve this problem. I don't think it's going to be very easy to stop coal use and so we better start looking at something called carbon capture and storage, where when we burn that coal, you capture the CO2 and put it underground. And I don't think that those kinds of solutions are going to be forever solutions. I think we've got a transition period and we've got a long-term period, and we need to start looking at what that transition period is. How do we decarbonize quickly? Nuclear power is another example. I mean, nuclear power produces an awful lot of energy without carbon dioxide and we're turning off our nuclear power.

In California, we've lost 2,000 megawatts of nuclear power. We've lost about a third of our hydropower which was carbon-free. We've added 17,000 megawatts in the last ten years of solar power which only delivers about 8 megawatts or a thousand megawatts because the capacity factors for solar, it's only when the sun shines, so you only get about a third of it. And at the same time, we've added 30,000 megawatts of fossil energy through natural gas. We should be capturing the carbon dioxide from that and putting in old depleted oil reservoirs and getting it out of the atmosphere because we can't get away from it fast enough. So that we need to put the tools back on, more tools on the table, and the tools need to be tools that are about carbon, not about renewable energy, not about nuclear power, not about how you feel about it, it needs to be about carbon. Carbon needs to drive the energy system.

Greg Dalton: Ken Caldeira, I heard that question as a plea for hope like someone wants -- is there hope? Give me some hope. What's hopeful?

Ken Caldeira: I think the hopeful part is that it's within our technological capability to build an energy system that's consistent with environmental principles, and that it's not that expensive and it's not really that hard to do. Economists estimate it would cost a few percent of GDP which would be maybe a quarter of the military budget or 10% or 20% of the healthcare budget. So it's solving this problem is smaller than other things we're already engaged in and we can do it if we can develop the political will to do it.

Greg Dalton: We have the technology. The money can be there. Let's go to our next question in Climate One. Welcome.

Male Participant: Thank you. On the topic of geo-modification now, we have seen efforts of that earlier in terms of cloud seeding and so on and so forth, and that was driven primarily by commercial impulse, agriculture, so on and so forth. As we develop the technologies and research them, isn't it likely, given the governance issues and that the major roadblocks are such, that we'll see people attempting regional commercial applications first. I know many of our farmers in the California Central Valley would jump on any sort of geo-modification that could promise them additional rain now. And both given the pace of research and what we saw in cloud seeding, the tendency for charlatans or snake oil salesman to get involved in a business like that, is it likely that

any attempt at geoengineering will come from that angle first on a reasonable scale and either destroy the reputation of it, or that we will then have to try and get a handle on that regulatorily before we even have the option of addressing the real climate issue?

Greg Dalton: Who would like to tackle that, the idea of hucksters getting into geoengineering helping farmers? That's a --

Jane Long: I think it's possible. I think there's a lot of things that are -- futures that are possible. You were bringing up Lucy in the Sky with Diamonds, how about Imagine? So imagine that the world becomes a place where the enemy is climate change and the military is out there fighting the enemy. I mean, maybe that will happen too. I have no idea. But these are things we should guard against and I think you also have a speaker that you -- your question is predicated on something that is very far away from global geoengineering. So if you're going to try to seed for rain, which we do now all over the place, and people do it for different reasons. The reasons are changing. People tried to make rain because there's drought that people are also beginning to try to make rain out over the ocean, so that their land doesn't flood. Those are things that are beginning to happen. That's very different than a global modification, a global intervention in the climate.

Greg Dalton: Ken Caldeira, think about drones. Drones are technology. Technology often outpaces policy. You put together drones and people could do all sorts of things that couldn't be done before. Could that happen with geoengineering?

Ken Caldeira: I think the question raised by the questioner is a real one. I mean, we've seen this already with iron fertilization. You could imagine if you can cool the ocean surface that that could bring more cool moist air into California, and there could be a lot of incentive to do that. And I think this is why we need governmental involvement in this and that we should avoid having the private sector run with this without the proper governance.

Greg Dalton: Let's have our next question in Climate One. We're talking about painting the sky if you're just joining us.

Darryl Harris: Hi. My name is Darryl Harris and I specialize in energy scenarios. In fact, I had Jane in one of my workshops. I also lead the science and technology forums here at the cliff. But I want to pushback against some of the things I heard up there. One, this term "silver bullet." That to me is a very loose language. No one says we need such a thing. And I think the real silver bullet, as we all know, is a carbon tax. If you raise the carbon tax to $150 a ton, you will quickly take a lot of carbon out of the system. You will quickly generate the kind of economic change, the technological innovation that we need to do this. Most climate models forecast those kinds of temperature changes 50 to 100 years out. Fifty to a hundred years is a lot of time for technological change and energy efficiency in a lot of other areas. So I want to pushback against some of the scare tactics I'm hearing up there. We're not in an emergency; we don't need a silver bullet.

Greg Dalton: Who would like to tackle that? Ken Caldeira?

Ken Caldeira: Well, yeah, I think many of us here on the panel are in complete agreement and I don't think -- I think we all agree that an energy system transition towards a clean energy system is what we need. I'm not saying that we're ever going to need to deploy these kinds of things and there's a tail of distribution of how bad climate change might be. And in my central expectation, we're never going to need any of these kinds of global scale technologies and there's some chance off on the tail of a distribution and I think it's worth investigating. But I did an Op-Ed in the New York Times and I said even in terms of research dollars, at least 99 cents of every dollar should be going towards an energy system transition, and this should be a little minor component. In terms of

deployment, it's probably thousands of times more in energy system transition. And so I think we would be happy to be here talking about the need for energy system transition without even mentioning geoengineering.

Greg Dalton: Let's go to our next audience question at Climate One.

Wayne: Hi. My name is Wayne and I appreciate your comment, Jane. We're coming on tipping points here. The Arctic is really beginning to melt faster. Greenland is beginning to melt faster. The glaciers, the Pine Cone glacier is coming into the Amundson Sea, have been shown to be unstoppable. That's only four-feet of sea-level rise but others are all happening at the same time.

Greg Dalton: Tell us some good news.

Wayne: I don't have any good news, Greg. And part of what I'm so upset about with you, Ken, is, "Well, it could be a problem." Climate change is a long fat-tailed slope. Once we go up high, once we do some sort of tipping point and release the methane in the permafrost, there is a very slow long line. It could last tens of thousands of years and we have very little time to get off of carbon before there will be no hope.

Greg Dalton: Thanks. So we've heard here that you are alarmist and that you're too sanguine so let's --

Ken Caldeira: I do work on coral reefs. I think there will -- if with business as usual emissions, there will be no sustainable coral reefs left on the planet within a few decades. We're doing a study now on that is concluding that if we continue in our business as usual scenario, we'll end up melting all of Antarctica - I'm pointing to Antarctica - and which would eventually, over thousands of years, many thousands of years lead to something like 200 feet of sea-level rise.

But I think that humans can live in a world with Chicken McNuggets and McBurgers, and this is not the kind of world we live in but it doesn't cause us to starve to death. And so I think this is a question about what kind of world we want to live in. I don't think climate change is really an existential threat for humans in the same way as it’s an existential threat for say coral reef ecosystems.

Greg Dalton: Let's go to our next audience question at Climate One. Welcome.

Male Participant: I'm curious. Are these radical schemes being funded by the fossil fuel industry?

Jane Long: No.

Greg Dalton: Albert Lin?

Albert Lin: I don't have anything to add to that except to say that there is a concern that they have an incentive to support these sorts of schemes or ultimately deployment. So yes, in terms of --

Greg Dalton: Because it allows them to continue business as usual.

Albert Lin: Continue business as usual and profits as usual.

Greg Dalton: Let's go to our next question here at Climate One. We're talking about painting the sky and reflecting heat back up into the atmosphere.

Elijah Brooks: My name is Elijah Brooks. In order to get my degree in electrical engineering, I had

to study thermodynamics. I've known about global warming since the early 70s. I do think it is an existential threat and I'm going to paint one scenario right now.

We have a runaway reaction with the release of methane. Methane happens to be flammable. There's enough of it that's released, there's some sort of ignition source, a fire starts. The fire then creates a runaway reaction, creating more methane release, and the next thing you know, we got a big problem on planet earth. Can anybody debunk that for me?

Greg Dalton: Explain big methane release. People are concerned about methane from tundra or under the sea. Ken Caldeira?

Ken Caldeira: Yeah. There's a substantial amount of methane --

Armand Neukermans: The permafrost is melting.

Ken Caldeira: -- a substantial amount of methane locked up in frozen soils in Siberia and Northern Canada and Alaska. And the concern is that, as the soil melts from global warming, it releases a potent greenhouse gas that could lead to further warming. And this is a risk. Most scientists think that most of the methane will get consumed by microbes and it will come out as CO2. But there is a very small chance that there'll be substantial methane release which would lead to a lot more warming. I think the -- actually, if the methane burned, that would be probably the best thing for the climate system because it has a lot more of a heating effect as a greenhouse gas in the atmosphere. And so this particular scenario isn't a concern. But again, I think most climate scientists think that this idea that lots of methane will come out is a very low probability event, and that's the kind of extremely low probability event that we might think about wanting to deploy these kinds of geoengineering options to address.

Greg Dalton: Next question, welcome.

Female Participant: My question is based on recognizing intent to be the primary reason for a social license. Are there other reasons we might need social license? Such as, what if the bad guys spray something else besides seawater? What if they cause flooding or steel rain?

Greg Dalton: Albert Lin?

Albert Lin: Well, we're not terribly well-equipped to deal with those sorts of situations. As you know, we don't have an international legal regime governing all sorts of activities. We generally govern things through nation states.

We don't have a very strong liability regime either. There's all sorts of issues regarding how do you even show causation? How do you trace the harm, the use of harm? What's the baseline? That is, what would have happened if a particular thing hadn't been deployed? So those are all sorts of difficult questions which I think would need to be wrestled with if you got to the point of some sort of global deployment.

Greg Dalton: We have to end it here. Ken Caldeira is a climate scientist at the Carnegie Institution for Science at the Department of Global Ecology at Stanford. Also with us today at Climate One, Albert Lin, professor of law at U.C. Davis, studies the governance of geoengineering; Jane Long a co-chair of the Task Force on Geoengineering at the Bipartisan Policy Center; and Armand Neukermans, a physicist and inventor. I'm Greg Dalton. You can listen to a podcast of this and other Climate One programs at our website climateone.org.

I'd like to thank our audience here at the Commonwealth Club, listening online and on air, thank you

all for coming.

[Applause]