

Geo-Engineering Climate Solutions

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Announcer: This is Climate One, changing the conversation about energy, economy and the environment.

Oliver Morton: Putting particles into the upper atmosphere like a volcano.

Ken Caldeira: Reflect incoming sunlight back to space.

Oliver Morton: Stimulating plankton blooms in the southern oceans

Ken Caldeira: A sprayer that could whiten marine clouds

Announcer: Geo-engineering is moving from science fiction to serious consideration. But will it be the silver bullet for avoiding runaway climate change?

Jane Long: If you keep emitting, you can't keep up with it with any of these technologies. The only thing is this might take the edge off for a while while we finish this energy transition that we have to make.

Announcer: Because the risks of geo-engineering are not just technological.

Kim Stanley Robinson: People will do the thing they do with the idea that humanity could live on Mars or on some other planet -- they will take less seriously the responsibility to decarbonize fast.

Announcer: Engineering Climate Solutions. Up next on Climate One.

Announcer: Is geo-engineering a realistic solution for stabilizing the climate? Welcome to Climate One - changing the conversation about energy, economy and environment. Climate One conversations - with oil companies and environmentalists, Republicans and Democrats - are recorded before a live audience, and hosted by Greg Dalton.

I'm Devon Strolovitch. For decades, a small group of researchers in the United States and other countries have been tinkering with the idea of reversing climate change by spewing dust into the air. They say humans could simulate volcanic eruptions which are known to temporarily cool the earth as

temperatures around the world continue to rise. The idea of such geo-engineering has moved from science fiction to serious consideration. Over the next hour we'll hear about the scientific, moral, economic and technological dimensions of humans getting so hot they decide to break the glass and spray a huge fire extinguisher into the sky.

In the first part of the show, Greg Dalton is joined by three guests deeply involved in the geo-engineering debate. Ken Caldeira is a Climate Scientist at the Carnegie Institution for Science at Stanford University, and a foremost expert on geo-engineering. Oliver Morton is Briefings Editor at The Economist and author of *The Planet Remade: How Geoengineering Could Change the World*. Kim Stanley Robinson is an award-winning author of science fiction. His most recent novel, now out in paperback, is *New York 2140*, which tells the story of how the city and the residents of one building adapt when every street becomes a canal and every skyscraper an island.

Here's our conversation about engineering a global thermostat.

Greg Dalton: Oliver Morton, let's begin with a story: 1965, US President Lyndon Johnson receives what is one of the first time a US president receives a report on climate change. And rather than talking about reducing the source, Roger Revelle had a novel idea for addressing it. Tell us that story.

Oliver Morton: Well, yeah, this is - the reason that the story matter so much is because it shows you how attitudes to the climate in the right place for humans to be in the world can change quite strongly in quite short periods of time. So Revelle has done the work in the 1950s that has shown that carbon dioxide is, contrary to some previous expectations, building up in the atmosphere. And he knows that this is going to lead to a level of greenhouse warming and he puts this into the report to the president in 1965, it's a sort of - it's an appendix to this report and says what should we do about it. And in 1965, talking to Lyndon Baines Johnson, you do not say well we're going to radically change the whole nature of capitalism, you don't say we're going to do anything about people making oil in Texas. You say things like we could put lots of little reflective bubbles on the surface of the ocean and reflect back some of the sunlight. And at that time, the idea of a technological fix had not taken on the somewhat condescended to sense that it has today. The idea for technological fix did not seem in and of itself absurd. And it's quite extraordinary that just in 50 years the fact that that was the only thing that report said, now seems extraordinary to us. But maybe in 50 years after now people will say the degree to which people are unwilling the president able to talk about this form of geoengineering, not little balls on the ocean, but any form of geoengineering maybe that would also look strange.

Greg Dalton: There's another story a few years later, Edward Teller and some other scientists were exploring the impacts; obviously this is the height of the Cold War nuclear winter and how is that connected to the evolution of what is geo-engineering?

Oliver Morton: Well it's connected in an interestingly unexpected way. When people talk about nuclear power throughout the early part of the 20th century, they link it in their minds with power over climate. Because it seems like it's like ultimate godlike power and so the great British radiochemist [Frederick] Soddy, when he writes the first popular treatment of radioactivity in the early 20th century, talks about how it can destroy icecaps and make deserts bloom that's what nuclear energy does. Same thing happens straight after the second world war, Julian Huxley, Aldous Huxley's brother, talks about maybe melting the Arctic ice and making a new world for us all up in the Arctic and this is the power of the atom. But when people like Teller actually talk about using atomic weapons, atomic power to actually fight wars, oddly this story goes in reverse. And for many, many years people do not talk about the climate impacts of nuclear war. And now it seems again in retrospect blazingly obvious that if you set off huge fires over much of the surface of the earth, you

might do something to the climate. But there is sort of like studied – and I don't think deliberate, but definitely psychologically telling – refusal to engage with that. And so the idea of nuclear winter comes about much later than most people think. I mean, I've chosen to correct some fairly eminent historians on this that they all talk, “oh nuclear winter, that idea of the 60s and 70s.” No, it starts in the 1980s. It was an idea, it was a way of thinking about the world, a way of thinking about human power within the world that was very late to come to attention because there was a vested interest in thinking that in some ways nuclear world could, nuclear power could end the world without changing it.

Greg Dalton: Or that nuclear power war could be fought and winnable, that sort of thing. Ken Caldeira, let's have you explain what is geoengineering give us a brief explanation of – this is a very abstract concept; how do you describe it?

Ken Caldeira: There are two main categories of geoengineering. If we think about the global warming that humans are producing. It's primarily due to the fossil fuel CO₂ that we're adding to the atmosphere and this carbon dioxide in the atmosphere makes it more difficult for heat to escape to space. And so one approach which is relatively noncontroversial is to just remove some of the carbon dioxide that we're adding to the atmosphere. But if we think about what's heating the earth up to begin with, it's the sunlight hitting the earth and we're absorbing this solar radiation. And so another way to cool off the earth would be to reflect some of that incoming sunlight back to space. And this is precisely what volcanoes do and the earth is cooled after each of the large volcanoes that have occurred over the last 50 years or so. And so the other leading idea is basically to emulate what big volcanoes do, put material in the stratosphere to reflect sunlight. And there's a few other ideas as well, but they're all based on the same idea of reflecting sunlight back to space.

Greg Dalton: Kim Stanley Robinson, is that is comprehensive enough, the idea of either sucking carbon out of the sky or bouncing heat back toward the sun?

Kim Stanley Robinson: Well, I think that the common understanding of this term geoengineering has morphed fairly quickly to the notion that it would be a technological silver bullet. Where you could do one thing and solve the problem of us burning fossil fuels. So people immediately object to it as a kind of a moral hazard that if we think that we can get away with it that we won't decarbonize fast enough. And then also there's a certain resistance to the technocratic in general, of taking over of the not just world history, but even planetary ecosystems themselves by some poorly defined technological elite with a method and mind and so many things have gone wrong in the human interventions in this planet before that people distrust in on several levels. So it's getting attacked almost immediately for things that are not quite right or true. And yet there's reasons why these attacks have come about. For instance, people will say well, you put something up in the atmosphere and then we're gonna accidentally cause an ice age and there's not an understanding that like volcanic explosions that dust goes in the atmosphere, for five years it's cooler then it falls down to the ground. So in a way, this is kind of an experiment that we could run that has a natural terminus to it. So it's a little bit safer than other things that might be suggested. So yeah, it's gotten complicated. I always try to say well geoengineering if we change if we plant a lot of forests, if we give all the women on the planet their full legal rights, we've changed the climate of the earth in a radical way so that's geoengineering too. And this kind of blows the discussion apart and I'm not sure that's where we want to go tonight. But I think it's important to point out that we're talking about humanity's relationship to the biosphere and the planet as a complex system that we can't hack, that's not the right word, but we might be able to finesse it in ways that will keep us from causing a mass extinction event. So we need to talk about it, but it can quickly get scary in several different ways.

Oliver Morton: Yeah, I don't particularly like the “hack” metaphor. But I – one thing that you were

saying I can't emphasize enough. The idea that there is in some minds and I think in some the popular conception of geoengineering that it's necessarily an alternative to reducing fossil fuel emissions is pernicious and wrong. There's no iron law that says you have to have one or the other. You can quite easily imagine worlds where you have both and. [here is this idea of moral hazard, this idea that, if you insured against risk or in some other way immune to risk, you will be riskier. And it's clear that that moral hazard is a real thing in the world. You can look at the banking system and see an awful lot of moral hazard and the people will take risks if they think they'll get bailed out. But that doesn't apply only to geoengineering and it doesn't apply only to solar geoengineering. The biggest amount of moral hazard that I see in the geoengineering debate at the moment is actually with the carbon dioxide stuff. I was at the Paris Climate Conference and it was a very inspiring conference to be at. And it came away with the world actually having the system for talking about dealing with this problem, and with a set of ambitions of keeping warming well below 2 degrees which is, you know, a high level of ambition but with pledges on action that are grossly insufficient to that high level of ambition. And so what you're finding in the discussion about future emissions at the moment is an acceptance that in the second half of the 21st century and the first half of the 22nd century something, somewhere will be pulling carbon dioxide out of the atmosphere. Well, there's no real discussion about how that's going to be done. And that's where moral hazard gets really dangerous because you begin to say, well, always we can trade off emissions cuts now with more sucking out later, when you haven't really done the research in a way to find out how you might do that sucking out, whether what level of sucking out as possible. That's very tricky. So there's been a lot talk about moral hazard with the sunlight mechanisms. I think sunlight mechanisms from this point of view, not from all points of view are kind of safer because it would be a really big thing that you know there would be big political debate about to do that. At the moment, now that we've let emissions, now we've let negative emissions, carbon dioxide reduction into our thinking, but haven't stopped to work out how to actually do it I think that's the area where there's moral hazard at the moment.

Greg Dalton: Ken Caldeira, where is the status of testing today? Is there any testing going on today either openly or secretly at the US, at the Pentagon or anywhere else?

Ken Caldeira: For carbon dioxide removal there is testing. There is a pilot plant going on up in Canada right now and also of course planting forests and so on, is a form of carbon dioxide removal. For the sunlight reflecting techniques basically all the research is indoors at this point, mostly in computers.

Greg Dalton: And do you think it should go outdoors, do you think that there should be real-life outdoor testing of this technology?

Ken Caldeira: I think with appropriate safeguards and oversight by appropriate governmental bodies there should be outdoor experimentation, but I don't think just rogue individuals should go out and do like some stuff.

Greg Dalton: Oliver Morton.

Oliver Morton: There's a really interesting precedent which Ken was actually involved in. One of the more radical ideas about removing carbon dioxide from the atmosphere was the idea that you could do it by stimulating plankton blooms in the southern oceans. This is my idea that was brought about partly because this is my idea about how ice ages might start and probably has a certain amount, not a complete but a certain amount of validity in that area. And people tried doing it and so they went out in southern oceans and well instrumented scientific experiments, dumped a lot of iron in, saw what happened, and it is true that there was increased photosynthesis not to the extent that they expected, and various complications. But what's really heartening about this story is that people

took the issue seriously. There is an international agreement about what you can and can't dump in the ocean. The people responsible for that took the advice of Ken and other people and started thinking about how to change the regulations to understand and take account of the scientific needs. And the scientific community decided that they didn't think that this really look like a particular effective way of sucking down carbon dioxide, though it's not a settled question. There were some people who like it; some people dislike it very much. But what I find interesting about this is that it was a kind of scary, weird idea that was tested and that was discussed, and that it was found that there were existing international rules for providing some level of governance. And so I think that's something, and I hope you feel proud of it, but don't you think that's something of a success story?

Ken Caldeira: I think there was some overreaction there but overall it was largely a success.

Announcer: You're listening to a Climate One conversation about engineering climate solutions. Coming up, Greg Dalton asks whether geo-engineering is a last-ditch hail-mary, or a way to start stabilizing the climate now.

Oliver Morton: A time when the earth is already going through severe climate changes and geopolitical panic is exactly the wrong time to launch a large planet-changing sort of effort.

Announcer: That's up next, when Climate One continues.

Announcer: We continue now with Climate One. Greg Dalton is talking about geo-engineering with Ken Caldeira, a Climate Scientist at the Carnegie Institution for Science at Stanford University; Oliver Morton, author of *The Planet Remade: How Geoengineering Could Change the World*; and award-winning science fiction author Kim Stanley Robinson.

Here's your host, Greg Dalton.

Greg Dalton: Oliver Morton, you write about Greenfinger. There is a scientist at the University of California, San Diego that writes about billionaires buying spaceships, et cetera. David Victor?

Oliver Morton: Oh David Victor yes, no David is a very insightful analyst of the political economy of energy. And David's worked a bit on climate geoengineering and he dubbed the idea that he created - he didn't create the idea but he dubbed this idea Goldfinger. And the idea is that the thing about putting particles into the upper atmosphere like a volcano does is that you don't have to be all flashy and boomy and multi-megatony like a volcano to do that, you can do that with aircraft or with balloons maybe or something like that. And there's debate about how difficult it is, but it's not very difficult. And in an era when a man like Elon Musk can, you know, build a space fleet. The idea of building the capacity to alter the planet in a way in such a way just out of one person's capital is oddly plausible. I mean the idea that it's possible, the idea that the political reality of the world would allow someone to do this without, you know, without shutting them down, that is a little bit less plausible to my mind. And Bill Gates gets pulled into this because it's known the Bill Gates funds some geoengineering research with Ken and David's labs and a few other places. And so when you got a billionaire and you've got this idea that this is in an odd way cheap enough that a billionaire can do it. I remember hearing someone from Google once talking about a space mission. And he said, is this really expensive, or is this something that a guy like me could do?

Greg Dalton: Ken Caldeira

Ken Caldeira: To give an idea of the scale of effort. It's estimated that the amount of flights that it would take to maintain an aerosol layer small particle layer in the stratosphere enough to offset all the warming expected this century would be about 1/1000 the size of the commercial aviation industry. So be about the number of flights each year that occur by commercial aviation every six or

eight hours. So it's really a tiny economically, tiny cost to this.

Oliver Morton: And just might even be smaller than that because enough geoengineering to counteract everything, is a very high amount of geoengineering. Especially if you're talking about geoengineering in some way being floated in on top of emissions reductions. That's not, you know, you don't want to reproduce the effect of a large volcano it would, I mean if you're talking about realistic scenarios down that line. You're talking about something actually yet more tenuous than that, yet easier.

Greg Dalton: So it's doable and so something that sounds like a science fiction novel. Kim Stanley Robinson, we're sitting here talking about and like, oh billionaire could do it with a few planes, not that big a deal. Your thoughts on how something like science fiction is becoming closer and closer to simple possibility?

Kim Stanley Robinson: Well what we're telling is a science fiction story, a science fiction scenario and we're running several scenarios at once and they tend to get tangled. But the single person changing the world is a very old science fiction story, basically the rocket ship that you build in your backyard and go to the moon. So this is a really common kind of Horatio Alger story. But I think it will instantly get tangled with governance and will be something that the civilization at large can approve or disapprove can shoot down or whatever. There are problems with the geoengineering of just blocking sunlight in that if you keep on spewing out CO₂, a third to half of it ends up in the ocean. The ocean gets more acidic, if the ocean is more acidic it may lose the bottom of the food chain and then the rest of the food chain collapses also and that's a third of humanity's food. So we actually do need to decarbonize as well as these other things. And the solar geoengineering is a kind of an emergency science fiction story. What if the temperatures really began to spike? What if methane begins to get released to the atmosphere off of the ocean floor or the permafrost begins to melt such that the frozen carbon in the permafrost and methane begins to release fast and suddenly every year it's like 2 degrees hotter than the year before. And we are clearly reaching a moment of crossing one of those tipping points into a completely different planet, a jungle planet. At that point, then you say we need to put the dust in the air.

Oliver Morton: But that sort of scenario is the one that really concerned me. Because that's such a very common way of framing the story about geoengineering, that you hear the idea that it's like in case of emergency break glass sort of thing. And a time when the earth is already going through severe climate changes and geopolitical panic is exactly the wrong time to launch a large planet-changing sort of effort. And it's very prone to, you know, the theory of emergencies that you get in Carl Schmitt and a lot of other places that, you know, he who makes the emergency makes the rule. It fundamentally challenges ideas about democratic or quasi or pseudo-democratic governments in the climate system. It seems to me that it's much, much wiser to talk about introducing small amounts of geo-engineering at a time when the world is not completely freaked out than large amounts of the time when it is.

Kim Stanley Robinson: Sure, but this is a - wiser means perhaps less likely to happen. When everybody would agree to do something is I think when after you have say the first food crisis, planetary food crisis, something severe enough to shock people. Before that it will be intensely argued and there will never be enough agreement for the world community to do it and then you get the idea of the Rambo individual doing it on their own. If you run the scenarios there's never a good one for geo-engineering unless you start talking about let's re-forest all the places that have been deforested. The Pacific Northwest, the Amazon, you can capture a hundred gigatons of carbon by reforesting. Let's try out geoengineering once over the Arctic. Let's us stabilize population. Let's capture the carbon that we're burning when we burn fossil fuels. People are saying oh my God that would make energy twice as expensive as it is now as if that's a stopper. Energy is insanely cheap,

it's too cheap. So you make it twice as expensive and your bill for the month goes from \$10 to \$20 and it's really only the big industries that are being hurt by this.

Greg Dalton: Let's let Ken Caldeira get in here.

Ken Caldeira: The same climate models that project all these terrible outcomes for global warming universally predict that those climate outcomes will be much less worse with solar geoengineering, applied at some reasonable level. And if you thought that we were eventually someday going to need it, the scenario that Oliver lays out where it slowly ramped in, where we sort of tiptoe into it would be the most environmentally responsible way to do it. Unfortunately, the most environmentally responsible way is also the most politically difficult and the political reality is closer to what Stan was saying where in an emergency situation there are model projections that suggest that mammals will not be able to survive outdoors, in the tropics because they won't be able to evaporatively cool themselves. There is potential for widespread crop failure in the tropics due to heat stress on crops. And, so there is potential for widespread suffering and if that happens, the incentive - if there's a leader of a country whose people are starving and they think by injecting some particles in the stratosphere, they can feed their people and alleviate suffering, the political pressure to do that is going to be intense. And so, well I think Oliver's scenario would be the most environmentally responsible. I think Stan's scenario is the more plausible.

Greg Dalton: Oliver Morton.

Oliver Morton: It's by framing scenarios like this that we make things plausible and possible. And one thing that I object to about emergency framing is that it lets Ken and his colleagues off the hook because they are then able to study geoengineering saying "we don't really have to worry about responsible plausible politics because those are unlikely to happen. And if it's an emergency of course, we'll use something." I think that if you actually think that something is good and could reduce harm then you should be working on trying to reach and trying to reframe those politics from the get-go rather than saying, well we'll do this interesting scientific research - and it's fascinating scientific research, if I didn't think that I wouldn't have written a book about it. But you can't just so, but if you just do that and say, "Well the politics will only be the politics of the emergency and we can't have any say over that," then I think you're now to some extent ducking the issue.

Greg Dalton: And do you think that doing research also makes it more likely that once there's more money, more funding, more jobs, momentum that sort of researching something kind of puts it in motion to happening, Oliver Morton?

Oliver Morton: I think the people worry very much about technological lock-in. And at the same time governments put huge amounts of money into nuclear energy and you're seeing less and less about around the world. I don't think the argument that just because we research something it will necessarily happen. There are a lot of things, I mean, for instance, a lot of this work dates back to - has its like prehistory in debates about supersonic air transport in the 1960s and 70s. In the 1960's everyone thought that the obvious next step for passenger air transport was to have supersonic planes. And my government and the French government actually did something about this, so did the Russians. The Americans talked about it and talked about what would be the effect on the stratosphere, putting lots of little particles up there, that's why this is familiar. And decided and also thought about what will be the noise at ground level, it's like no that's not something we'll do. The idea that research necessarily leads to deployment; there are examples where it's the case because most things that end up deployed have been researched. But then a lot of examples where things have been researched and then quietly let go. And I'm - I don't think that there's any evidence that geoengineering is particularly pernicious in that respect.

Kim Stanley Robinson: I want to clarify that I like the idea of geoengineering because I think we're already doing it. And once we admit to it and begin to try to take control of it for good, we are in a more honest relationship with the planet. And I would agree that the best scenario would be to go ahead and try it out. And what's shocking about that is that trying it out is really the full thing. And that you put some dust in the atmosphere and see what happens to temperatures, and we know from volcanoes that really not that much experimentation is necessary; we know that it works at what it does. So and also I've seen the human terrain and the discussion in this civilization has changed so fast in the last 10 years that even now us talking is changing the perception of what geoengineering is and how acceptable it might be. Ten years ago we couldn't have had this conversation but the 10 hottest years that we have on record took place in this century. So global warming is happening and everybody knows it. The denialists are now just a fraction of the power that they had in the society 10 years ago. They're going to slink away from this and pretend they never said it, and we are going to be in a world of global warming. And geoengineering is going to be something that's talked about more and more and it may happen in the good scenario rather than the emergency where once you have a food crisis, everybody's going to be behaving with that level of craziness that won't be good for any human decision.

Greg Dalton: Although there is some recent evidence recently that the more the scientific evidence has consolidated around climate change, the more deniers and actually I'm not so sure that denial has been gone down as the scientific consensus has advanced. If you're just joining us, our guests today at Climate One, Kim Stanley Robinson, a science fiction author. Oliver Morton, Briefings Editor at The Economist and Ken Caldeira from the Carnegie Institution for Science at Stanford. I'm Greg Dalton. I'd like to ask each of you, when you think about geoengineering, Kim Stanley Robinson, what gives you fear?

Kim Stanley Robinson: That people will do the thing they maybe do with the idea that humanity could live on Mars or on some other planet. That they will take less seriously the responsibility to decarbonize fast.

Greg Dalton: Oliver Morton, what gives you fear when you think about the prospect for geoengineering?

Oliver Morton: Well, I think the biggest risks of entailed in relatively small-scale solar geoengineering of the sort we've been talking about. The big risks are geopolitical rather than geophysical in my mind. And what worries me about almost all geopolitical risks, is nuclear weapons. And I find it extraordinary that I read people say that geoengineering provides an unparalleled threat to human existence and it's something unlike anything else we've ever done. We build machines that can end civilization and set them loose in the oceans, I mean not uncontrolled obviously. But the idea of the geoengineering is a problem that's somehow vaster than the ability we have to start and end nuclear wars, it doesn't make sense to me. So, nuclear war is what worries me about geoengineering.

Greg Dalton: Ken Caldeira?

Ken Caldeira: I think my fear is that the same lack of thoughtful societal deliberation that we're applying to GMOs and healthcare and policy in many areas will also extend to the discussion of geoengineering. It seems that we've devolved into a period where tribalism trumps careful analysis of empirical evidence. And I think unless we can make political decisions based on sound information our society is in big trouble.

Greg Dalton: Oliver Morton, you write that planet-speak weakens the ties between the nature and humans and makes the planet as this abstract geophysical entity. And that talking about the planet,

distances the – that's a problem, talk about that.

Oliver Morton: Yes, I do say that. So not surprising I agree with it.

[Laughter]

On Wednesdays and Thursdays, on another day. Yes, the idea of the planet, that very powerful icon for the environmental movement of the planet floating in space, it's extremely powerful. But it's also strangely alienating because it takes us out of the environment that's nurturing us and that we are changing. And that has a – there's a lot of modernist thought, that's similar to this and it leads to this strange paradox to me that as we see, we feel ourselves divorcing from nature to some extent, living a more urban lifestyle, living with more high-tech food these sort of things living with high energy – we are in a strange hidden way becoming much more intimate with nature. Because there is a sense in the preindustrial age where you can make a sort of like reasonable distinction between the human and the natural. But when you think that, for instance, due to nitrogen artificial nitrogen in fertilizers 40% of the nitrogen atoms in your body come from a factory, that's the sort of thing that makes you realize there is a big intimate interconnection between what it is to be human and what it is to be part of the planet. That we kind of lose when we see the planet over there and us over here behind the moon looking at it and saying oh we have a duty to this poor little fragile planet. And that's not the way to think about it. We are inside it. One of the strongest images of the planet, the images of the planet that I keep coming back to the moment are the images that you get in the paintings of Turner where you can't see where the industry and where the weather and where the human activity begin and end, where your whole perspective is within the movements and the motions of this great engine.

Greg Dalton: Kim Stanley Robinson, let's turn to Hollywood popular culture. There's been a number of films, going back to *The Day After Tomorrow* about 10 years ago, which talked about the changing Arctic currents and kind of like Super Storm Sandy hitting New York. There's been others; Matt Damon seems to go to different planets all the time. *Snowpiercer* was a movie –

Oliver Morton: Never works out well for him though, don't you think?

Greg Dalton: Yeah, and *Snowpiercer* was a film about geoengineering gone wrong. Tell us about the portrayal in popular culture of these concepts.

Kim Stanley Robinson: Well, I've dealt with it myself and it's a difficult narrative problem because climate change is going to take place over decades or centuries. And so you want your narrative to take place over days or at most months. And indeed for me I can speak for myself and it happened with this movie *The Day After Tomorrow*. When they analyzed the Greenland ice core data they saw that the Younger Dryas, where we went from a warm and wet world into a cold dry world had had happened in about three years. And they postulated that perhaps the Gulf Stream had shut down because of freshwater on its surface and that this explained it, and all this scientific work and explanation of peculiar data gave us the idea of abrupt climate change. And then I had my story and so did *The Day After Tomorrow*. You can tell a story that takes place in three years and it's a frightening one, but it also allows you to get narrative traction on it. So and also telling the story of things going wrong is inherently more dramatic than the story of things going right and as a Utopian science fiction writer I've dealt with that one also. So there are several problems for the way that we tell stories to be able to engage with climate change.

Announcer: Greg Dalton has been talking about engineering a global thermostat with Ken Caldeira, a Climate Scientist at the Carnegie Institution for Science at Stanford University; Oliver Morton, author of *The Planet Remade: How Geoengineering Could Change the World*; and award-winning

science fiction author Kim Stanley Robinson. This is Climate One. Coming up, Greg welcomes a new panel of guests, and asks how more local concerns might influence the push for geo-engineered solutions.

Jane Long: 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 drive a need for a technology that really hasn't been invented.

Announcer: That's up next, when Climate One continues.

Announcer: You're listening to Climate One. Let's continue the conversation about geo-engineering as Greg Dalton now welcomes Albert Lin, a professor at the U.C. Davis School of Law who studies the governance of geoengineering research; Jane Long, co-chair of the Task Force on Geoengineering at the Bipartisan Policy Center in Washington, and former associate director for energy and environment at Lawrence Livermore National Lab; and Armand Neukermans, a physicist and inventor involved in geoengineering.

Here again is your host, Greg Dalton.

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 took a course in climate science 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: 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 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 small 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 after - ?

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: 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 they came out 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 that 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 very 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. 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 research is 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 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: 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 possibility that ultimately some of these activities could be undertaken privately without public say, without say by government over what goes on.

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 competent body. Whoever is going to fund it, that's something else, but you need the approval from who is competent 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. 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 gigatons 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 credit, 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 competent body."

Greg Dalton: 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.

Greg Dalton: 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. Jane Long, let's talk about some of the regional impacts. 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.?

Jane Long: 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 palpable and I think they will drive a need for a technology that really hasn't been invented. And there's no body of science 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: 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.

Greg Dalton: Albert Lin?

Albert Lin: I think we have to be careful about research. I'm not oppose 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.

Announcer: Greg Dalton has been talking about geo-engineering with U.C. Davis Law professor Alber Lin, who studies the governance of geoengineering research; Jane Long, co-chair of the Task Force on Geoengineering at the Bipartisan Policy Center in Washington; and Armand Neukermans, a physicist and inventor involved in geoengineering.

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[Applause]

Greg Dalton: Climate One is a special project of The Commonwealth Club of California. Kelli Pennington directs our audience engagement. Carlos Manuel and Tyler Reed are the producers. The audio engineer is Mark Kirschner. Anny Celsi and Devon Strolovitch edit the show The Commonwealth Club CEO is Dr. Gloria Duffy.

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