



21 OCT 2009: INTERVIEW

Geoengineering the Planet: The Possibilities and the Pitfalls

Interfering with the Earth's climate system to counteract global warming is a controversial concept. But in an interview with Yale Environment 360, climate scientist Ken Caldeira talks about why he believes the world needs to better understand which geoengineering schemes might work and which are fantasy — or worse.

Atmospheric scientist Ken Caldeira first became known for his groundbreaking work on ocean acidification, a phrase originally coined as a headline for one of his papers. Of late, however, Caldeira's research has led him into the controversial area of geoengineering — the large-scale, deliberate manipulation of the Earth's climate system.

Many scientists have shied away from the subject because they feel it is a wrongheaded and dangerous path to pursue. But Caldeira — who heads a research lab at the Carnegie Institution for Science's Department of Global Ecology at Stanford University — has not been so dismissive, in part because his climate modeling has demonstrated that some geoengineering schemes may indeed help reduce the risk of climate change. In fact, few scientists have thought harder about the moral, political, and environmental implications of geoengineering.



Ken Caldeira

Caldeira has become a focal point recently in the controversy surrounding the publication of Steven D. Levitt and Stephen J. Dubner's *SuperFreakonomics*, the follow-up to their previous best-seller, *Freakonomics*. A chapter of the book that deals with geoengineering and quoted Caldeira was circulated on the Internet prior to the book's publication and was widely criticized for its poor understanding of climate science and its cynical, contrarian perspective.

In an interview with *Yale Environment 360*, conducted by author Jeff Goodell, who is working on a book about geoengineering, Caldeira spoke about how his work was misrepresented in *SuperFreakonomics*, as well as the prospects — and pitfalls — of plans to engineer the planet's climate system. He views geoengineering as a last resort, one fraught with risks and unintended consequences. What if, for example, industrialized nations decide to inject heat-reflecting dust into the stratosphere and set off a climate reaction that causes drought and famine in India and China? For this and many other reasons, Caldeira argues that sharply reducing greenhouse gas emissions is by far the most prudent course.

Still, given the huge volume of carbon dioxide that humanity continues to pour into the atmosphere, Caldeira says it would be folly not to undertake research into geoengineering. With the prospect that the world could reach a level of dangerous warming this century, Caldeira maintains it's necessary to determine which projects — such as putting particles in the stratosphere to reflect sunlight into space — might work and which will not. He likens geoengineering schemes to seatbelts — a technology that

might reduce the chance of injury in case of a climate crash.

But, warned Caldeira, “Thinking of geoengineering as a substitute for emissions reduction is analogous to saying, ‘Now that I’ve got the seatbelts on, I can just take my hands off the wheel and turn around and talk to people in the back seat.’ It’s crazy.”

Yale Environment 360: I want to start with this little dust-up over *SuperFreakonomics*. In the book, you are quoted as saying, when it comes to global warming, “Carbon dioxide is not the right villain.” Is that accurate?

Ken Caldeira: That is not accurate. I don’t believe I said anything remotely like that because I believe that we should be outlawing the production of devices that emit carbon dioxide, and I don’t think we can solve this carbon climate problem unless we drastically reduce our carbon dioxide emissions very soon.

e360: They also write that you are convinced that human activity is responsible for “some” global warming. What does that mean?

Caldeira: I don’t think we can say with certainty whether we’re responsible for 90 percent of it or we might be responsible for 110 percent of it. But the vast majority of global warming, I believe, is due to human release of greenhouse gases to the atmosphere.

e360: Another thing that plays in to the same kind of sensibility is the idea that the doubling of CO₂ traps less than 2 percent of the outgoing radiation emitted by the Earth. When that’s phrased like that, it makes it sound like it’s not really much of a problem.

Caldeira: You should think of the whole global warming problem as a 1 percent problem, at least for doubling of CO₂. In absolute temperature Kelvin — scientists like to use the Kelvin scale — the current Earth temperature is around 288 degrees Kelvin, and a 3-degree warming on top of that is basically a one-percent additional warming. And so this whole issue of climate change, when viewed from an Earth-system perspective, is a story about 1 percents and 2 percents. Two percent might sound like a small number, but that’s the difference between a much hotter world, and the kind of world we’re accustomed to.

Listen to the full interview (29 min.)



e360: The authors also cite you as saying that a doubling of CO₂ yields a 70-percent increase in plant growth, suggesting it would be a boon to agricultural activity. It sounds like one of those old CO₂-is-good-for-you ads. Can you explain that?

Caldeira: Yes, first of all, there are two parts of that. One is the 70-percent increase in plant growth. And that came out of a paper that we produced, I believe, in 2005.

We took a model and emitted all of the carbon dioxide available in fossil fuel resources, and that model — which has a very low climate sensitivity, and what I would consider a hyperactive land biosphere — produced 9-degree Centigrade warming globally and 20 degrees around East Antarctica.

Now that’s 16 degrees Fahrenheit globally, and something like 36 degrees around Antarctica, which could be enough to threaten the ice sheet. For that study we knew that the land biosphere model was overactive and taking up too much CO₂, but we felt that was conservative to the hypothesis we were addressing, because if you had a biosphere that took up

less CO₂, it would only make the planet even warmer.

So we were showing, look, even if CO₂ fertilization is at the high end of anybody's imagination, we still produce rather frightening temperatures. But I do believe the basic sign is correct, that with more CO₂, plants can use water more efficiently, and even the IPCC [International Panel on Climate Change] says that agricultural productivity is expected to go up with global warming.

But that will not be distributed uniformly. It's thought that agricultural productivity will increase in the mid and high latitudes, where warmer weather will help the plants grow, but will decrease productivity in the poor equatorial nations where heat is already stressing crop yield.

e360: Overall, do you feel like your work has been accurately and fairly represented in this book?

Caldeira: The main misrepresentation is the quote that says that CO₂ is not "the right villain." Now, again, I don't use "villain" talk myself, but if you say what's the primary gas responsible for the planetary warming, I would say it's carbon dioxide.

Now, there's a tougher question when it comes to the other statements that are attributed to me. All of those other statements are based in fact and based on studies that either I have published or other scientists have published. And if we pull back to the case of the biosphere taking up 70 percent of CO₂ — well, yes, we have a published study that said that. It also presented results saying that we might warm up the planet enough to risk melting Antarctica ultimately. And so there is a selective use of quotes.

The casual reader can... come up with the misimpression of what I believe.

If you spend several hours talking to somebody and they take a half-dozen things and put it in a book, then it's going to be in the context and framing of arguments that the authors are trying to make. And so the actual statements attributed to me are based on fact, but the contexts and the framing of those issues are very different from the context and framing that I would put those same facts in...

So I think that the casual reader can... come up with a misimpression of what I believe and what I feel about things.

e360: Let's talk a little bit more broadly about geoengineering. I was struck by something one of the authors said on NPR the other day — that he got interested in geoengineering when he realized that the problem with global warming is not that there is too much carbon in the air; it's that it is too hot. Do you agree with that?

Caldeira: The reason it is too hot is that there is too much carbon dioxide in the air. Now the carbon dioxide itself, of course, has big negative implications for ocean acidification and ecosystems, including coral reefs. So there are direct CO₂ effects.

But I think if we had some magic thing that would reverse all effects of CO₂ perfectly, then you could say, "Well the problem is not CO₂." But nobody really expects that we are going to have some magic, perfect CO₂ nullifier. And it's clear to me that if we continue allowing greenhouse gas concentration to grow in the atmosphere, and try to engineer our climate to counteract those effects, that as the greenhouse gases accumulate, and our counteracting system grows ever larger and larger, that the risk of some kind of catastrophic failure of this offsetting — or the imperfections in this offsetting — would grow in time and the net result would be pretty

negative, I would imagine.

So, I do see CO₂ as the problem. I think to present it as if, “Well, it not’s really CO₂, but the effects of CO₂,” it’s like if you got shot by a bullet and you said, “Well, it wasn’t really the bullet that was the problem, it was just that I happened to have this hole through my body...”

e360: Right. Well, a lot of people think of geoengineering as a quick and cheap fix for global warming. Is it?

Caldeira: Let’s pretend for a moment that putting dust in the stratosphere is easy to do and works reasonably well. And let’s say the United States and England and the “Coalition of the Willing” decided to go ahead and deploy this system, and that China or India then went into a decade or two of deepdrought. Whether the system caused that drought or not, I think the Chinese or the Indians would rightly suspect that the reason they have this drought and ensuing famines might be due to this system that was put up by these other countries. And you could easily imagine that there would be a great amount of political tension, and possibly even leading to warfare. So I think just the political dimensions and the governance dimensions of these geoengineering options suggest that we would be very reluctant to deploy these things, even if we thought they worked more or less perfectly.

I look at geoengineering as something only to consider if our backs were really up against the wall.

Another example is that, in many climate model simulations, the area around Egypt tends to get wetter with global warming. And so what if you do this geoengineering scheme and it takes away water from countries that didn’t have water a few centuries ago? Are they are going to be happy you’re doing this? So I think just the political problems associated with perceived winners and losers are so great that a politician is not going to want to deal with these problems.

Then, of course, the system is *not* going to work perfectly. First of all, it’s not going to address the issues of ocean acidification. It’s not going to perfectly offset global warming, so you’ll have some residual effects. So, I look at these geoengineering options as something we would only want to consider if our backs were really up against the wall, and where all these environmental and political risks seem worth taking because the alternatives look so frightening.

e360: I know that some scientists have suggested that there should be some kind of taboo on geoengineering research. But I know that you’ve been outspoken in the need for a federally-funded geoengineering research program. Can you explain that?

Caldeira: Yes, I think we don’t know right now whether these kinds of approaches have the potential to reduce risk or not. In our climate models, the amount of climate change can be reduced by these kinds of approaches, but the climate models are an imperfect reflection of reality, and they don’t consider the kinds of political risks that I was mentioning before. And so I think we just have to say we don’t know whether these options can really reduce overall risk...

Let’s say geoengineering *doesn’t* work, and that it would add to risk. It seems to me it would be worth having a research program to demonstrate that beyond a reasonable doubt so we can all forget about this and move on.

On the other hand, if these options *do* have the potential to reduce risk, then it seems to me that we would like to have the option to reduce that risk should a time come where that would seem necessary. I kind of think

of these geoengineering options as seeing, “Well, can we invent some kind of seatbelts for our climate system?” We need to drive the climate system carefully, we need to greatly reduce emissions. But even if we’re driving carefully we still run the risk of getting into an accident. And seatbelts can potentially reduce the damage when we’re in an accident.

But the reason I’m concerned about geoengineering is because I am so concerned about greenhouse gas emissions, and so, again, I’m in favor of essentially making greenhouse gas-emitting devices illegal. But I don’t think we’re going to reduce emissions fast enough to make me feel that we’re not running some really grave risks. And so I think we need to develop options to diminish those risks.

I don’t think we’re going to reduce emissions fast enough that we’re not running some really grave risks.

And it’s not just geoengineering. I’m much in favor of a very broad-spectrum approach. I think one of the things we saw with the subprime mortgage crisis is that a few million people in the United States defaulted on their mortgages and we have a worldwide economic crisis. I think we have to assume that climate change damage will be a much bigger amplitude than a few million mortgage defaults.

If there’s some kind of climate crisis in Southeast Asia, is that going to amplify and shake the whole global economic system? This is the kind of thing that Jim Lovelock is afraid of, that you’ll have “economic migrants” resulting from climate change that will ultimately destabilize modern civilization.

And so I think we also need to be doing research in how do we make our society more robust, so that these local climate damages won’t turn into global problems. We need to be doing basic adaptation planning; we need to look at geoengineering options. But the main thing we need to do is work to eliminate carbon dioxide emissions.

But thinking of geoengineering as a substitute for emissions reduction is analogous to saying, “Now that I’ve got the seatbelts on, I can’t just take my hands off the wheel and turn around and talk to people in the back seat.” It’s crazy.

e360: Can you sketch briefly what a geoengineering research program might look like?

Caldeira: The first thing I would do is use the plural, and say “programs.” Because many different things are lumped into the same category of geoengineering, which I think there’s no real good reason to link together.

For example, people like [David Keith](#) and Klaus Lackner have been looking at capture of carbon dioxide from the air, which could then be isolated underground in underground storage reservoirs. And this is a kind of slow process that will likely be expensive and take many decades to make a real difference in atmosphere CO₂ concentrations. But it’s an important line of research that needs to be undertaken. But it won’t do any good in the event of an emergency. Maybe after an emergency when we realize we need to reduce greenhouse gas concentrations it would be useful.

But that’s very different from, say, putting sulfur dust in the stratosphere, which would reflect sunlight back to space, and cool the Earth, much as Mount Pinatubo did in 1991 and 1992. Again, I think there needs to be a research program on that, but I don’t see any reason to couple that with these carbon dioxide removal approaches.

So I think there at least needs to be two new programs — one looking at

what are the scalable, fast-acting things we could do in the event of an emergency. What could we do fast that would start the earth cooling within a couple of years if we really wanted to? And then I think we need another research program in saying how can we backpedal out of our high greenhouse gas concentrations. Are there any things we can do to get the greenhouse gases that we've already emitted into the atmosphere out of the atmosphere?

e360: Do you think it's inevitable that we're going to try to engineer the Earth's climate?

Caldeira: First of all, nobody can really see the future, and I'm not foolish enough to try to predict the future. But I think that there's a very decent likelihood that we might go down a slippery slope in this direction. For example, we've done some simulations recently looking at this idea of whitening clouds over the ocean. John Latham has proposed this... Now we

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did a very idealized simulation, but in our simulations, by cooling the ocean relative to the land, this brought in a cool sea breeze from the ocean to the land, and then the sea breeze brought with it water and increased rainfall over land. Now, in principle, this could be deployed regionally. You could imagine whitening the clouds off the Sahel or off the coast of Los Angeles, and bring cooler, wetter air either to West Africa or the southwestern United States. And if we have global warming, and there's some regional

manipulation that would start making the regional climate more comfortable and more agriculturally productive, I think it's going to be pretty hard to tell people, "No, no, you shouldn't do that. You should swelter in the sun."

And so I think that there are pathways that we might start regionally and slowly ramp up to something more global. I think that's a possibility.

The other possibility is a real emergency situation where there's a phase change in public opinion, [where] it becomes conventional wisdom that we can't tolerate this climate change any more, that we have to do something.

Whether that will ever happen or not, I don't know. If I had to wager, I would wager that we would never deploy any geoengineering system, and that we're more likely just to try our best to adapt to it.

But I think there's enough of a risk that it's worth investigating whether there are options to reduce risk and damage.

And the way I look at it is that we're talking here about people's lives, and I don't think we're going to deploy these systems to save polar bears. I think if they're going to be deployed, it's going to be to help people from dying of famines, or something dramatic like that. And I think that these techniques have a potential to save lives and reduce suffering, and we should explore whether that's true or not.

The idea that it would somehow be better to let people starve than to intervene in the climate system, we're presented with that option... It sounds like the moral high ground to say, "Oh, well, we should never interfere with the climate system." But we're obviously interfering with the climate system wholesale now, and it's possible that more intelligent interference could reduce the damage from the first interference. But it could make it worse. I don't think we know, which is why we need the

research program.

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COMMENTS

Many people are speaking and writing as if "geoengineering" can only mean using a method to reflect radiation away from or out of the planetary system to cool the planet, even Ken Caldeira in the first quotes of this article.

Later on, when Caldeira refers to the work of Keith, and Lackner, he indicates he is aware that "geoengineering" has a broader meaning.

And so I point this out, in the interest of furthering precise and meaningful discussion of the subject, one timely reason being that with Copenhagen approaching, more people are tuning into the climate debate than have ever done so before.

The discussion has evolved since Paul Crutzen first gave his blessing, if we could call it that, to bringing this debate out of the shadows, when he published his paper on stratospheric sulfur injection.

The way the recent (September 2009) Royal Society report ("Geoengineering the Climate") put it is this: "a very wide range of potential geoengineering methods has been proposed..." "there are rather few general statements about them that can be usefully made", hence, "it is therefore unhelpful to lump them all together".

That Royal Society report breaks geoengineering techniques down into two basic 'classes':

- 1) Carbon dioxide removal (CDR) techniques which remove CO2 from the atmosphere;
- 2) Solar Radiation Management (SRM) techniques that reflect a small percentage of the sun's light and heat back into space."

The SRM techniques suffer from the fact that because they leave CO2 accumulating in the atmosphere the oceans remain condemned to acidification. However, the CDR methods, because they are aimed at removing CO2 from the atmosphere, do not have this problem.

Except for the anticipated high cost, air capture of CO2 techniques are regarded by the Royal Society report as the most promising method of the CDR methods of geoengineering, and except for the anticipated long time frames involved, the best geoengineering method overall.

Jim Hansen wrote in 2007 ("Climate Change and Trace Gases"): "We conclude that a feasible strategy for planetary rescue almost surely requires a means of extracting GHGs [greenhouse gases] from the air."

Posted by David Lewis on 22 Oct 2009

Caldiera is an atmospheric physicist. He has no credentials in marine biology, so I fail to see how credence can be placed on his simplistic view of the role of CO2 in the world's oceans.

Posted by Judy Cross on 23 Oct 2009

It seems rather strange that Caldiera would make these statements. He did read the chapter more than once before it being published and had ample opportunity to correct anything that might be "not accurate".

Either he didn't read it, didn't find the quotes inaccurate or wanted inaccuracies to appear in the book.

As to his statements that some of the warming = 90-110 percent man-made; is this something that can be backed up with research that is repeatable? If not, why not say "some of the warming" is man-made, as the authors did?

Posted by Craig on 25 Oct 2009

Why would one place credence in Ken Caldeira's views on ocean acidification? Let's glance at his background.

Physicist/Environmental Scientist (Lawrence Livermore National Laboratory, 1995 to 2005) Research ocean carbon cycle, atmospheric CO₂, ocean/sea-ice physics, climate, and energy systems

Post-Doctoral Researcher (Lawrence Livermore National Laboratory; 1993 to 1995) Research the ocean carbon cycle, atmospheric CO₂ and climate

European Project on Ocean Acidification (EPOCA), Advisory board member (2008-present)

Intergovernmental Oceanographic Commission, representative at International Maritime Union negotiations (2008, 2009)

UK Royal Society ocean acidification report panel member (2007)

IPCC Special Report on CO₂ Capture and Storage, Oceans Chapter, Coordinating Lead Author (2005)

UNESCO International Oceanography Commission CO₂ Panel of Experts (2002-2004)

Publications (only a sample)

Matthews, D.L., L. Cao, and K. Caldeira. 2009. Sensitivity of ocean acidification to geoengineered climate stabilization. *Geophysical Research Letters*, 36, L10706, doi: 10.1029/2009GL037488/

Adams, EE, Caldeira, K, 2008. Ocean Storage Of CO₂, *Elements* 4 (5):319-324, DOI: 10.2113/gselements.4.5.319.

Cao, L; Caldeira, K, 2008. Atmospheric CO₂ stabilization and ocean acidification, *Geophysical Research Letters* 35 (19), DOI: 10.1029/2008GL035072.

There is too much to fit in a comment, but this is enough to show that if you wanted information on ocean acidification, Ken Caldeira would be a good source.

Posted by Lee Ellis on 30 Oct 2009

Judy Cross, you asked:

"As to his statements that some of the warming = 90-110 percent man-made; is this something that can be backed up with research that is repeatable? If not, why not say "some of the warming" is man-made, as the authors did?"

The most recent IPCC scientific conclusion in 2007 was that "warming of the climate system is unequivocal" and the "increase in global average temperatures since the mid 20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."

This is the conclusion of 4,000 scientists appointed by governments from virtually every country in the world, and the term "very likely" is defined in the scientific conclusion of this report as being 90 per cent probable.

Posted by Scott on 19 Nov 2009

Isn't it wonderful that people like Judy Cross and Craig (above) find it in their hearts to criticize the messenger rather than the message?

If you cannot competently respond to what someone is saying, why not just attack the speaker?

Judy and Craig, why don't you come up with some information to refute my statements? Why do you resort to ad hominem attack?

The deterioration of public discourse is a sad thing to witness.

Further, I love that Craig is so familiar with my reading habits that he knows what I have read "more than once".

If truth be known, I still have not to this date read the entire chapter of *SuperFreakonomics*. I read the beginning and then skipped down, searching for the statements attributed to me. As I have said many times before, I objected to the "right villain" line, but the other statements attributed to me are indeed based on things I said.

I have no responsibility to fact-check every bit of journalistic prose that comes in

over the transom. If someone wants a fact checker, they can do what the New Yorker does and hire a fact checker. I have no responsibility to provide those services to millionaires for free.

Posted by [Ken Caldeira](#) on 28 Nov 2009

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