

I'VE ADDED  
A MIRROR, A  
PARTICLE CANNON,  
SOME IRON FILINGS  
AND A VACUUM.  
I THINK I'VE GOT  
IT RIGHT THIS TIME!

TOLES

Excerpted from *The Madhouse Effect: How Climate Change Denial Is Threatening Our Planet, Destroying Our Politics, and Driving Us Crazy* by Michael E. Mann and Tom Toles. Reprinted by arrangement with Columbia University Press. Copyright 2016 Michael E. Mann and Tom Toles. <http://amzn.to/29W2N7d>

## **GEOENGINEERING, OR “WHAT COULD POSSIBLY GO WRONG?”**

There was an old lady who swallowed a fly,  
I don't know why she swallowed the fly,  
Perhaps she'll die!

There was an old lady who swallowed a spider,  
That wriggled and wiggled and tiggled inside her;  
She swallowed the spider to catch the fly,  
I don't know why she swallowed the fly,  
Perhaps she'll die!

There was an old lady who swallowed a bird;  
How absurd to swallow a bird.  
She swallowed the bird to catch the spider,

...

There was an old lady who swallowed a cow,  
I don't know how she swallowed a cow;  
She swallowed the cow to catch the goat,  
She swallowed the goat to catch the dog,  
She swallowed the dog to catch the cat,

She swallowed the cat to catch the bird,  
She swallowed the bird to catch the spider,  
That wriggled and wiggled and tiggled inside her;  
She swallowed the spider to catch the fly,  
I don't know why she swallowed the fly,  
Perhaps she'll die!

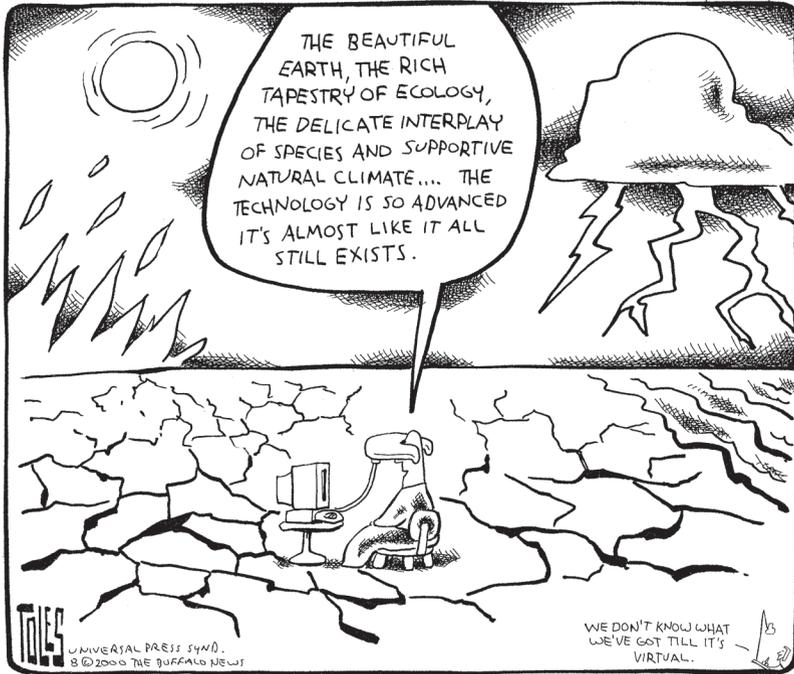
There was an old lady who swallowed a horse . . .  
She's dead, of course!

Many of us grew up listening to and singing this song. As it turns out, the song is a perfect parable for the risks of *geoengineering*. In the old lady's case, the "solution" proves far more dangerous than the initial malady. Thus it potentially is with many of the technofix schemes proposed as purported solutions to the problem of human-caused climate change.

### Searching for a Breakthrough

Many of those who advocate against taking action when it comes to dealing with the underlying problem—our ongoing burning of fossil fuels—have instead turned to possible technosolutions for counteracting climate change that involve other massive interventions in the Earth system: *geoengineering*. In some ways, for the free-market fundamentalist, *geoengineering* is a logical way out because it reflects an extension of faith that the free market and technological innovation can solve any problem we create, without the need for regulation.

Unsurprisingly, even many rather level-headed captains of industry, such as Bill Gates, have embraced the concept along with techno-Pollyannas, such as Bjorn Lomborg and the Breakthrough Institute.<sup>1</sup> Price on carbon? Nah, the market doesn't need it. Renewable energy? It's a pipe dream. Massively interfering with the Earth system in the



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hope that we might get lucky and offset global warming? Yeah, that's the ticket!

It could very well be that we find ourselves in a situation where a stopgap measure is needed, where dangerous climate change is upon us and even worse impacts appear unavoidable, regardless of our best efforts to lower emissions. But every bit as likely—arguably more so—is that the prospect of geoengineering merely provides a crutch for critics of restraints on carbon emissions. Hey, climate, there's a simple remedy for what ails you, a sort of climate change methadone. No need to kick that carbon addiction after all. But as it turns out, that simple remedy ain't so simple. Seemingly the stuff of science fiction, many of the schemes that have been proposed—placing mirrors in space to reflect sunlight away from Earth,

shooting reflective particles into the atmosphere to reduce the amount of incoming sunlight, “iron seeding” the oceans to get them to take up more CO<sub>2</sub> from the atmosphere, and quite literally sucking the CO<sub>2</sub> out of the atmosphere—come with potentially dangerous side effects. Such massive manipulations of the Earth system evoke the principle of unintended consequences. What, after all, could possibly go wrong? Well, a great deal, as it turns out. We could very well end up even worse off than if we hadn’t engaged in these additional uncontrolled experiments with laboratory Earth.<sup>2</sup>

### Mirrors . . . in . . . Space

One proposed geoengineering scheme involves placing a huge number of small mirrors in space to reflect some of the incoming sunlight back out to space—a planetary-scale “sunshade,” if you will. If enough of these mirrors were placed above Earth’s surface, they could reduce the incoming heating from the sun enough to offset the overall warming of Earth due to human-produced greenhouse gases.

If this idea sounds a bit like something from *Star Wars* to you, then you might not be surprised to learn that Cold War hawks such as Edward Teller, a major force behind President Ronald Reagan’s proposed Strategic Defense Initiative (“Star Wars”), was a proponent of this geoengineering scheme.<sup>3</sup>

Sounds simple, right? Well, not really. The typical scheme involves placing many extremely thin individual mirrors, each less than 3 feet (1 meter) in diameter and weighing less than 0.035 ounce (1 gram), at a gravitationally stable location along the axis of Earth’s orbit around the sun more than 620,000 miles (1 million kilometers) above Earth’s surface. Trillions of these mirrors would be required to achieve the necessary cooling effect, and the logistics and expense of getting that many mirrors to a position that many miles above Earth are obviously prohibitive. By some estimates, it could cost as much as \$350 trillion.<sup>4</sup> That amount is well over an order of

magnitude larger than prevailing estimates of what it would cost to simply reduce our carbon emissions in the first place.

Even the primary advocate of this scheme, Roger Angel of the University of Arizona, while arguing that the approach may be needed as a last-ditch effort if we find ourselves barreling ahead toward a climate crisis, has conceded that “the sunshade is no substitute for developing renewable energy, the only permanent solution.”<sup>5</sup>

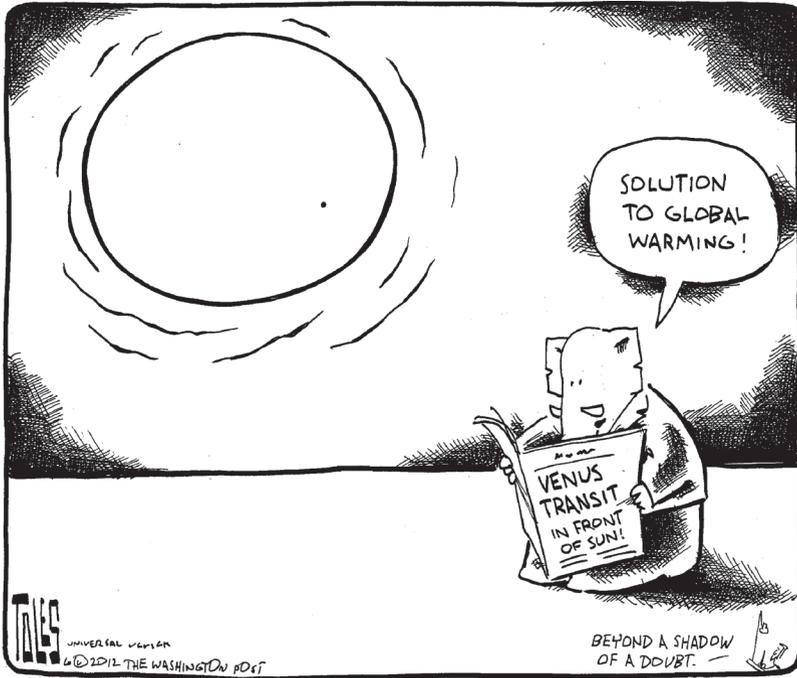
### Shooting Stuff into the Atmosphere

A related scheme involves shooting reflective particulates into the very stable upper part of the atmosphere, the stratosphere, where they can reside for several years. In principle, this process would mimic the way volcanic eruptions cool the planet. An explosive tropical volcanic eruption like that of Mount Pinatubo in 1991 puts enough reflective sulfate particulates into the stratosphere to cool the planet by about 1°F (0.6°C) for several years.

It turns out that it is quite feasible and not especially expensive to use large, specially built canons to shoot large amounts of these particulates into the stratosphere—as much as Pinatubo produced. If you do the calculations, you find that all it would take is a Pinatubo-size injection of particles every couple of years to offset the current warming effect of carbon emissions.

So, great, we’ve solved the feasibility and expense issues that proved so problematic with space mirrors. Problem solved, right? Not so quick.

It turns out that a number of problems emerge with this scheme.<sup>6</sup> One is pretty basic—if you implement this scheme, you don’t get back the climate you started with. The spatial pattern of cooling due to a volcanic eruption—or, more to the point, due to a sulfate-injection scheme that mimics a volcanic eruption—isn’t the mirror image of the pattern of greenhouse warming because the physics is different. In the case of a volcanic eruption, you are reducing the pattern of incident sunlight, whereas



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in the case of greenhouse warming, you are preventing the escape of heat energy from Earth's surface. Those effects vary differently with respect to latitude and altitude.

The globe may not warm upon implementation of this scheme, but that's a consequence of a global averaging, wherein some regions will warm even faster than they were before the injection and some regions will actually cool. You read that right. *Some* regions will end up warming even faster. We could conceivably end up, for example, warming the southern oceans more rapidly, furthering the destabilization of the West Antarctic Ice Sheet and, with it, the acceleration of global sea-level rise. We can't rule out that scenario.

It turns out that the continents tend to cool relative to the oceans in model simulations. That pattern would reduce the vigor of the hydrological

cycle over land. That's just a fancy way of saying that the continents would dry out. We might end up with worse droughts than if we had done nothing at all. So the question is: Do you feel lucky?

Meanwhile, those sulfate particles we're putting in the stratosphere have the potential to do some nasty things. As you may recall, it was the production of sulfate particles by industrial activity that created the acid rain problem in the 1960s and early 1970s before the passage of the Clean Air Act. The sulfate particles we are talking about in this case would be higher in the atmosphere (the stratosphere), above the region where raindrops form. But they ultimately would make it down into the lower atmosphere, into clouds and rainfall, and, finally, to the surface, where they would find their way into rivers and lakes.

OK, this solution would worsen the acid rain problem, but at least it won't worsen the other major global environmental problem of the past century, the hole in the ozone layer. Right? Wrong. It would worsen that problem, too. The sulfate particles would provide extra surface area for the ozone-depleting chemical reactions that take place in the stratosphere. Although the ozone layer has mostly recovered due to passage of the Montreal Protocol in the 1980s, there are still enough ozone-depleting Freon gases in the stratosphere that the extra kick they would get from the sulfates would likely continue the destruction of the protective layer.

And what about all that CO<sub>2</sub> that is continuing to accumulate in the atmosphere? Yes, we almost forgot about that. As with any "cover-up" solution to climate change that doesn't deal with the root cause of the problem, CO<sub>2</sub> would continue to build up not only in the atmosphere but in the oceans as well. The problem of ocean acidification—global warming's evil twin—would get continually worse. We would still have to say so long to the coral reefs.

That raises another issue. Assuming that we were to continue to burn fossil fuels, this "solution" would require us to continually shoot more and more sulfates into the stratosphere as CO<sub>2</sub> continues to accumulate in the atmosphere. It's a Faustian bargain if ever there was one. Most of that extra

CO<sub>2</sub> will remain in the atmosphere for thousands of years—CO<sub>2</sub> levels will be permanently elevated for all intents and purposes. What happens if there is a war, a plague, an asteroid collision, anything that might disrupt our technological infrastructure and interfere with our regular administering of sulfate injections? Within a matter of years, the reflective “cover” would disappear, and we would experience the full impact of decades’ worth of greenhouse warming in a matter of years. That would give the term *abrupt climate change* a whole new meaning.

One other thing, by the way: reflecting more sunlight out to space before it ever reaches the surface of Earth means less potential for solar power, less availability of alternative energy. Geoengineering in this case would make even more difficult the already tough challenge of weaning ourselves off the fossil fuels that are at the very root of the problem we are trying to solve.

### Dumping Stuff into the Ocean

If shooting stuff into the atmosphere turns out not to be the greatest idea, maybe dumping stuff into the ocean will work out better.

As it happens, one geoengineering scheme involves doing just that. The process is known as “iron fertilization” and is fairly straightforward. Over vast regions of the world’s oceans, the primary limiting nutrient in the upper ocean is iron. If more iron were available, there would be more algae or “phytoplankton,” which take up CO<sub>2</sub> when they photosynthesize. So by dumping modest amounts of iron dust into the ocean, we could potentially generate a *bloom* of phytoplankton activity, taking more CO<sub>2</sub> out of the atmosphere. As these phytoplankton continually die, they would, in principle, sink to the ocean bottom, where the carbon they gobbled up would be buried for the long term.

One of the seeming advantages of this approach is that it is solving the problem at its root cause, helping to take CO<sub>2</sub> out of the atmosphere. In principle, it also deals with the problem of ocean acidification. The idea

seems so encouraging that a number of companies—Planktos and Climos being the most prominent—emerged on the scene in the past decade to commercialize it. Planktos was even so bold as to sell carbon credits—for \$5, it would promise to take a ton of CO<sub>2</sub> out of the atmosphere, a seemingly cheap way for an individual, an organization, or a company to lower its effective carbon footprint.

Once again, though, the scheme hasn't quite delivered on its initial promise. Controlled field experiments have shown that iron fertilization at best leads to enhanced cycling of carbon in the upper ocean, with no apparent increase in deep carbon burial. Without deep burial, the removal of carbon from the atmosphere is only temporary. Even worse, some studies suggest that iron fertilization may actually favor harmful algae blooms, which are responsible for ocean dead zones and so-called red tides.

Without evidence of actual carbon burial, and with environmentalists and entire governments growingly increasingly concerned about rogue, uncontrolled, and potentially harmful iron-fertilization experiments being performed by companies such as Planktos, interest in the scheme has dried up.<sup>7</sup>

You might see a pattern emerging here.

### A Giant Sucking Machine!

Let's continue with this theme. Although iron fertilization hasn't quite panned out, a scheme that works by removing carbon directly from the atmosphere is appealing for a number of reasons. Are there other ways to do it?

Certainly. Trees do it, after all.

Trees (and other plants) take carbon out of the atmosphere as they photosynthesize; store it in their trunks, branches, and leaves; and bury it in their roots, in the leaf and branch litter that falls and gets deposited on the forest floor, and in the soil. But the trees aren't very efficient at

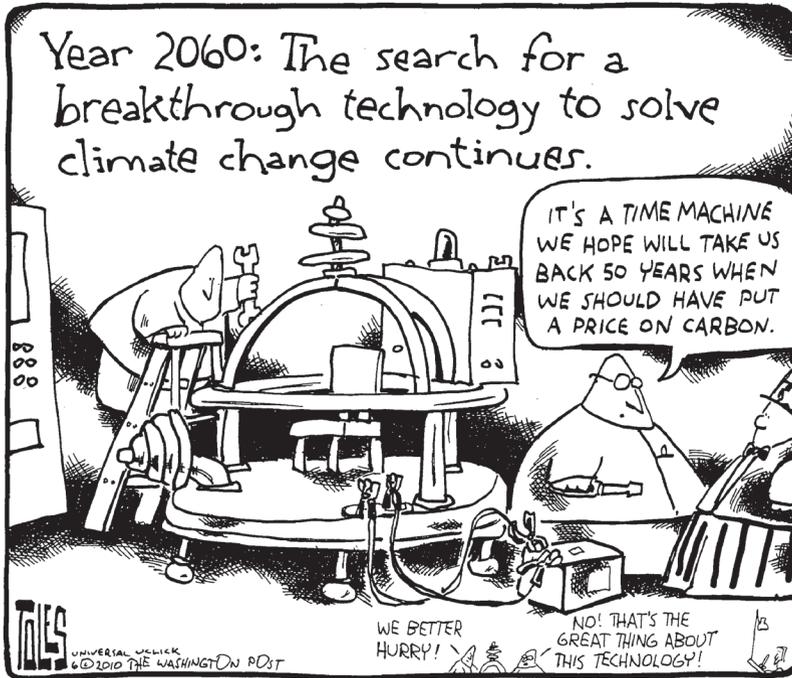
taking CO<sub>2</sub> out of the atmosphere. They, like us, respire CO<sub>2</sub>. And when they die and decompose, they give some of their carbon back to the atmosphere.

What if we could make the “perfect” tree (from a climate standpoint, that is)? A *synthetic* tree that takes CO<sub>2</sub> out of the air using chemical processes that are 1,000 times more efficient than photosynthesis in their carbon-removal ability. A tree that doesn’t give any of its carbon back to the atmosphere. Rather than dying and decomposing, it would turn the carbon into baking soda, which in principle can be buried for the long term. An array of 10 million of these trees distributed across the continents of the world could potentially serve as a “giant sucking machine,” taking up a significant chunk (at least 10 percent) of our current carbon emissions.<sup>8</sup>

But . . . wait for it . . . there are some complications. After all, it’s a lot harder to get the genie back in the bottle once you’ve let it out. In taking CO<sub>2</sub> out of the atmosphere, you’re fighting the laws of thermodynamics, and that’s a very expensive battle to wage. By some estimates, it would cost more than \$500 per ton of carbon removed (though the cost could in principle be brought down substantially with additional research and through economies of scale). That’s 100 times as much as what Planktos was charging for its scheme. The difference is that the artificial trees could actually work.

The prohibitive expense nonetheless means that at present it is *far easier and much less expensive to prevent the CO<sub>2</sub> from getting into the atmosphere in the first place*, whether by capturing and sequestering the carbon emitted from coal and natural gas power plants or, better yet, by getting our energy from renewable sources instead of from fossil fuels.

If, however, after doing everything possible to reduce our carbon emissions, we still find ourselves in need of a stop-gap scheme to avert catastrophic climate change, carbon-sucking artificial trees may be the safest and most efficacious of all the available geoengineering schemes out there.



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### What Could Possibly Go Wrong?

We have reviewed only some of the most prominent geoengineering schemes. There are other proposals, involving everything from painting rooftops white to seeding low clouds over the oceans. Certain things are common to nearly all of them.

With the possible exception of “direct air capture” (the technical term for the giant-sucking-machine scheme), each of the ideas comes with potential nasty surprises and the threat of unintended consequences. We could end up worse off than if we hadn’t implemented these schemes at all.

The schemes are also fraught with political and ethical complications. For one thing, who gets to set the global thermostat? For low-lying island nations such as Tuvalu, current CO<sub>2</sub> levels are already too high—the island’s inhabitants are threatened with the loss of their land and their rich cultural heritage by the several feet of sea-level rise that is already likely in train. While the industrial world debates whether we can still avoid “dangerous” warming of 3.6°F (2°C), dangerous warming is already here for many people on our planet. If they had their hands on the dial, they might want to set it at a lower temperature. Other nations might prefer it warmer. Who makes the decision?

One could easily imagine a whole new form of global conflict wherein rogue states employ geoengineering to control the climate for themselves. A climate model simulation might show, for example, that injecting sulfates into the stratosphere would relieve the drought that plagues a particular nation. Yet it would do so at the expense of causing a drought somewhere else. Perpetual conflict in the Middle East, it has been argued, has fundamentally always been about access to precious and scarce water resources.<sup>9</sup> Would geoengineering provide yet another weapon to be employed in this ongoing epic battle?

### A Path We Want to Go Down?

The fundamental problem of geoengineering solutions is the monumental danger of tinkering with a complex system that we don’t fully understand—Earth’s climate system and the delicate, complex web of ecosystems that it supports. A crudely applied speculative mechanical fix might make things worse, not better. It is simply impossible to know or game out all the unintended consequences of deploying an untested technology on such a massive scale.

Compare this scenario with an experimental new treatment for a disease. “What’s wrong with experimental medical treatments?” you ask. Well, consider the history of medicine. It is a history of many wrong turns and, unfortunately, many fatal results. Gains have accumulated over time,

but a lot of time is required to get a treatment right. And in the case of global warming, there is only one patient, planet Earth, and we can't afford a fatality. There are no opportunities for controlled, randomized trials. There can be no control group. You may be treating the malady with aspirin, or you may be treating it with thalidomide. The proposed cure could well be worse than the disease. Indeed, it could prove fatal.

Although the threat the planet is facing is huge in scale, its cause is profoundly simple: an unhealthy dose of carbon dioxide. The simplest and safest solution is to address the problem at its root cause.