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COVER STORY

Risky Gamble

Reducing emissions of greenhouse gases may be well intentioned and even helpful. But as the sole strategy for climate change control it is nevertheless inflexible, expensive, risky, and politically unrealistic, according to this government economist. Such a strategy could even make matters worse. Fortunately, there is a better solution.

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Solar radiation management could be a far more effective and economical climate policy

The environmental community has done a great planetary service by highlighting the need for worldwide climate change control. There has been remarkably little analysis of the specific problems posed by global warming, however, and of the best ways to respond to them. Instead, most advocates have endorsed a panacea that I will characterize as exclusive regulatory de-carbonization, or ERD. They argue that since greenhouse gases are the cause, the solution must be mandated cuts in emissions or possibly removal of gases already in the atmosphere. This is a well-meaning conclusion consistent with previous pollution control efforts. But while ERD can help, recent research shows that it would not be enough to solve the most serious problems posed by a rapidly warming world. Fortunately, there is an option that would solve most of these problems, more quickly, effectively, and efficiently, and without the need for alterations in lifestyle: solar radiation management, or SRM. The one problem that cannot be resolved through such an approach (detailed below) may well be beyond the capability of regulatory de-carbonization as well, so SRM may be our best hope of coping with a changing world.

By now it is well known that efforts to reduce emissions of GHGs in only a few countries — whether under the Kyoto Protocol, regional agreements, or national programs — cannot achieve the temperature limits the European Union believes are necessary to avoid dangerous changes to the environment. What is less well known is that these measures would be unlikely to do so even with the full cooperation of every person and every nation on the Earth. Considering the high levels of atmospheric GHGs and the as-yet unrealized warming from climate system lag, this disturbing conclusion is hard to escape. It is made worse by factoring in the drastic, immediate cuts that would be required; the unwillingness of people, and therefore politicians, to pay the costs and endure the requisite reductions in energy services; the strong economic incentives to continue increasing energy services; and the extreme difficulty of achieving and maintaining a precise heat balance for the Earth through what would amount to centralized world energy planning.

Even worse, pursuing regulatory de-carbonization as the only control strategy — whether through cap-and-trade, carbon taxes, efficiency standards, bio-fuel subsidies, or plain-old facility emissions limits — is likely to bring about the very effects that the environmental community has worked so hard to publicize, by diverting the world's attention and resources from more effective solutions. Both in financial terms and in lost opportunities, the cost of this single-minded approach is likely to be huge.

Our myopia in the global warming area is caused in part by a confusion of goals. Too often the end result of climate change control is expressed as reducing GHG emissions, even though this is merely a means. Thus the first task is to identify what the risks are and establish performance measures to evaluate proposed solutions. There appear to be three major problems to be solved:

PROBLEM 1. Gradually increasing world temperatures and the immediate effects on humans and ecosystems is the most well known risk. Some people (those living in colder climes) may welcome this. Others (those living in coastal areas) will probably be flooded out. Almost everyone will face adaptation costs.

PROBLEM 2. Dangerous, self-reinforcing climate change. This appears to be the most critical risk. The concerns most often mentioned are release of large quantities of methane (a potent GHG) from thawing permafrost or from under the ocean floor, melting of the Greenland and West Antarctic ice sheets, and a breakdown of the ocean currents that warm Western Europe. Any of these could cause a regional or global disaster.

PROBLEM 3. Non-temperature effects of increasing GHGs, particularly the effects of increasing carbon dioxide levels on the oceans. The resulting acidification is believed to be already affecting shellfish and coral reefs. This risk is the most difficult to solve.

Although most public discussion has addressed the first risk, the technical discussion has rightly centered on the second as the basis for setting de-carbonization goals, since the feared environmental changes could well be catastrophic and possibly irreversible. To this end, the EU has adopted a target of restricting global warming to less than a 2° Celsius (3-6° Fahrenheit) increase from pre-industrial levels to prevent "dangerous . . . interference with the climate system." This goal has also been implicitly adopted by many environmentalists and climatologists and the British, German, and Swedish governments.

Recent modeling work, however, suggests that the proposed implementation of this goal by all four of these jurisdictions would actually result in a near certainty of more than a 2°C increase if applied worldwide. Research published this year by James Hansen, head of NASA's Goddard Institute for Space Studies, and others supports the view that even smaller increases may be dangerous. Worse, a 2007 study by Nathan Rive

of the Center for International Climate and Environmental Research in Oslo can be used to show that Hansen's prediction of a 15-foot rise in sea level by 2100 because of disintegrating ice sheets cannot be avoided by achievable emissions reductions. This would mean that without mega-engineering projects to protect them, London, Miami, Mumbai, New York, Tokyo, Shanghai, and much of the Netherlands and Bangladesh, among other regions, would be under water by the end of this century, unless some other approach is used to control global temperatures. Al Gore has envisioned a 20-foot sea level rise and like Hansen advocates the use of ERD.

Even if Hansen's predictions should be wrong, the Rive study also shows that the world would need to reduce GHG emissions by 80 percent to obtain a mere 50 percent chance of preventing a 2°C increase. The marginal cost of abatement would be $3,500 per ton of carbon in this scenario, assuming average projections and early action. This is 10 or more times higher than most previous estimates. Naturally, most people would not want just a 50 percent chance of avoiding the risks posed by Problem 2. Given current GHG concentrations, however, a more acceptable 75 percent chance of avoiding such risks is probably unachievable. A 10-year delay would make even a 50 percent chance unachievable.

Another way of looking at this problem is the reduction in energy use needed to achieve even this modest risk reduction. Even when future economic growth is left out of the calculation, global energy efficiency per person would have to be increased by roughly 87 percent or human services provided by energy use reduced by 87 percent per person, or some combination of the two. (The reductions required to meet Hansen's concerns would be even larger, if they were achievable.) Energy efficiency can be increased, but only slowly and at considerable cost. It appears unlikely that all the reductions that would be needed could be implemented rapidly enough to meet the 2°C target using only energy efficiency measures, particularly inexpensive ones.

Alternatively, energy services could be cut, either voluntarily or by government mandate. This won't be easy. Stephen Pacala and Robert Socolow of Princeton's Carbon Mitigation Initiative propose to reduce per capita average vehicle-miles traveled from 10,000 annually to 5,000 through better urban design, mass transit, and telecommuting. But to entice drivers out of their vehicles for half their trips would require monumental social investments and individual subsidies; the more likely prospect is coercion. The even more drastic proposal for individual emission rationing reported to be under consideration in Great Britain is a logical extension of the ERD approach, but it is difficult to see how it would attract much support. While increased efficiency may eventually contribute significantly, the deep, almost immediate cuts in energy services required to stay below 2°C is politically unrealistic.

Avoiding Problem 2 is thus either impossible or very risky through ERD. The limited experience to date is that those jurisdictions with some of the most active programs (such as California and Britain) have been roughly holding their own in recent years. Given economic and population growth, this may be the most that can be achieved by regulatory de-carbonization through energy efficiency and reduced energy services. Even if more can be achieved in particular countries, it would not approach the 80 percent needed on a worldwide basis. Except under special circumstances, such as the collapse of Eastern European industry after 1989, most countries have experienced a gradual increase in emissions, and some are growing rapidly. Most countries have also been unwilling or unable to participate in emission cuts. More than governmental cooperation would be needed, but the idea that all the people of the world would cooperate to make something effective happen is unlikely.

ERD probably won't solve Problem 3, ocean acidification, either. Though it has received scant attention, the projected change in pH of the world's oceans may be the most constraining in terms of the degree of control required. One prominent scientist working in the field, Ken Caldeira of the Carnegie Institution of Washington's Department of Global Ecology, has stated that human-caused carbon dioxide emissions need to be reduced by 98 percent in order to save the world's coral reefs. The 80 percent global reductions believed necessary to have a 50 percent probability of meeting the 2°C target are already practically infeasible; a 98 percent cut would require that human-caused emissions return almost to pre-industrial levels.

A Notable Lack of Candor

Perhaps the most unfortunate aspect of the disjunct between the necessary and the possible is that many of the technical experts advocating ERD have not been forthright about explaining the needed sacrifices or the small chance of success to the public. A worrisome scenario is that politicians who impose significant reductions would be voted out of office and less stringent measures enacted to take their place.

A central problem with ERD is the fact that most of the world would have to drastically reduce GHG emissions if the 2°C temperature goal is to be met, not just a few countries. Reductions by only the major developed countries may decrease the growth in emissions but cannot meet this goal. So far the less developed world has shown little willingness to impose reductions, and is not likely to do so until their citizens demand it. That would require the same sort of concerted public information effort that has occurred in the United States, Europe, and Japan. The major existing measure to coordinate international reductions, the Kyoto Protocol, suffers from this problem and is furthermore unenforceable. It is unlikely to achieve even its modest goals. ERD supporters respond that if only the United States were to enact drastic reductions, the rest of the world would come along. Although there might be advantages in the United States' showing leadership, if the intent is to influence the behavior of the rest of the world, we would have more leverage before we enact stringent reductions because we could still bargain. Enacting them first would also put the United States at a competitive disadvantage in the likely event that not everyone enacts equivalent cuts.

In sufficiently wealthy countries where the change in energy costs may have a smaller impact on the public, it may be possible for politicians to persuade their constituents to accept some measures involving increased energy efficiency if they do not impose too large a burden or result in the loss of too many jobs, but in less developed countries, where prices of common forms of energy are often subsidized due to strong popular demand, even increases in prices due to using more energy efficient devices could easily prove politically unpalatable.

Proponents of GHG control argue that the cost would be just a few percent of GDP and that future growth will be many times the costs involved. Even if these broad generalizations were correct, those who will have to pay these costs, particularly if it is not a very broad cross-section of the population, will object strongly. They will see it as a tax rather than an investment in the future.

There are strong economic incentives not to reduce GHG emissions. These incentives could be changed by governmental action, but they are so fundamental that this will prove to be difficult. As illustrated by the problems many EU countries and Canada face in meeting their commitments under Kyoto, politicians would be required to maintain unusually strong resolve as the population learns what the real effects of the measures will be. Under current circumstances, politicians can argue that higher energy prices are a result of the operation of the laws of supply and demand. But if markedly higher prices or energy use restrictions were imposed for the purpose of reducing global warming, they would face a tougher situation.

It is difficult to see why politicians would be willing to force their constituents to adopt unpopular and expensive constraints on their activities, or why many constituents would not pursue every available loophole rather than reduce their welfare and freedom of choice. Grandmothers, for example, may not agree that trips to see their grandchildren on the opposite coast can be dispensed with or priced out of their reach. Global warming has all the psychological characteristics — a long time horizon, uncertainty, and no visible effects to remind people that there is a problem — needed to keep it at a modest level of priority, even with a huge public education campaign.

Another fundamental problem with ERD is that it has many of the characteristics of economic planning, such as picking technological and economic winners in advance rather than leaving this to the market. Governments would determine the allowable GHG emissions and seem anxious to dictate the precise means of doing so too. This is already happening, by attempts to legislate the percentage and even the type of renewable energy sources that must be used. Unfortunately, the history of economic planning has shown it to be very unsuccessful and inefficient because of political interference with economic decisions and the inability of governments to finely regulate economic activities they may not understand.

If Hansen's predictions are correct, major catastrophes that would make New Orleans look like a minor event can be expected if the energy balance of the Earth is not stabilized soon. As he points out,

events that would reasonably precede his predicted ice sheet disintegration are already happening. But global warming will continue until the energy balance of the Earth is actually stabilized, not when proposals by politicians say it should some time in the future. The balance needed is fairly precise since nature, unlike humanity, does not fudge.

The natural systems creating this balance are exceedingly complicated, constantly changing, not well understood, and need fine adjustments — all of which ERD-style world central energy planning is most unlikely to deliver in a timely way, particularly in a world of sovereign states requiring extended negotiations just to agree on what to do let alone actually doing something effective. The experience to date with the Kyoto Protocol suggests what can be expected from continued pursuit of ERD.

A Long Ignored Alternative

Fortunately, there is an alternative to relying on ERD, although it is almost never mentioned by environmentalists and not widely known, much less understood, by the public — solar radiation management, sometimes called stratospheric geoengineering or engineered climate selection. An extensive review of management strategies and currently available alternative technologies for global climate control gives the inescapable conclusion that SRM is the most effective and efficient first step toward solving most of the problems that ERD supporters are concerned about, quickly and easily.

SRM would control temperatures by reducing the radiation reaching the earth from the sun. This would be accomplished by adding particles to the stratosphere to scatter a small, carefully calculated portion of selected wavelengths of incoming sunlight back into space. These particles would naturally slowly drop out of the stratosphere, and would have to be replaced, making relatively rapid adjustments possible. This and similar approaches could be viewed much like any other aerospace project, would cost a fraction of the cost of ERD (roughly 2 to 10 cents per ton of carbon compensated for, not hundreds or thousands of dollars), would need no public involvement once a decision had been made to proceed, would not require the alteration of lifestyles or standards of living, and would provide the flexibility needed to rapidly respond to any warning signs of imminent danger — thus solving all of the problems except ocean acidification. SRM would also avoid the need for extensive economic and energy planning by leaving GHG emission decisions to the private sector, possibly using an institution patterned on the Federal Reserve Board or International Monetary Fund to make periodic adjustments to incoming solar radiation to achieve the desired global energy balance.

As pointed out by Paul Crutzen in 2006 and the National Academy of Sciences in 1992, we have a planet-wide proof of concept: when major volcanic eruptions occur, approximately once a decade, they shoot huge amounts of particles into the air, cooling the planet for several years. One of the best known examples was the explosion of Mt. Tambora in 1815, which caused the "year without a summer" in Europe. The sulfur-containing particles thrown out by eruptions are probably less than optimal. It appears reasonable to believe, however, that humans could improve on nature substantially by refining the type of particles used and minimizing other possible environmental side effects with a little research and development.

The reason that SRM cannot solve ocean acidification is that carbon dioxide levels would continue to rise. ERD would help in theory, but given the impossibility of meeting a 98 percent reduction worldwide to prevent the destruction of the world's coral reefs, it may not be a useful solution to this problem either. Fortunately, recent research illustrates that nature has worked out an efficient system for removing carbon dioxide from the seas: fertilizing ocean plankton to stimulate them to absorb carbon dioxide (much as plants do) and transport it to the sea floor. Humans have not yet figured out a very efficient way to emulate nature in this regard — seeding the ocean with iron particles has been suggested — but ocean fertilization may be the best current hope, whether under either the ERD or the SRM approach. Given the magnitude of the threat, research on and implementation of geoengineering or other solutions to ocean acidification also needs to become a top priority.

Some scientists have suggested a related strategy: using SRM immediately to bring down temperatures during the long period required to reduce GHG emissions, thus avoiding all the adaptation costs and risks of using regulatory de-carbonization alone, while helping the oceans a bit. This appears to be much more expensive than an SRM approach since extensive de-carbonization expenses would be incurred as well, but it would solve Problem 2, the one of most concern because of the possibility of catastrophic

effects, in the interim. And it is clearly safer than an ERD approach. Others have advocated using SRM as an insurance policy to back up de-carbonization. The problem with this is that very large adaptation and de-carbonization expenses would be incurred in the meantime. And the world may be totally unprepared to use SRM when an emergency arises unless decisionmaking processes for using it are actively developed and research and development is carried out to optimize the particles and minimize the environmental effects. This is unlikely to happen unless there are real plans to deploy SRM in the immediate future. Even though any nation with the technical and financial resources could implement such a solution on its own, it would be much better to use an international institution to make decisions on how and when such projects should be undertaken and maintained, given their global impact.

Numerous arguments against SRM have been made, such as the risk of unintended consequences. Certainly there is a need for research to better determine the other environmental effects of SRM. But although great care needs to be taken in pursuing SRM, it is not often recognized that ERD is also likely to engender unintended consequences, as it already has by encouraging the destruction of rain forest to increase the production of palm oil as a fuel, for example.

As author Jay Michaelson wrote almost ten years ago there exists an extensive inventory of other arguments for and against SRM, but the issue really turns on a metaphysical question. Even though most GHG control supporters believe that humans are causing major climate changes, they would rather let nature translate human actions in increasing or decreasing GHG emissions into the ultimate effects on climate. Advocates of SRM and other geoengineering approaches, on the other hand, argue that it would be better for humans to determine the desired climato-logical outcomes (such as lower average temperatures) directly and relatively precisely rather than letting nature, which has no incentive to help humans, sort out the net effects of GHG producing activities. More research could refine geoengineering solutions, but de-carbonization supporters generally oppose it, so there is currently no way to find out what the most refined solutions might be.

Humans have advanced as much as they have in no small part because they have used fossil fuel energy to provide services that once depended on animal and muscle power. The way forward is not to turn back the clock, but rather to search for and implement solutions to each of the problems posed by global climate change using the best engineering and scientific knowledge in the most effective and efficient manner. Unfortunately, the major effect of relying entirely on the hope of drastically reducing carbon emissions may well be to delay the time when effective action is taken to actually solve the three problems. Developing, testing, and deploying refined versions of SRM and determining its environmental effects needs to be a priority.

Any approach to climate change control needs to be able to handle all credible threats. It needs to be flexible, to rapidly adapt to new knowledge or events. It needs to be inexpensive enough to minimize damage to the economy but effective enough to protect us. Although regulatory de-carbonization can play a useful role, this is really a description of SRM or some combination of SRM and regulatory de-carbonization. Building, testing, and deploying a workable SRM capability is the best investment we can currently make to control climate change. Unfortunately, we are not taking this modest step and probably will not as long as we remain fixated on solutions that demand wholesale reform of the world's energy economy. •

The conclusions reported here are based on three technical papers: "Global Climate Change Control: Is there a Better Strategy than Reducing Greenhouse Gas Emissions?" University of Pennsylvania Law Review, June 2007; "Implementation & Utilization of Geoengineering for Global Climate Change Control," Sustainable Development Law and Policy, Winter 2007; and "New Research Suggests that Emissions Reductions May Be a Risky and Very Expensive Way to Avoid Dangerous Global Climate Changes," http://yosemite.epa.gov/EE/epa/eed.nsf/WPNumberNew/2007-07.