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Geoengineering: The radical ideas to combat global warming

Artificial clouds and creating colossal blooms of oceanic algae are among the ideas scientists say must now be considered

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Artificial clouds to reflect away sunlight, creating colossal blooms of oceanic algae and the global use of synthetic carbon-neutral transport fuels are just three of the climate transforming technologies in need of urgent investigation, according to leading scientists. The eminent group argue that, with governments failing to grasp the urgent need for measures to combat dangerous climate change, radical – and possibly dangerous – solutions must now be seriously considered.

The idea of engineering on a planetary scale in a bid to control climate has been around for more than 50 years but, to date, has remained on the fringes. The potential for dramatic and beneficial change has hitherto been outweighed by the risk of unexpected side-effects in the complex climate system, with global consequences. Now, in a special edition of the journal *Philosophical Transactions of the Royal Society*, climate scientists and engineers have brought together the latest research and issued a call for a far-reaching assessment of a raft of geoengineering techniques.

"We are now, or soon will be, confronting issues of whether, when and how to engineer a climate that is more to our liking," argues Ken Caldeira, a leading climate scientist based at the Carnegie Institution in Stanford, California. If a decision is made to move ahead with climate engineering, he says, then it will be essential to understand the point at which the risks and costs of geoengineering outweigh the impacts of global warming.

Not everyone is so unequivocally positive, however, including Stephen Schneider of Stanford University. In an overall assessment of the geoengineering challenge, he notes that critics ask whether it is socially feasible to expect the many centuries of international political stability and co-operation that would be needed to operate global scale schemes. He adds that the potential also exists for conflicts between nations if geoengineering projects go wrong.

Air

Some of the most extreme ideas for climate engineering involve reducing the sunlight falling on the Earth's surface, as a way to offset the increase in temperatures caused by greenhouse gas emissions. Caldeira calculates that reflecting just 2% of the Sun's light from the right places on Earth (mainly the Arctic) would be enough to counteract the warming effect from a doubling of carbon dioxide in the atmosphere.

One approach is to insert "scatterers" into the stratosphere. Caldeira cites an idea to deploy jumbo jets into the upper atmosphere and deposit clouds of tiny particles there, such as sulphur dioxide. Dispersing around 1m tonnes of sulphur dioxide per year across 10m square kilometres of the atmosphere would be enough to reflect away sufficient amounts of sunlight.

In a separate study, Stephen Salter of the University of Edinburgh proposes building 300-tonne ships that could spray micrometre-sized drops of seawater into the air under stratocumulus clouds. "The method is not intended to make new clouds. It will just make existing clouds whiter," he wrote. The ships would drag turbines in their wake, which would provide the power needed to spray the water.

Ocean

The growth of marine algae and other phytoplankton captures vast quantities of carbon dioxide from the atmosphere, but growth is often limited by a lack of essential nutrients. Adding such nutrients, such as iron or nitrates, to stimulate growth was studied by a team led by Richard Lampitt of the National Oceanography Centre in Southampton. The organisms incorporate atmospheric CO₂ as they grow and, when they die, sink to the bottom of the ocean, taking the carbon with them.

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Lampitt argues for a large-scale experiment of an area of ocean measuring 100km by 100km and monitored by an independent team of scientists. "Once this research has been carried out, it will be the responsibility of the science community to perform appropriate cost-benefit-risk analyses in order to inform policy."

However, there is at present a moratorium around the world on iron-seeding experiments. "The idea is unpopular with the public because it is perceived as meddling with nature," writes Victor Smetacek of the Alfred Wegener Institute in Germany and Wajih Naqvi of the National Institute of Oceanography in India. But they say rejecting seeding is premature as there have been no experiments to date that fully test the concept and the counter-arguments are based on worst-case scenarios.

Transport

More a fifth of the world's human-induced emissions of carbon dioxide come from transport. While technical fixes for these emissions might not count as geoengineering by the strictest definition, their global effect means they can be considered alongside other options to reduce the CO₂ in the atmosphere. In the long term, experts believe people should be driving electric or hydrogen-fueled cars but those technologies will take too long to arrive for Frank Zeman of Columbia University and David Keith of the University of Calgary.

They propose the development of synthetic fuels called carbon-neutral hydrocarbons (CNHC) as a near-term alternative to petrol and diesel. Made by reacting together carbon dioxide and hydrogen, these fuels can be used in cars without the need for major modification of either vehicles or infrastructure. More importantly, burning them would not contribute to global warming, provided the component ingredients have been manufactured in a carbon-neutral way. The CO₂ could come directly from the air, from plants or else from coal-fired power stations using carbon capture and storage technology (CCS). The latter method could also reduce the potential problems of the planned worldwide increase in the number of fossil-fuel power stations. The International Energy Agency predicts the world's use of power will increase by 50% by 2030, with 77% of that coming from fossil fuels; CCS holds the promise of preventing up to 90% of the carbon emissions from a power station escaping into the atmosphere.

Wild Card

Other ideas considered by scientists, though not in the papers published today, include scrubbing carbon dioxide directly from the atmosphere. Klaus Lackner of Columbia University has designed a machine that could, if built to full scale, take up the CO₂ emissions of 15,000 cars. With around 250,000 such machines, it would be possible to remove as much CO₂ from the atmosphere as the world is currently pumping into it. The gas could then be stored underground or used in a manufacturing process.

An idea further into the realms of the fantastic involves using shiny spacecraft to block sunlight. Scientists have suggested launching a constellation of free-flying craft that would sit between the Sun and Earth forming a cylindrical cloud around half the Earth's diameter and 10 times longer. "Approximately 10% of the sunlight passing through the 60,000 mile length of the cloud, pointing lengthwise between the Earth and the Sun would be diverted away from the Earth, which would uniformly reduce sunlight over the planet by approximately 2%," writes Stephen Schneider of Stanford University. The cost would be a dazzling \$100bn (£55.5bn) a year.

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