**Brighten Up! – The Case for Albedo Cooling**

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As the dust settles on COP27 it is worth taking a moment to reflect on more than three decades of international climate negotiations under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC).

From the outset, the UNFCCC has been focussed on reducing emissions ‘to prevent dangerous human interference with the climate system’, the ‘ultimate objective’ declared in its 1992 constitution. This policy is rooted in the conventional reductionist scientific method dating back to Bacon and Descartes. The logic is that greenhouse gas emissions cause global warming, therefore reducing emissions will reduce global warming, and enough emissions reductions will stop, or even reverse global warming. This logic does not recognise that new emissions are only a secondary cause of the dangerous consequences of climate change. It is the accumulating heat in the climate system that is the immediate cause of the changed weather patterns that deliver the floods, storms, droughts, heatwaves, sea level rise, wildfires and many other negative impacts that are being increasingly experienced. Significant emission reductions would slow or even reverse global warming, however, a question that the UNFCCC has yet to confront is whether its current policy of net zero emissions by 2050, is now likely to reduce the warming sufficiently quickly to prevent its feared dangerous consequences. The art of responding climate change is, much like the art of comedy, all in the timing.

In 1990, despite the relative lack of detail, the general nature of the threat from human greenhouse gas emissions was well-understood. Net zero or net-zero emissions were not mentioned. The most aggressive action proposed in the First Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) saw annual carbon dioxide (CO2) emissions reducing by 2050 to 50% of their 1985 level, a reduction of 10GtCO2. Now, rather than reducing annual emissions by 10GtCO2 over 60 years, net zero requires a reduction of 40GtCO2 in less than 30 years. That is an eightfold increase in effort; four times as much in half the time. Yet, as [Alok Sharma](https://www.gov.uk/government/speeches/cop26-presidents-speech-at-cop27-closing-plenary) recently observed, after 27 COPs there is still no international commitment to phase out fossil fuels, and as the data shows, since 1990 annual emissions have increased by almost 70%, and the [most recent data](https://essd.copernicus.org/articles/14/4811/2022/) shows they are still rising, albeit slightly less steeply. But, [the positive thinkers declare](https://www.wemeanbusinesscoalition.org/blog/corporate-climate-action-progress-at-cop27/), COP27 has seen a major leap in awareness in the for-profit sector concerning scale and urgency. This narrative maintains that investment is on the verge of exploding and once underway in earnest, net zero by 2050 will look much less daunting.

The climatic effect of net zero depends on two primary factors: how soon we get there; and how quickly the climate responds once we do. However, climate response is also critically dependent on [the largely ignored role of aerosols](https://www.nature.com/articles/d41586-022-03763-9). Reducing emissions will also reduce the aerosol pollution emitted with them. Aerosols have a cooling effect of about 1oC. Unfortunately, because the aerosols fall out of the atmosphere in days and weeks, in contrast to the decades and centuries for the cooling effect of less CO2 to take hold, significant reductions in the burning of fossil fuels will cause surface temperature to rise long before they begin to fall. This short-term increase would take warming towards 3oC, accelerating the prospect of triggering irreversible tipping points. Counterintuitively, emissions reductions would require the short-term release into the atmosphere of particulates to preserve the cooling from the lost aerosol pollution. That release is a form of Albedo Cooling (AC). Albedo is the technical term for reflectivity. Planetary albedo is a primary direct driver of temperature.

In the wake of COP27 it would be a form of reckless denial not to consider the possibility, many would now say the likelihood, that net zero will not be reached by mid-century, or that even it were, possible tipping points and the effect of the reduced aerosols will combine with inertia in the climate system to enable dangerous global warming. Might policymakers have become so fixated on a decarbonisation policy that has been overtaken by events, that they are unable to let it go in favour of one more suited to the new needs of the moment?

Central to this policy reappraisal is a recognition that to prevent the dangerous consequences of global warming it isn’t sufficient merely to stop the warming, it is also necessary to induce cooling. Net zero means that we lock in a temperature increase of 1.5o or 2oC, or perhaps more, that will subside only slowly over a century or so, if at all. This additional heat will continue to melt the polar ice caps, drive more frequent and severe weather events, and disrupt plant and animal habitats, intensifying the rapid rise in extinctions of the last century ([1](https://www.science.org/doi/abs/10.1126/science.aaa4984), [2](https://www.pnas.org/doi/10.1073/pnas.1704949114)), the increasing frequency of severe weather events and the advent of [other ecosystem tipping points](https://www.nature.com/articles/d41586-019-03595-0).

Recent research, from several independent teams, suggests a multi-decadal, even centennial, delay between net zero and the onset of cooling as the atmospheric burden of greenhouse gases slowly subsides ([3](https://www.nature.com/articles/s41467-020-17001-1), [4](https://bg.copernicus.org/articles/17/2987/2020/bg-17-2987-2020.pdf), [5](http://iopscience.iop.org/1748-9326/9/12/124002), [6](https://www.sciencedirect.com/science/article/pii/S221209632100108X), [7](https://www.hks.harvard.edu/publications/three-prongs-prudent-climate-policy)). In addition, the sheer scale of the effort required to deliver net zero is daunting. In 250 years, no legacy fuel was significantly reduced by new energy sources. We burn as much wood for fuel today as in 1800, even if it now represents a tiny proportion of total energy supply. All energy sources are at, or close to, their historical peaks. History suggests that the 80% of global energy that is still generated from fossil fuels will reduce only slowly. In this event, with emissions reducing gradually, net zero will require 40GtCO2 (40 thousand million tonnes), or more, to be removed from the atmosphere each year for several decades. This annual amount of CO2 weighs the same as 40 km3 of water, 8,000 Great Pyramids of Giza or 120,000 Empire State Buildings.

All the methods of removing greenhouse gases from the ambient atmosphere (GGR) involve resources such as land, water, minerals and energy. Although the demand for specific resources varies with different methods, at multi-gigatonne scale, the numbers are extraordinary. For example, assuming 100% efficiency, to remove 40GtCO2 by reacting it with silicate minerals to form limestone requires 200Gt of material to be processed each year. To put this in context, annual global coal production is about 8Gt, and concrete is 24Gt. While it would not be possible to rely on just one method of GGR to remove 40GtCO2, the many methods needed would require, in aggregate, vast amounts of a range of resources. There is no precedent in human history of a new industry growing to that scale in less than three or four decades. While it cannot be dismissed as impossible, it is beyond the capacity of normal market forces. Carbon credits and emission trading might enable significant reductions in emissions, but they are not conceptually capable of generating the net negative emissions that will be necessary to produce the cooling needed to stop the polar ice caps and glaciers melting and sea levels also rising from the thermal expansion of the oceans, among the many other harmful impacts of global warming.

Given the stakes, a prudent risk management approach to climate change now requires a Plan B. The objective of Plan B is the same as that for Plan A as articulated in the UNFCCC constitution, to cut the risk of global warming. The difference is in the nature of the intervention. Instead of acting indirectly by reducing emissions to reduce the growth rate of atmospheric greenhouse gases to allow more heat to escape to outer space to cool the planet, Plan B involves acting directly by cooling the planet by reflecting the the sun’s warming light out to space, increasing planetary albedo.

AC (often referred to as solar radiation management or modification (SRM)) was the only approach to climate change considered in an early study commissioned by President Johnson in 1965. Until recently, the most studied method of AC was stratospheric aerosol injection (SAI). SAI mimics volcanic eruptions by lofting sulphur compounds into the stratosphere. They are quickly dispersed and the particulates they form back-scatter a small amount of sunlight. The often referred to natural analogue is the eruption of Mount Pinatubo in 1991. This eruption reduced global mean surface temperature by about 0.5oC in less than a year, an effect that lasted for about 2 years. An even more spectacular example was the [eruption of Mount Tambora](https://www.wowshack.com/12-facts-1815-eruption-tambora-will-blow-mind/) in 1815 that caused a [year without summer](https://en.wikipedia.org/wiki/Year_Without_a_Summer).

In addition to SAI, more recently, a dozen or more different ways of increasing the earth’s albedo have been conceived, including fields of mirrors, marine cloud brightening, genetically modifying crops to be more reflective, refreezing the Arctic, and so on. None of these ideas has yet been tested outside of a laboratory other than at very small scale. However, the local cooling effect of the vast expanse of [greenhouses in southern Spain](https://www.youtube.com/watch?v=yX5xtfDT9A8) that have caused local cooling of 1oC has been observed although this was an unexpected side effect of agricultural innovation.

This is not the place for a detailed survey of these technologies, but researchers working in this field understand that each carries its own risks. However, if cooling the planet urgently is now a necessary response to avert the onset of irreversible effects of climate change, the time has come to assess whether the overall risk from climate change could be significantly reduced by one or more of the AC approaches. The acceptable risk threshold for AC might now be high and getting higher as it becomes more widely recognised that net zero can no longer prevent the dangerous near-term consequences of human induced climate change.

That said, net zero remains important and a new focus on AC should not diminish efforts to wean ourselves off fossil fuels. Moral hazard arguments that AC would give fossil fuel producers licence to continue their activities are ill-conceived. Moral hazard, properly understood, implies a choice between acceptable behaviours, some of which might be a bit riskier than others and where those creating the incremental risk are insulated from its potentially harmful effects. A decision to not do something that is essential to reduce serious risks to the wider community, in favour of doing something that increases that wider risk while serving the short-term interests of a privileged minority, is not properly described as moral hazard, it is recklessness, duplicity and selfishness on an epic scale.

Net zero will mostly benefit future generations: our grandchildren and their successors. If we have any sense of obligation towards them, net zero by mid-century is essential and is not to be traded off against other climate responses intended to deliver more immediate benefits. Those more immediate benefits are also essential, not just for the present generation but crucially to stabilise the climate so that the slower acting benefits from decarbonisation have an opportunity to take effect. There is no rational choice between decarbonising and AC, both are essential and urgent.

Apart from the science and engineering challenges of AC, it presents a set of even knottier geopolitical and socio-economic challenges. First, it is not possible to cool the planet globally without having effects across national boundaries. This requires international cooperation. Even regional cooling is likely to have cross-border impacts because the climate is a complex integrated global system where everything is interconnected and interdependent. Second, it is difficult to see how AC could be commoditised for exploitation by the for-profit sector. Third, the complexity of the climate system makes it difficult to isolate the climatic effects of any single intervention as a basis for incentivisation. These three features place the burden for promoting and funding research, development and the eventual deployment of AC firmly on the shoulders of state and supra-state actors. They might be motivated to begin such a process because initial indications are that most forms of AC will deliver significant climatic benefits at a fraction of the cost of emissions abatement and GGR. The big questions are not about how to do AC cost-effectively, but how to do it sufficiently safely and minimise risk of harm.

Technologies that deliver AC, like most other technologies, cannot be designed and made ready for full-scale deployment without extensive testing, initially at small and then at increasing scales, as the normal process of learning by doing allows risks to be identified, assessed, and mitigated. A reluctance to engage in that early research, including the field testing, is to guarantee the technologies are slowed down. The so-called slippery slope argument, that we shouldn’t start for fear of where it might lead, is an indulgence of imprudent caution given the urgency, lack of viable alternatives, and the existential nature of the threats we face.

There are many ways the international community could begin a concerted effort to investigate AC but all of these require them to listen to the scientists and engineers currently active in this field, so ending their screaming into a policy void. Government agencies concerned with climate policy must engage with their counterparts regionally and globally to create fora in which these ideas can be progressed and supported with the necessary funding. Probably half the $93 billion budgeted for the Artemis mission to the moon would be more than sufficient to put us on a secure path to deploying AC to rescue earth, and all who travel on her, from the ravages of climate change. It is little more than a simple question of priorities. The moon and Mars might be enticing, but it would seem smart to secure the base station first.

The absence of reflection on the importance of AC in the negotiating halls of COP27 is a major concern for those aware of the accelerating impacts of climate change and the now closed window of opportunity for these to be averted by a policy limited to decarbonisation. The one major step forward at COP27 was the acceptance of the need for a loss and damage fund, although we are a long way from that being operational. However, the viability of such a fund depends on the ravages of climate change not spiralling out of control. A little more focus on cooling would make the progress on loss and damage more meaningful.