Chapter 6

GEOENGINEERING AS A RESPONSE TO THE CLIMATE CRISIS: RIGHT ROAD OR DISASTROUS DIVERSION?

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> Man has lost the capacity to foresee and to forestall, he will end by destroying the world.
>
> — Albert Schweitzer[1]

Introduction

The 2015 Paris Agreement on climate was hailed as a successful breakthrough in the process of addressing anthropogenic climate change. However, the truth is that the agreement is hollow, anthropogenic climate change is accelerating dangerously and little real action is being taken, action of the kind and at the scale that would actually measure up to the threat. Instead, there is a desperate search for any kind of 'solution' that avoids having to reduce emissions and collectively tackling our deeply fossil-energy-dependent model of 'development'. In fact, the Paris agreement contains major loopholes and a central one of these is its tacit reliance on geoengineering. This involves basically two approaches: proposals for technologies to (a) reduce incoming solar radiation, that is: reduce the heating effect of the sun and (b) remove greenhouse gases from the atmosphere. However, the agreement fails to ask what are the risks involved in such approaches, and above all, who decides—and who has the mandate—to take those risks, which involve the whole planet

1 Rachel Carson dedicated *Silent Spring* to Albert Schweitzer with this quote from him. It is said to come from a letter he wrote to a beekeeper suffering losses due to pesticides.

and all of humanity, present and future. Can seeking to engineer the climate possibly ever be consistent with precaution?

Our key claim in this chapter will be that to gamble on geoengineering is precisely to *avoid* facing up to climate reality.

Where are we now after Paris (and Katowice)?[2]

Let us start by asking bluntly what it *means* to face climate reality, in relation to our topic in this chapter. What if mainstream assumptions around action on climate change actually embody tacit denial of its reality?

Consider the hard realities around the 'successful' Paris climate change accord:

- The Paris Agreement's targets are inadequate safely to address what the Agreement itself considers 'dangerous climate change', 1.5–2 degrees of overheat compared with preindustrial levels, because they give us at best a 66% chance of reaching those targets. (Imagine being asked to board a plane with a 66% chance of safely reaching its destination.)
- The Agreement has an inadequate definition of 'dangerous' climate change: for, as increasing extremes of weather underscore, it is clear that the climate change unleashed by human action is already dangerous, and we're not yet even at 1.5 degrees.
- Pledges from countries are entirely inadequate to reach the Paris targets—they head us instead toward probably 2.7–3.4 degrees of overheat (New Scientist staff and Press Association, 2016).
- There are in most cases no clear plans for how countries will reach those pledges, and virtually no plan is legally binding (Britain's Climate Change Act remains a rare exception; and its enforceability is arguable. Meanwhile, Britain is 'on schedule' to miss its climate targets without urgent action (Carrington, 2018)).
- Virtually all countries have economic, industrial, agricultural and transportation policies, plans and practices that directly *contradict* their stated aspirations to tackle man-made climate change.

2 See the article 'The Paris Climate Accords are starting to look like fantasy' (Wallace-Wells, 2018a). Moreover, 'progress' at Katowice seems to have gone into reverse.

- As implied above, and, crucially for this chapter, Paris's achievability rests additionally on 'Negative Emissions Technologies' (NETs), aka geoengineering (Anderson, 2016).[3]

We consider these points in detail below, especially in relation to the Precautionary Principle, but we start by making the following elementary observation: as yet, there is very little reason indeed to believe that (even if these NETs were acceptable philosophically or ethically) they will actually *work* even on their own terms (Wallace-Wells, 2018b; see also Proctor et al., 2018).

There is instead increasing reason to believe that they will not be economically or technologically viable, nor constitute worthwhile returns on energy invested (Radford, 2017). We are gambling the future of the human race on non-existent technologies which are quite likely not to work even on a best-case scenario. One might even, only slightly tongue in cheek, make the claim that 'Non-Existent Technologies' is a more accurate rendition of the 'NET' acronym…

- There is no enforcement mechanism for Paris.
- And, again crucially: in order to reach its inadequate and unenforceable targets, the Paris Agreement (Article 6) proposes the voluntary use of Internationally Transferred Mitigation Outcomes (ITMOs) that are meant to represent improved offsetting mechanisms (Rabinowitz, 2017). Article 6 point 4 of Paris mentions the establishment of a 'mechanism' 'to contribute to the mitigation of greenhouse gas emissions and support sustainable development' to be established by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). Once again, such a mechanism as this could serve to distract attention from the fundamental need to *reduce* emissions drastically and in a sustained manner.[4]

The conclusion one has to draw from all this is unattractive but unavoidable: the Paris targets will not be achieved. Within a generation or less, we will very probably be facing an *exponential* increase in climate disasters—with inexorably rising tides, and global temperatures heading up toward 3 or 4 degrees of global overheat, a level incompatible with civilisation or human

3 Some will claim that NETs are not geoengineering. We consider the use of the term NETs little more than a marketing rebrand to escape the justifiably negative connotations of 'geoengineering'.

4 Thus this clause might be dubbed the 'Hopeful Houdini' clause.

'development' as we know it (Spratt, 2010). Furthermore, a key reason why some scientists and Paris have somewhat arbitrarily picked 1.5–2 degrees as the maximum 'safe' limit of temperature increase is simply that, above this, we are *likely* to face escalating feedbacks, possibly leading to runaway climate change. These feedbacks are many, including albedo loss (less sunlight reflected back toward space due to dust and snow melt), the disastrous consequences of the die-off of the Amazon rainforest, and the accelerating release of the ultra-potent GHG methane into the atmosphere.

If Paris is as good as it gets, then the going is going to get very bad indeed. It is therefore important that the Intergovernmental Panel on Climate Change (IPCC) report published in October 2018 (Allen et al. 2018), makes it clear that there is a big difference between the impacts of 1.5 and 2 degrees and that we must urgently commit to 1.5 degrees and no higher. Even 1.5 means serious disruption of ecosystems and major challenges to which biodiversity generally and humanity in particular will have to adapt. And, especially given the recent failure of international will at the Katowice COP, to achieve 1.5 degrees is virtually inconceivable.

Why do we say that Katowice was a failure? It was the chance for the world to *embrace* the 1.5 degree target, and its eye-watering consequences—but this did not occur. To the contrary, that target was in effect rejected, as a result of the concerted action of the USA, Russia, Saudi Arabia and Kuwait.[5] There can be little starker proof that the world is not even going to aim at 1.5 degrees.

And this, of course, is a key reason why Green House is seeking to focus our collective attention on facing up to climate reality—on how bad that reality now is and is set to become.

The longer view—past and future

Let us put this into a longer context. The discovery and exploitation of fossil energy could turn out to be the greatest temptation in human history. The 'Industrial Revolution' that began in the 18th century marked the beginning of measurable human-induced climate change, perhaps our first really perceptible long-term mark on the planet. In its absence we just might have succeeded in living in balance with this planet's myriad other inhabitants and extraordinary, intricate and subtle systems. Instead we are moving swiftly towards

5 See https://www.middleeasteye.net/news/saudi-arabia-and-kuwait-bid-block-un-endorsement-global-warming-report-1251204896.

an almost-unprecedented extinction of species and we humans are seriously damaging and degrading most of the ecosystems on which our lives depend.

Shockingly, it is clear that, while we could still potentially avoid or at least mitigate some of the worst problems we face if we reduced emissions of GHGs now, in 2019, (a process which we should really have begun back in 1990), *we show no real signs of actually deciding to do so*. Instead we tend to turn to 'solutions' such as geoengineering, which (as we will sketch below) would likely add to our problems—as well as for the most part being heavily dependent on the large-scale use of still more fossil energy to develop and deploy.

Our line of thought in this chapter therefore issues in a radical suggestion: it's time to wake up and embrace a new *form* of development, most of the elements of which are already in operation somewhere on the planet, either in cultural memory or indigenous and local practice. This radically revisioned idea of development involves reducing our consumption of resources and embracing the idea that human development is not the same as economic growth, nor is it dependent on high energy consumption and fossil fuel dependent technologies. Such a shift could also help to address the injustice and inequality built into the current model of development that is destroying our companion species and all our habitats, and that could soon destroy us.

However, the likelihood of this sensible, truly radical path being taken in good time is slim indeed if we persist in considering geoengineering as a potential escape from our current plight. For this is the proposed *substitute*, in effect, for the kind of action that is actually needed.

What *is* geoengineering?

Geoengineering, according to the Convention on Biological Diversity which has discussed the topic at length, is:

> A deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts.

Fundamentally, geoengineering involves two basic ideas: 1. diminishing the amount of sunlight reaching the earth (Solar Radiation Management or SRM) by blocking the sun's rays or reflecting them back into space; or 2. removing greenhouse gases from the atmosphere by capturing and burying them in the sea, in the earth, in fast growing trees, in old coal mines and oil wells, etc.—and hoping they stay there—(Greenhouse Gas Removal or GGR—also called Carbon Dioxide Removal or CDR).

Proponents claim that, even if we were to stop emissions now, there is a huge amount of CO_2 already circulating in earth systems that will continue to push up temperatures for some years. Thus we need to block sunlight or remove greenhouse gases as well as cutting emissions of them.

We agree that there need to be some efforts at carbon-removal. Centrally, we need to restore wild biodiverse carbon-rich ecosystems.[6] Doing so would involve us in *reducing* our impact on ecosystems, and placing them in a position potentially to flourish, whatever we do—however well or badly our species fares—in future. But the kinds of interventions involved in geoengineering all involve us in *increasing* our would-be domination of the planet via a fantasised control of planetary systems.

This *is the respect in which geoengineering is fundamentally not precautionary.* (We will expand on this point further in the next section.)

Let us now examine the methods collected under the heading of 'geoengineering' in a little more detail. SRM techniques include measures to increase surface albedo—basically the whiter a surface is, the more sunlight it will reflect back into space. Ideas range from painting most roofs white (a harmless and probably helpful suggestion, but too small-scale to constitute engineering the climate), to spreading white plastic over deserts, to developing genetically modified or gene edited crops engineered to be greyer leaved and hairy, or even cutting down boreal forests so the snow can better reflect the sun's rays out into space.

There are also proposals to reflect sunlight back into space before it hits the planet. These include increasing the reflectivity of clouds by continuously spraying salt water into them as they form; inserting particles into the stratosphere on a continuous basis to mimic the effect of volcanic eruptions; or sending gigantic mirrors or sunshades into space to shade or to reflect sunlight away from the planet. Particle insertion and salt water spraying would have to be maintained on a continuous basis, as their cessation, especially suddenly, could lead to even worse impacts than not doing them at all; we'll return to this point below. Injecting particles into the stratosphere might have disastrous side effects, for example halting or disrupting the monsoon cycle, with impacts on millions of people, their food security and biodiversity in general.

GGR techniques involve capturing and sequestering greenhouse gases, using different techniques to take CO_2 directly from the atmosphere, for example through reforestation and afforestation, the former being the

6 See the 'Restoration' section of Read & Rughani (2017).

restoration of forests that have been lost, while afforestation is the mass planting of trees in areas where they have not grown in the recent past. Other proposals include capturing CO_2 in specially constructed 'trees', known as direct air capture. Captured CO_2 must then be stored where it is unlikely to leak out, for example in the strata of near-exhausted oil fields. This is familiar to oil companies as it is already used for squeezing the last oil from such reserves. This GGR approach is known as carbon capture and storage. It has been combined with the idea of growing vast plantations to become a proposal for bioenergy with carbon capture and storage or BECCS. This would involve growing huge numbers of trees and other crops that absorb CO_2 as they grow. These would then be cut, burned in power stations and the resulting CO_2 captured and buried in old oil wells and other geological strata, as well as being used in certain industrial applications or in greenhouses to accelerate plant growth. Indeed proposals for using the CO_2 captured are becoming an industry in themselves, called Carbon Capture and Utilisation and Storage (CCUS) (Bio-Based News, 2018). The use of BECCS was assumed to be essential by the IPCC's A5 report and could be included under the 'mechanism' in the Paris Agreement. However, the recent Special Report on Global Warming of 1.5°C from the IPCC (Allen et al, 2018) seems to reflect revised IPCC opinion. It is critical of BECCS, noting that it would require between 25–46% of arable and permanent crop land on the planet, while BECCS plus afforestation might require all of such land, leading to untenable trade-offs for example with food production. It would also require a large expenditure of energy to put in place, together with major inputs of fertiliser.

Another proposal for GGR geoengineering is enhanced weathering. This entails mining, crushing and spreading of silicate minerals, to be broken down into carbonates by wind and rain, pulling carbon dioxide from the atmosphere and storing it in the soil and eventually the oceans (Beerling et al, 2018). However, there are questions about how long it will remain stored and about the efficacy of its potential soil and ocean co-benefits. For the technique to make a significant contribution to global mitigation efforts, major—carbon-heavy—infrastructural development and energy use would be required to mine, crush and transport the rocks.[7]

Other GGR approaches also involve using the soil as a carbon sink; for example, adding huge amounts of 'biochar' (industrially-produced charcoal) to

7 There are further questions about the release of toxic substances with potential human health impacts, particularly if dunite, also known as olivinite, is used (Strefler et al., 2018). Thus basalt is the preferred option. However, to sequester 1 billion tons of CO_2, more than 3 billion tons of basalt would have to be spread: a mindboggling amount equal to almost half of the current global coal production.

soils. This has been discussed in detail over several years and its efficacy remains questionable, while its deployment at scale would again require large plantations and infrastructure (Paul, 2011). Other ideas include adding nutrients to the oceans to encourage plankton to bloom and then sink, carrying CO_2 with them for unknown periods of time—this is not necessarily a permanent sink.[8] Some have proposed intervening in various ways in ocean currents; or enhancing the upwelling and downwelling of water in different parts of the oceans. This last is meant to pump nutrients to the surface to encourage plankton growth, while the plankton and their CO_2 would then sink back down to the depths. Again these would be, or involve, major engineering projects and there is no real data on the long-term effectiveness of any of these approaches. Moreover (and this is a point we shall return to), it is hard to see how there *could* be, without an experiment of such a scale that it would be reckless to begin the experiment in the first place.

By contrast, restoring seagrass meadows and farming seaweed is a safer potentially nature-friendly process that should be investigated swiftly and scaled up (Greiner et al, 2010). Similarly, management-intensive rotational grazing, which mimics the way that flocks grazed before domestication, can increase soil carbon drastically (Machmuller et al, 2015). A key part of our positive claim in this chapter is that agroecological techniques such as these, which do not attempt to manage the climate as a whole through aggressive technological intervention, but rather to *reduce* our malign influence on it so that natural systems and patterns can re-establish themselves, are the alternative to geoengineering, one that should be pursued as the complement to radical emissions reduction.

Many of the geoengineering ideas listed above are based on multiple models and projections developed by many different interests. However, models cannot be relied on (Norman, 2015), since earth systems are complex and the climate is turbulent and involves many factors, many of them unknown, which make prediction notoriously difficult, even impossible. A small variation at a single point can lead to completely different outcomes—the so-called butterfly effect or 'sensitive dependence on initial conditions'. This means that there is really no possible way of reliably predicting the impacts of geoengineering.

We would also need to understand how different applications might interact with each other, since we are increasingly told that we would have to use several at once in order to prevent runaway climate change. It seems

8 Using the oceans as a CO_2 sink would inevitably promote ocean acidification, which makes it more difficult for marine organisms with shells or skeletons of calcium carbonate, such as corals, to form and may also dissolve existing shells or skeletons, with potentially disastrous consequences.

inconceivable that (the results of) this multiplicity could be understood in advance. This makes such applications necessarily highly risky.

Small scale tests, models and laboratory experiments cannot tell us what the impacts of geoengineering would be—only full deployment could do that. This is itself a powerful reason for thinking that geoengineering is fundamentally distinct even from other dangerous technologies. It cannot be tested precautionarily but only deployed—recklessly.

There are also serious issues of equity to be considered. Climate change itself tends to impact regions and populations of the global south more seriously while some of the proposed geoengineering techniques would also tend to do this, as could poorly thought-out adaptation approaches, leading to increased inequality. Even afforestation and reforestation could have serious negative consequences if they involve huge plantations of non-native trees, especially on so-called marginal land, or land used by local communities but to which their rights are not recognised by governments. This point is worth exploring further, because it brings out nicely the conceptual distinction crucial to this section between geoengineering on the one hand and large-scale but more bottom-up interventions designed to return the geosphere to a more natural and self-sustaining state, on the other.

*Geo*engineering means just that: the (ultra-hubristic) project of seeking to manage—to engineer, to plan and control top-down—the entire planet, the geosphere. Now, if what we do is grow vast (perhaps genetically-manipulated) forest-monocultures and then burn them and seek to sequester the carbon, that would certainly count as an example of geoengineering. And that is what is being planned; as outlined earlier, it is a little-known and terrifying fact that the Paris targets are premised on exactly that plan—terrifying, especially because there is very little reason indeed to suppose that the plan will work, even on its own terms (Rabinowitz and Simson, 2017). We are gambling our planetary survival on technologies, such as this one, that don't even yet exist.

But the right way to plant trees as a response to the climate threat is very different. It is to seek to restore natural wild ecosystems; to recreate forests that used to be there (albeit slightly tweaking what you seed, to reflect the likely coming temperature changes, etc.). This means our moving away from trying to control ecosystems towards working with them, collaborating with some elements (beneficial predators for example) to keep others such as pests in balance. We create a situation where we have to do less, not a situation where we have to seek to control ever more.

This is not seeking to manage—to engineer—the planet. It is *the opposite*—removing our interferences with natural systems, by taking out (for instance) artificially-created grazing land and returning that land to how it was before we got too big for our boots. It would mean reinforcing and recreating, rather than diminishing, the Amazon rainforest—and every other rainforest and major forest that we can.[9]

And this *is* the fundamental logic of precaution. The logic of the '*via negativa*'; move to doing less rather than always more; seek to de-fragilise systems; switch the burden of proof such that anyone wanting to do something radically new needs to provide evidence that what they propose is safe, rather than our having to provide evidence that what they propose is harmful. It is particularly vital that this burden-shifting is effected, so far as geoengineering is concerned; because, given that geoengineering can only meaningfully be done at the planetary level, there is a real danger that its advocates are going to claim that there is no evidence that what they propose to do is harmful—until they have *done* it, by which time it will be too late to call out their recklessness.

The philosophy of geoengineering and real politics

What are the consequences for real politics of projecting climate-engineering approaches? The moral hazard of deterring action to reduce emissions through constantly promising near-future technical fixes is very real and has to be addressed—see below for some detail on this. There is, in any case, nothing to guarantee that geoengineering will not exacerbate the increasing extremes we face: droughts, heat and floods, together with sea level rise and ocean acidification. In fact it is *likely* that if geoengineering is adopted then extremes will be increased in at least some areas, raising the deeply worrying prospect of competing geoengineering schemes being tried out by different parts of the globe, each of which will have negative effects on others (Nalam et al., 2018; Gass, 2013).

To generalise the point: it is highly risky to intervene in complex and dynamic climate systems we do not understand, and it is recklessly risky, if there is a real alternative path (as we are suggesting there is). Rather than fantasising that we can manage or control the entire future of our planet, of which we have made a particularly bad job in the last generation or two, we should accept living in a world that we can never 'fully' understand or predict—and find effective ways to *reduce* our impact upon that world. This is the logic of precaution.

9 E. O. Wilson has created a vision of how it could be done across half the planet in his book *Half-Earth* (Wilson, 2016).

The techno-science behind the current development of climate engineering is deeply flawed, based on assumptions and presumptions of certainty, whereas uncertainty is primary in real ('post-normal') science (Funtowicz and Ravetz, 1993). However, the sense that we will 'have to' deploy geoengineering is gradually hardening in the face of the collective failure to take real preventative action. This failure is of course hardly surprising, due to a particular failure to take action in the industrialised countries with most responsibility for climate forcing emissions. If these made a unilateral commitment to cut emissions swiftly, deeply and verifiably, this might well help to build trust in the international arena. Until this happens it is hard to see how real progress can be made.

We also have a dangerous arrogance about human capability, as our technical capacities increase—we can see (perhaps) how far we have come, even possibly how wrong we have often been, but not how far we still have to go to understand the systems we seek to modify. Geoengineering simply extends the hyper-'Promethean' logic that has got us into this fatal mess (Read, 2016).

The very idea of the 'Anthropocene', at least among its fervent fans,[10] seems to show this—the idea that we have moved from the inadvertent manipulation of earth systems to having the capacity to make deliberate interventions (which presumably means we think we know what we are doing). We might develop technology and seek to deploy it, without the capacity to predict or deal with impacts.

That is a pattern that has occurred before, as we will shortly explain.

The need for the Precautionary Principle

As the geoengineering debate shows, it seems likely that human technical capacity to intervene in complex systems will grow faster than our understanding of them, especially those systems that are inherently turbulent and unpredictable, such as Earth's climate system.

However, if that is the case, will our wisdom increase at a similar rate as we become more dependent upon technologies? As technologies become more powerful, does society have the means, tools and the will to make wise decisions about whether and how to use them, and (above all) how to control their development and deployment by corporate actors?

We need to find a way of examining emerging technologies to try to assess their potential for harm before they are fully developed or deployed. The

10 Such as Mark Lynas: see his book *The God Species* (Lynas, 2011).

Precautionary Principle provides an excellent overarching framework for this discussion.

The most widely-accepted definition of the Precautionary Principle (PP) in international law is that contained in the Rio Declaration (1992):

> Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The PP states that when you are at risk of causing 'serious or irreversible harm', even if you are not sure, then you must step back: for example, when our actions may be causing a possible ecocide then we must take a different path. If there is a route available to us that *doesn't* involve potential serious or irreversible harm then it should be chosen over other routes that may involve such harm.

Contrary to what is sometimes claimed, the PP doesn't prevent or discourage innovation—it *encourages* it. By preventing actions and behaviours that could be dangerous, the Precautionary Principle supports the case for companies (and governments) genuinely to innovate within the constraints set by the possibility of serious or irreversible harm, rather than continue lazily to do something risky. However, despite this truth, there is now considerable pressure from corporate interests to prioritise an 'Innovation' principle over and above the Precautionary principle.[11] Such a 'principle' prioritises human ingenuity over human impacts and proposes that the former can solve problems arising from the latter—and do so profitably as well, *instead* of reducing or avoiding those impacts. This 'Innovation Principle' is a rationale for recklessness (and it may well be used to 'legitimise' geoengineering). The point is that there is an asymmetry here: the Precautionary Principle is designed above all to prevent potentially ruinous scenarios. Hopes invested in inventiveness—and profit—cannot outweigh risks of ruin.

In reality, the Precautionary Principle *already is* an innovation principle.[12] For it is lazy commercial activity, happy to profit from a situation forcing silent risks onto the broader public, that typically wishes to maintain the *status quo* of reckless activity (for example the continued use of lead in petrol, or the continued use of huge amounts of petrol); whereas the Precautionary Principle

11 The EU has started to give in to these pressures, highly regrettably: on 13 December 2018, the European Parliament voted for the so-called 'innovation principle' for the first time.

12 How it is, is made clear in great detail in Volume 2 of the report: 'Late lessons from early warnings' (EEA, 2001).

forces them to seek instead to find a safer path, a new innovative route. The need for precaution thus often *drives* innovation.

Consider for example the CLARA report, which concludes that: we should stop forest destruction, restore peatlands, end conversion of grasslands to cropland and restore and expand natural forests (Missing Pathways to 1.5°C, 2018). At the same time we should convert from industrial agriculture to agro-ecology, which would *inter alia* constitute a whole series of innovations. In doing all this we should work closely with indigenous peoples and local communities, including peasant farmers, who still provide some 70% of our food in spite of the expansion and claims of industrial agriculture. 'Innovation' shouldn't be restricted to meaning: reckless high-tech innovation.

It would be ironic (though sadly predictable) if the 'Innovation Principle' were used to 'justify' the reckless roll-out of geoengineering; for this would almost certainly lead to *less* innovation in the vital fields of energy-conservation, renewable energy technology, sustainable and regenerative agriculture, etc.[13] For it would 'license' more business as usual where climate-dangerous GHG emissions are concerned.

PRECAUTION IN UNFCCC ARTICLE 3

'The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.'

Questions and values related to geoengineering and precaution

The debate over geoengineering provides us with a vital opportunity to call for the democratic assessment of new technologies and advocate for the precautionary principle into the future, as for instance approaches influenced by Hannah Arendt would have us do.[14] If society is to carry out a meaningful assessment of geoengineering, we must decide what questions to ask. For example, what is the effect on our values and ethics if we believe that we can (both morally and practically) freely alter earth systems to counteract

13 As we will discuss in greater detail in the section on 'Moral hazard', below.
14 On which, see for example the work of our Green House colleague Anne Chapman.

the climate forcing we are now knowingly involved in? Or: considering how profoundly we depend on ecological systems that we do not yet understand in any detail, is it ethical or scientifically valid to intervene in those systems in ways that may be irreversible? We must not use the excuse that man-made climate change is already causing irreversible damage to those systems as an excuse to seek to engineer them, if there is available a less reckless route that would return them to a more natural, self-sustaining state.

As we have outlined above:

- In order to understand the impacts of geoengineering (which models and laboratory experiments cannot show us, due to the complex nature of climatic systems and the number of variables involved), we would need full deployment, which could easily have irreversible consequences.
- Certain approaches, such as injecting particles into the stratosphere, would have to be continuously maintained, as halting them would lead to an extremely rapid increase in temperature. Is it ethical to oblige future generations to do this? *A highly-climate-stressed future is hardly the safest environment in which to rely on the organisational and resource capacity to maintain geoengineering efforts* such as SRM.

Moral hazard issues

While we play with the idea of geoengineering the planet in order to tackle global overheat, we are not reducing emissions. It seems likely that as long as politicians and many publics feel they can 'change the subject' they will continue to do so, which means that the focus is shifted away from effective action. Geoengineering is a diversion from the real issues, which involve: leaving fossil fuels in the ground, changing our diets, adapting transformationally to the dangerous climate change that is coming—and thereby increasing, not reducing, human happiness.

When it comes to practical questions for the technology assessment process we need to ask many things about the safety and effectiveness of geoengineering and the potential unintended consequences. Above all we need to ask who makes the decisions and how. How does the application of the precautionary principle change this debate? Here is one possible way:

> We … need to find a way of examining emerging technologies to assess their potential for harm before they are fully developed or deployed.

> This requires a process based on precaution and work with a wide range of people including scientists, sociologists, philosophers, politicians, and the general public. It is particularly important to consult with Indigenous Peoples and local communities who have their own knowledge systems and cultural references.
>
> — Steinbrecher and Paul (2017: 45)

Precaution and development

The proper application of Precaution actually indicates a completely different development path from that which we are currently following. Instead of the impossible paradigm of endless economic growth we need to shift to a paradigm of economic and ecological justice, which means contracting and converging—the rich give up privileges and the very poor gain some—and all this must take place within planetary boundaries, that is, within the capacity of the planet and the ecosystem functions essential to our lives.[15] As outlined above, precaution also means a different approach to the development and deployment of new technologies which is often described as blocking innovation but which can actually encourage a new kind of innovation, less risky, less short-term in focus. This too will be a part of the required new development path.

An objection?

Some will say however that the days of precaution in relation to *climate* are over, because the evidence is in, the science is settled.

It is true that evidence-based (climate-) science now clearly provides a sufficient basis for the need for radical action to address the changing climate, and in this way climate differs from other threats (for example genetically modified organisms, or GMOs) against which the evidence-based case alone is inadequate (Read, 2015; Taleb et al, 2014).[16] (The evidence against GM is

15 On which, see Kate Raworth's book *Doughnut Economics* (Raworth, 2017).

16 Climate-change deniers downplay the risk of human intervention in natural systems. GMO proponents similarly downplay the risk of human intervention on natural systems. GMO proponents are in an analogous position, therefore, to geoengineering proponents. In both cases, rampant technophilia runs beyond any evidence-base, and there is no evidence-based case for the safety of the technology in question. (Our thinking in this note is influenced by Joe Norman.)

not overwhelming, in the way that the evidence against climate-change denial *is* overwhelming. What is overwhelming against GM is the purely precautionary case: which translates into saying that the evidence-based case *for* the safety of GM crops is far from adequate.)

However, the Precautionary Principle remains relevant and important in the case of climate generally, and specifically of geoengineering. Examples of its general relevance include:

I. 'Climate-sceptics' emphasise the uncertainties inherent in many aspects of climate science. They are right. What they have not understood is that *uncertainty* makes the argument for climate-action stronger, not weaker. For uncertainties cut both ways. If we are uncertain where tipping points are, how different tipping points may interact, or what the level of 'climate-sensitivity' is, then we should be *more* precautionary, not less, because the outcome is harder to control, and could be even worse than we predict. It is cherry-picking to assume that uncertainty always points in the direction of climate science being 'alarmist'. The reverse may well be true.[17]

II. There remains significant uncertainty about key elements of climate science as these are applied to what is required for a good quality of human life in the long term. For example: is 1.5 degrees (let alone 2 degrees) really a 'safe' level of heating from pre-industrial temperatures, or might even 1.5 degrees lead long-term to complete break-up of the Earth's ice-sheets, or render significant parts of the Earth's surface long-term-incapable of supporting significant food-production for human consumption (let alone for supporting a wide diversity of species including humans)? We dare not await complete answers to such questions before acting precautionarily. The PP enjoins us always to err literally on the safe side. It keeps us safer than a purely modeling- and risk-based approach would.

III. Looking back over the last generation, especially the last few years, there has been a persistent tendency for various outcomes to *exceed* the 'likely worst-case scenarios' of climate modellers. Consider the unprecedented Arctic temperatures and diminishing sea ice recorded recently. This would have been less of a disaster, were we already taking strong precautionary action. The same is true, going forward.

Now, how do these three points impact the case for geoengineering?

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17 Thus the Precautionary Principle offers an independent argument for strong action on climate, even to those unconvinced by climate-science. It has the capacity to persuade, on the basis that even a low probability of the climate science being right would already demand that we act strongly and precautionarily because, if it is right, we risk catastrophe.

The idea of accepting raised levels of CO_2 emissions, and seeking to engineer the workings of the planet to avoid the harmful consequences of those raised temperatures will, we have no doubt, become increasingly popular in the next few years, as we face increasingly the results of our accumulated emissions, our accumulated climate-recklessness and refusal to take action. It is clear that we have failed to listen sufficiently to climate science, and failed to act precautionarily, and are moving inexorably and fairly swiftly closer to the dangerous 1.5 degree temperature-rise threshold. Our argument has been that *geo-engineering is a highly reckless response to this situation*, not a precautionary one. We have shown that by definition there can be little that would constitute empirical evidence that geoengineering is a bad idea before it takes place, since it can only really work at a planetary level and therefore cannot be introduced in small-scale experiments. This is why we should apply the Precautionary Principle: We ought to seek a route to climate safety that does not rely on an untried and hazardous experiment with the whole Earth. We need instead *to put an 'emergency brake' on emissions.* And, given that that is tragically unlikely to happen, we need, as Green House have been urging, a programme of transformational adaptation, and indeed a series of measures taken at all levels to prepare for possible collapse and to start living now on much less.

The case for geoengineering is reckless. There is a strong precautionary case *against* climate-engineering.

Taking stock

To sum up the argument so far: the situation is genuinely desperate. That desperation is being used to argue that geoengineering is required in order for us to save ourselves. But: we are in fact *choosing* to fail at present. The real question is 'only': how badly are we going to choose to fail? The difference between 'badly' and 'atrociously' is a big difference, in terms of harm-reduction. We in Green House hope that we will choose to fail badly, not atrociously.

However, geoengineering gives us a tacit 'excuse' for failing atrociously. The extreme moral hazard that it leads to will 'legitimise' a cocktail of massive ongoing GHG emissions and reckless rolling out of untried, costly, hazardous technologies.

The future will be bad. But we don't have to behave atrociously and risk everything, as continued high-emissions pathways and geoengineering do. We can instead choose to seek to do the best we can to create a future which is as 'least bad' as possible. What does this mean?

Collective decisions to consume less (whether made by enlightened cities, or rural areas, or particular groups of people voluntarily) would be a true expression of values and democracy. Many indigenous groups take time to make decisions, partly because they believe that everyone must be included and reach a consensus on the final decision. Perhaps we should learn from them if we are to respond adequately. (Probably we *will* do so sooner or later, and we could try to make it sooner.) Our so-called democracies give no space for real deliberation by the people over the kinds of issue central to this chapter. What is needed for it to be possible for the global community to eventually agree to take real action? Real information, time, trust… However, elected governments are always focused on staying in power, and therefore they often do not represent the true, long-term interests of the people. Moreover, they typically lack any mechanisms for representing future people.[18]

Thus below we propose a major shift in the way that deliberation and consultation take place, in relation to new technologies. The application of precautionary thinking strongly suggests that instead of going for novel top-down technologies whose impacts we cannot predict, we should prioritise the actions whose impacts we can basically understand—for example reducing emissions, halting forest, ecosystem, soil and water supply destruction and degradation and reforesting sensitively with native trees. We should 'deconstruct' our impacts rather than build them up. We should simplify the aspects of the system involving and dependent on us and our agency, rather than complexifying that system further. We should not fragilise the Earth system further—and geoengineering inevitably fragilises, because it complexifies yet further and thus builds in additional ways in which things can go wrong; for instance as a result of the need to maintain geoengineering once it has started. As noted above: *It is utterly reckless to depend on geoengineering to be long-term sustainable, given that we are uncertain that we can sustain the operation of industrial civilisation at a high level of inputs*.

How can we start to shift away from the current climate of opinion, in which geoengineering risks coming increasingly to seem 'necessary'? We should turn for inspiration to indigenous peoples, and adopt an approach which means thinking about the welfare of the next seven (or indeed 77, or 777) generations before making such major decisions. This would entail tackling the chronic short-termism of currently-hegemonic modes of politics, technology and development, and thinking beyond short-term human advantage to properly consider the biosphere on which all lives depend.

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18 On which, see Rupert Read's 'Guardians for future generations' proposal for Green House.

Facing up to climate reality surely requires not that we go in for geoengineering but that we refrain from doing so, if only out of humble awareness that climate reality itself may scupper the long-term viability of sustaining geoengineering programmes.[19]

However, the mainstream is a very long way from accepting any of this. In fact, we have a lethal combination to deal with: the profit imperative, the 'normalcy bias' and the fascination with technical fixes.

The proper application of precaution could address this too. We know we have to take action, but we do not seem prepared to take the right action. Instead we keep going for diversions, because the right action means fundamentally rethinking our model of development starting with those countries that have followed that model for the longest time. Such fundamental rethinking may eventually come—once enough disasters have shown the utter inefficacy of the current model,[20] and have started to take down growth-obsessed international capitalism.

What is needed is not extreme technology, but rather action at every level by people, not just government but everybody, starting with those who are not too poor or hungry to act. Governments need to communicate with people to explain what is needed and help to provide an enabling context.

Precaution can completely change the nature of the debate and take it out of the hands of the technocrats. What we need is often low-tech and involves the cooperation of networks of people at ground level, not top-down solutions from government and big corporations.

We turn now to thinking about how society and the economy could be differently organised, so as to change this dangerous dynamic.

The stage gate process

There are often several phases in the development of a product or technology and the aim of a *stage gate process* is to identify points where the proposed development should be examined and a decision taken as to whether or not to proceed to the next stage. It was in fact (as we will discuss below) a stage gate process that helped to stop the first proposed geoengineering project in the UK, the SPICE (Stratospheric Particle Injection for Climate Engineering)

19 Instead we should do as much as we can by way of mitigation and transformational adaptation – while fully aware that it is unlikely to be enough to head off bad outcomes, disasters.

20 This is the hopeful argument of the chapter in this book authored by Rupert Read and Kristen Steele.

project (in 2010), which was to use a tethered balloon and hose to disperse water at a height of 1km to try out a prototype for delivering particles into the stratosphere at some 20 km above the surface of the earth. In the stage gate process for this project:

> …a panel of external experts considered the progress of the project against a number of criteria, such as checking that mechanisms have been identified to understand wider public and stakeholder views on the envisaged applications and impacts.
>
> Following the stage gate meeting, the panel advised the research councils and the SPICE team that further work on stakeholder engagement and the social and ethical implications was required.[21]

In order to properly assess geoengineering we need a thorough stage gate process combined with the strict application of precaution and ongoing public consultation. Public consultation should happen at every stage of the development of a new technique and should have the power to halt it completely. If such an approach had been taken to polychlorinated biphenyls (PCBs) and asbestos, it is possible that their development and deployment could have been halted early in the twentieth century (EEA 2001).

Public consultation

This is a vital part of any precautionary process of technology assessment. Representatives of the public, randomly selected to have no particular bias or knowledge of the subject, have consistently shown themselves to be perhaps-surprisingly wise advisers. They are not specialists, but nor do they have specific *interests* and they have a *broader perspective* than any group of specialists.

However, there has so far been too little public consultation on the subject of geoengineering and certainly no attempt to set up a continuous process of consultation to follow developments as they take place. One example from the UK provides some key insights into the principles that should be applied to any discussion of geoengineering. In 2010, the Natural Environment Research Council (NERC) held a public dialogue on geoengineering in the UK.[22] The members of the public involved came to some strong basic conclusions, relating to human ignorance of climatic systems, justice, and equity. These

21 See https://www.epsrc.ac.uk/newsevents/news/spiceprojectupdate/.

22 See https://nerc.ukri.org/about/whatwedo/engage/engagement/geoengineering/.

are highly relevant and make an excellent starting point for any discussion of geoengineering today.

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The members of the public concluded that:

- We have no right to interfere in complex ecosystems if we do not understand what we are doing, or the consequences, or if (and in what ways) the impacts will last a long time.
- The values involved go beyond economics to include social and ecological values.
- The rich do not own the planet and have no right to exploit it for gain or increased inequity.
- As much of the population of the world as possible should be included in making decisions that will affect them (like on geoengineering).
- The UK population should be given as much information as possible to enable them to participate in making such decisions.
- Scientists need a public mandate to move forward with any geoengineering.
- The public that considers whether to give them that mandate should be given as much information as possible in order to decide.
- Interfering with natural systems using geoengineering could legitimise further interference later, dubiously.

As regards uncertainty of outcomes, the public typically takes a pretty full precautionary approach to the consequences of intervening in complex and delicate planetary ecosystems that we do not understand. Ongoing public consultations could be part of a required, rigorous, non-commercial, scientific stage gate process, that is an examination of progress and questions that arise regarding the investigation of a proposed application of geoengineering at every stage of its development, with the mandate to halt further development at any point.

Our guess is that, if stage gate processes were properly deployed, geoengineering never would be.

Conclusions

It is good to discuss geoengineering because it reveals what a dangerous situation we are in, as regards the climate and especially human hubris. But it is one thing to talk about geoengineering and quite another to recommend implementing it. We recommend *talking* about it—so that the enormity of what the proposals reveal about us and the situation we have got ourselves into can hopefully wake us up so that we don't actually *do* it.

In fact the sheer arrogance of geoengineering proposals reveal just how deluded we have become about the power of our technologies. Anyone who believes that they can successfully engineer an interacting series of complex systems that we mostly do not understand and which are innately unpredictable and incredibly powerful must be either deluded, or, at minimum, recklessly over-optimistic (especially given 'our' record to date). What we need now is a strong dose of humility and a recognition that all human inhabitants of the planet are in this together and need to collaborate respectfully, learning from each other—including via the kind of inspiration from indigeneity, and the more prosaic but very valuable possible deliberation methods, described above. We must recognise that we depend for our lives on these planetary systems that we now contemplate altering deliberately. At the same time we urgently need to cease destroying ecosystems and their human and non-human inhabitants, and disrupting climate systems at every level.

This implies a philosophical shift, away from arrogance about human technical capacity to resolve any problem we create, and to do so with a main eye on profit, towards a better sense of epistemic humility and our proper place in the planetary system. We are used to believing in 'progress' and assuming that technology represents 'innovation' and therefore 'progress', while indigenous and biocultural knowledge of all kinds allegedly belong to the past and must be superseded. What we need to do now is to strongly question this position. Doing so would represent a true paradigm shift away from the mindset that conjures up geoengineering.

Climate-realism enjoins accepting that the human race is walking more or less knowingly into disaster, but nevertheless seeking to prevent catastrophe (On this, see John Foster's chapter). There will be bad climate-damage; there will be disasters. (See the chapter by Rupert Read and Kristen Steele, on the lesson of this.) Geoengineering pretends that we can avoid disaster while continuing with a model of development based on high emissions, but it could actually contribute to a catastrophic situation: one in which there are huge ongoing GHG emissions *and* reckless rolling out of geoengineering technologies.

Geoengineering is both risky in itself and a dangerous diversion from what we should be doing, urgently, as a global community: reducing emissions and sensitively restoring the ecosystems that are our life support. This process must be honestly led by those with most responsibility for global overheating: the nations that were the first to industrialise. Our technical capacity has outrun our ethical frameworks and we urgently need to focus on strengthening the latter and applying the Precautionary Principle. We have plenty of clear examples of how the emergence of new technologies highlights the assumed positive aspects long before the negative impacts become clear—except to a few, but they are often disbelieved (just as the prophet Cassandra was doomed to prophesy truthfully and never to be believed). But those who cannot learn from history often have to repeat it, as examples such as the development of PCBs show. We must try to avoid repeating this kind of mistake, because the stakes are now too high. There are fewer unknown risks in reducing consumption of energy and resources than there are in deploying untried technologies, many of which would have to be maintained beyond the foreseeable future and whose potential impacts and interactions cannot be fully known until they are deployed. Our legacy to future generations does not look like a happy one. We need to change. Given new political will and commercial frameworks, this may still just be possible, but time is rapidly running out.

So that is our pitch. Climate-reality is going to hit us hard, whether or not we geoengineer. Some of our ideas in this piece may seem politically unrealistic at present, and they probably are. But *they will come to seem realistic in time.* The only thing that might stop them from doing so is if we decide to send ourselves to sleep again by deluding ourselves that 'negative emissions technologies' can save us and allow a continuation of near business-as-usual. The real danger of geoengineering is that it is a continuation and indeed accentuation of *the very mindset*—'progressive', reckless, anti-revolutionary, basically mindless, while stuck within human solipsism, and without respect or love for the Earth—that has set us on our current tragic path. As such, it could prolong that path beyond a point of true no-return, a point of runaway climate-damage *or* of catastrophe induced directly by geoengineering technologies (for example, a catastrophic failure of the world food system, if BECCS were rolled out across an area almost twice the size of India, which is what it would need in order to be effective; or a catastrophic failure of the world's weather, if for instance we lost the monsoon completely, as a result of deploying SRM).

We will take an alternative route. That route will either quite simply be forced upon us, by collapse; or (one hopes) will come to seem realistic before that point—when we finally are willing to face up to climate reality.

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