A Report on the Climate Geoengineering Governance project Scenarios Workshop

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On 13 October 2014 the Climate Geoengineering Governance (CGG) project convened a one-day scenarios workshop with key national and international experts and stakeholders. The purpose of the workshop was to stimulate more thinking about the temporality or process dimensions of geoengineering governance, as distinct to prevailing thoughts about outcomes. It sought to explore how far geoengineering proposals may develop and under what institutional arrangements. Participants were presented with four policy-relevant geoengineering proposals: stratospheric aerosol injection (SAI); cloud albedo enhancement (CAE); bio-energy with carbon capture and storage (BECCS); and air capture and storage (DACS). Allocated into four heterogeneous groups of between 6 – 10 participants, the groups were asked to consider two of these proposals (one solar geoengineering proposal and one carbon geoengineering proposal), either: SAI & BECCS, SAI & DACS, CAE & BECCS or CAE & DACS.

The groups were asked to develop a timeline for geoengineering research over the next twenty years, considering major events in both the development of the technologies and in their governance. They were asked to think about the possible role of four idealised governance models: self-regulation; global governance; principles and protocols; and a moratorium: if, when, and how they might play a role. At each group's discretion, the timelines were approached as either an exercise in forecasting (beginning with the 'starting point', and exploring how governance might respond to events) or in backcasting (beginning with the 'end point', and exploring how governance may shape events); allowing for branching pathways. The timeline was used to construct a narrative storyline, which was later presented to the other groups in plenary. In advance of the workshop, participants were sent, or given access to, documents for preparatory reading relating to the four idealised governance models: self-regulation (Keith, 2013); global governance (Bodle et al., 2014); principles and protocols (Rayner et al., 2013); and a moratorium (Hulme, 2014).

What follows are comparisons of the different groups' discussions of each geoengineering proposal under consideration. The timelines are included as Appendices at the end of this report.

Comparison of Group 1 and 2 Discussions of Cloud Albedo Enhancement (CAE)

[Note: Group 2 treated CAE and Marine Cloud Brightening (MCB) as synonymous]. Group 2 also developed a general view of regulation as both global and local, but with an emphasis on local geopolitics, in line with the gradualist principles/protocols style of governance. Group 1 put greater emphasis on the role of global governance.

Both groups agreed on the immaturity of the technology and the need for extensive assessment as to its effectiveness and wider impacts, especially on precipitation. Group 1 pointed out that it was possible that some sizes of particle might contribute to climate warming, rather than cooling. Both groups saw potentially huge problems of attribution and liability and in the case of group 2, distributional justice with the technology - witness the issues with disputes between Provinces over weather modification in China. Group 2 thought that the predictability of impacts might be at the limits of modelling capacity. Testing at scale would be particularly challenging in terms of both assessment design and practice; as with all SRM, blame for any adverse subsequent weather events would be likely to fall on the experimenters. Group 2 also thought that CAE would play into contrail conspiracies, and this might impact public discourse more generally.

Both groups saw a failure of UNFCCC COP in Paris 2015, and in particular failure to determine an agreed carbon price, as a condition of any increased importance of CAE and of SRM approaches in general.

Group 1 saw a moratorium or global agreement as equally unlikely for CAE. This led it to suggest a timeline whereby broad governance principles might be developed between 2015 and 2024, when a 'coalition of the willing' might take up the running. Such a coalition was envisaged as a consortium of powerful nations which would build on broad governance principles to define a research agenda, conduct experimentation including testing at scale, and define a development path, with the aim of assessing whether CAE might have a role, perhaps around Arctic ice. The analogue of the consortium's regulatory role would be GEOMIP, with its main role being to police developments. The Convention on Biological Diversity (CBD) might also contribute to regulation.

Group 2 saw the MCB trajectory as being research led - technical problems and/or the perceived ability to know or to manage the extent and severity of predicted global impacts may lead to an early full stop for this approach. Similarly, positive results on the albedo of certain types of cloud brightened through CAE might propel the approach forward.

Both groups saw CAE as a technology deployed potentially at local scale only, relatively cheap, and therefore a candidate for unilateral action by nation-states. In group 2's scenario the possible locus of early action to develop the technology was seen to be more likely to be local coastal communities trying to find ways of alleviating heat stress; potentially in China (a progression from their weather modification programme), California or Australia. A relevant research take-off point might be EPEACE - the Eastern Pacific Aerosol Climate Experiment, 2011, involving University of California San Diego and the Scripps Institute, using satellite analysis. Under a local-action scenario much of the initial regulatory responsibility would fall to the nations concerned, which might lead to jurisdiction shopping from the technology's promoters; although there would be additional issues associated with ships deploying the technology in international waters, such as the possible creation of fog or congestion in sea lanes, on which LC/LP might need to rule.

Both groups saw some general SRM issues with CAE. Group 1 thought that in common with other SRM approaches CAE raised issues of moral hazard, though 'negative moral hazard' - a reinforcement of the public's commitment to mitigation - was also a possibility given that the use of this technology would underline the challenges of climate change.

Group 2 looked at what advantages CAE might present over Stratospheric Aerosol Injection (SAI), were SRM approaches to come onto the agenda in an acknowledged climate emergency. CAE would be short-lived compared with SAI, would not contribute to ocean acidification, and is potentially cheaper, although there were huge uncertainties about cost. As such CAE might be seen to be in a relatively sweet spot as a relatively benign form of SRM: 'recycling sea-water'.

Comparison of Group 1 and 3 Discussions of Direct Air Capture and Storage (DACS)

Both groups questioned whether DACS should, or could, ever become preferential to flue-gas carbon capture and storage (CCS). Whilst DACS would capture highly diffuse CO_2 from the ambient air, CCS would capture the gas from far more concentrated point sources. This makes DACS a far more expensive prospect than CCS, in terms of cost/t CO_2 captured. Moreover, both groups believed that the only sensible energy source for powering DACS would be some form of renewable energy. The question thus arose: if renewable energy became sufficiently inexpensive, why not simply prevent the release of CO_2 in the first place by mitigating climate change through renewable energy? In competition with both CCS and renewable energy alternatives, the groups were sceptical of the uptake of DACS. Yet, the groups also recognised that such approaches would neglect accumulating historical emissions of CO_2 already in the atmosphere.

Both groups saw the creation of an effective, globally agreed carbon price as critical to determining the future trajectory of DACS. It would provide the necessary fiscal stimulus for further DACS R&D. Both groups were, however, sceptical as to when such an agreement might be realistically reached. Indeed, Group 1 noted 'difficult partners' in some nations and the temptation of 'free-riding' that might impede progress. Whilst sceptical, Group 1 assumed this might occur during the 2015 international negotiations at COP21 in Paris. For Group 3, the agreement on an effective carbon price was not envisioned until at least ~2028. Nevertheless, until the time that an agreement could be reached, DACS R&D was viewed as likely to remain a 'boutique' interest.

The two groups did, however, note some possible alternative routes to incentivising DACS R&D. Group 1 suggested that the occurrence of significant climate change impacts might provide motivation. Alternatively, Group 2 proposed that the prospects for corporate reputational benefits could stimulate market demand for R&D. The possibility for concurrent development of a solar climate engineering proposal, such as stratospheric aerosol injection, might also stimulate interest in DACS as an 'exit strategy' to avoid termination effects. Moreover, CO_2 regulation was seen more likely to induce larger reductions in emissions than CO_2 pricing, thus questioning the imperative for an agreement in the first place.

For Group 1 the governance of DACS would be indistinguishable from the governance of climate, sharply contrasting with their view on the governance of solar climate engineering which was more focussed on the technology proposals themselves. 'NIMBY' public opposition was seen as the most likely challenge for DACS governance by Group 1. On the other hand, DACS was seen as posing 'no special governance issues' by Group 3, who claimed that lessons could be learned from its CCS counterpart. Yet, at the same time, it represents something of a regulatory paradox in that while the proposed technology would operate within national boundaries, it would pose transnational effects. The European CCS Directive, they explained, sets requirements for storage and monitoring. An equivalent, 'International Air Capture Agency' could help to build trust through an accounting system with a reporting requirement.

Comparison of Group 2 and 4 Discussions of Bioenergy with Carbon Capture and Storage (BECCS)

Group 4 noted that there was a definitional issue with BECCS - when and at what scale will it be considered as a climate engineering technology.

Group 2 saw a potential scarcity crisis as critical to the development of a narrative around BECCS, with the peak of global population recently being revised upwards in some forecasts from 9 billion to 11 billion. There might exist 10% of underused land capacity which could support BECCS , yet there was a lot of uncertainty about the trade-offs in land use centred around possible dietary change - a huge factor - and the use of urban areas as possible sites of food production.

Given these considerations BECCS could be considered a short-term measure only. At best it could be only a contribution to climate modification - a wedge. To remove 150 ppm of carbon out of the atmosphere would require capturing 50 gigatonnes a year for 50 years. The possible sustainable scale of BECCS is 1-15 gigatonnes so it could contribute 10-50%. Biomass could be buried rather than burned (e.g. biochar) - the economics of burning are thought to be more favourable because of energy generation.

BECCS might properly be considered as two or even three technologies, all confronting socio-technical uncertainty; potentially putting two unpopular technologies together, as group 2 put it. There is little political lobbying for BECCS as such, although IPCC's RPC 2.6 scenario assumes that it would make a substantial contribution; and this carried through into national positions such as that for the UK's Department for Energy and Climate Change (DECC). Group 2 noted that CCS had more support, linked to local political circumstances: the link of CCS to enhanced oil recovery fuelled political suspicions. Group 4 saw the UK White Rose CCS project at Drax power station as a significant potential test site of some of the technologies involved.

While both groups had a similar perspective on the technology-specific challenges, group 2 emphasised the difficulties of ensuring sustainable biomass supply; in itself a problem in scaling up the technology. Group 4 focused on problems in infrastructure at scale and in the safety and effectiveness of storage. Germany, it noted, is concentrating on carbon capture, but not on storage. Political will would be crucial to these scaling-up challenges. Group 2 saw storage under the sea floor, as envisaged in White Rose, as implausible on grounds of technical challenge and cost.

Group 2 considered that one problem in the assessment of BECCS is lack of research funds, and a mismatch between the apparent policy salience of BECCS and research funding priorities. Given an environment in which few researchers are attempting to assess all stages of BECCS, and given the shortage of research funds, there is a real question as to the strength of the BECCS community in confronting major socio-technical challenges or set-backs: if part of BECCS fails, can the community adapt?

The two groups had somewhat different perspectives on how BECCS would play out in the period up to 2035.

Group 4 saw the key event being an agreement coming out of Paris 2015 to establish a global carbon price in 2025. Were this to happen it would incentivise research on BECCS, and the main thrust of this would be taken up as a commercial investment by the private sector. The size and course of this development could be affected by a number of factors, including (a) regulation of global land use, which could affect the energy sources (b) development of new energy sources and (c) catastrophic technology failure of BECCS. Were there to be no agreement on a carbon price, research funding and regulation would be left in the hands of states (although not necessarily in the case of undersea storage), and research would continue without significant growth up to 2035. BECCS would still be at risk of being derailed by technical flaws/failures, or by changes in energy policy in this period.

Group 2 thought little of significance would emerge from Paris and in line with its decentralised and gradualist 'principles and protocols' approach to governance saw local geopolitical priorities establishing a variety of different prospects for BECCS around the world. BECCS in 2035 could not be expected to be as it is now. Research might speed it up - for example, developments in GM crops might create more space for biomass production; or slow it down - for example, should a consensus develop that it were better to wait for another generation of air capture to improve efficiencies. However, the group felt that research is unlikely to deliver a decisive blow to BECCS during this period, although wider social and political reasons, such as a global food crisis well might.

Having said this the group questioned whether political and popular acceptability for BECCS would be hard to achieve. This may be true in Europe, but not everywhere. Take China, for example. If the switch from coal to shale gas is not feasible for China, a country with huge amounts of land, does BECCS become more attractive as a substitute for shale gas and as the means to keep coal plants running longer (BECCS as a sort of greenwash for coal)? This scenario might provide incentives for research on BECCS in China. Further, when it came to deployment, the political system might be more amenable to BECCS there than in Europe or India which has to square such developments with democratic traditions, and where local considerations of climate and energy policy are more directly related to different types of public response. There would be a value to the Chinese in greening its Western Provinces not just in term of energy production and climate change, but also in helping to further integrate them geopolitically. Similar incentives apply to other coal-intensive energy systems, especially if they have large tracts of under-utilised land, such as in Russia or Kazakhstan.

This led the group to the idea of variable geometry, of seeing the management of climate change in terms of local portfolios of actions whose make-up would be prompted by local values and interests. National geopolitical considerations mean that not all inflection points in the assessment of a single technology will be the same, and there will be different inflection points on policy too. Some national portfolios might mean one concentrating on nuclear, another on CCS. For example, India is moving from local biomass energy production to centralised burning of biomass, and China to coal gasification; both could be extended by CCS, but in the meantime there could be substantial co-benefits in the form of reduced smog in the cities of China and North India. National narratives playing into energy and climate policy can open up choices, but it can also limit them: for example, different kinds of national narrative have led both Germany and China to react strongly to Fukushima, but if it reduces their policy options, is there a risk that these are over-reactions?

The broader group 2 analysis is that the emergence of local pressures in individual countries such as India and China are far more important as drivers of choice of technological portfolios than global climate change management norms; we should expect technologies to be assessed differently in different contexts; and that in looking for contributions to managing climate we should look for diverse national portfolios of socio-technologies whose composition rested largely on the geography, historic investment choices and political priorities of each country. So instead of talking about technology wedges, which assume that the pros and cons of each technology are equally valid everywhere, we should expect countries to function as selection environments, and to come forward with distinct 'geopolitical wedges' of mitigation, adaptation and CDR approaches which correspond to their individual circumstances and needs.

Comparison of Group 3 and 4 Discussions of Stratospheric Aerosol Injection (SAI)

Both groups expressed concerns over the uncertainties and potentially harmful consequences of pursuing SAI. They noted that while the proposed technology has appeared to be both effective and cheap in many early assessments, these conclusions are based on somewhat shaky assumptions. Harmful impacts on agriculture and the wider environment raise significant concerns; as do the proposal's failure to address ocean acidification; its potential for fostering a moral hazard; the need for justly compensating those affected by harms; and the risk of a 'termination effect' whereby sudden cessation would bring about rapid rise in temperature commensurate with background levels of unmitigated atmospheric CO_2. For Group 4 these concerns were strong enough to rule out SAI as an option for tackling climate change, and to doubt that SAI would ever be used. The group nevertheless concluded that research would, and indeed perhaps should, continue. Group 3, on the other hand, it argued that further SAI research would not increase knowledge, but uncertainty.

Both groups saw collaborative international efforts as key to determining the future trajectory of SAI, albeit in different ways. With a de facto moratorium on SAI deployment, due to the indeterminacy of the technology and the absence of any collaborative framework at present, it would provide the necessary stimulus for further SAI R&D. For Group 3, such collaborative efforts meant reaching an international agreement as to the research and development objectives and linking the research and development efforts to ongoing mitigation efforts. Such an international agreement could generate optimism that coordination on climate issues was possible. It was recognised that such research could be seen by some as negatively 'meddling' with the Earth and by others as positively 'curing' the Earth. If successfully deployed SAI could 'buy time' until mitigation efforts kicked-in – if unsuccessful, it could provide a false hope and undermine mitigation efforts. For Group 4 it meant the formation of a multilateral 'coalition of the willing'. Such a coalition was seen as likely to form around a specific environmental objective, such as reversing losses to the Greenland ice-sheet. Nevertheless, Group 4 also argued that a distinct risk of unilateralism remained. For example, a small-island state at risk of sea-level rise was seen as potentially likely to deploy SAI as a symbolic act of civil disobedience to draw attention to its plight. Moreover, China was noted as particularly capable of deploying SAI by itself at short notice if desired, owing to its existing advanced weather modification programmes.

The two groups both felt that SAI research would endure in the immediate to mid-term, with a continued focus on computer modelling and governance considerations. In the mid- to long-term the groups believed that research could advance more quickly in response to harmful impacts of climate change. Any unilateral deployment of SAI was seen as likely to be met with the establishment of a formal international moratorium. Group 4 considered issues of attribution and compensation for inequitable climatic consequences of deploying SAI would be a substantial challenge. For example, a perceived need to consider compensation payments for poor equatorial countries affected by sharply changed patterns of precipitation after SAI might be sufficient to challenge to the culture and values of international development and prevent some governments from pursuing SAI R&D. Moreover, the possibility of 'counter-geoengineering' raised significant concerns for geopolitical stability.

While an international agreement was viewed as the most suitable governance regime for controlling SAI R&D in Group 3, Group 4 noted that its multilateral 'coalition of the willing' might be governed in different ways. The scale of experimental research was considered to be one such point of debate. For example, should a small-scale experiment in Arizona be governed under the regulation of the US Environmental Protection Agency (EPA), or would it require international assent? The London Convention and Protocols, adapted for ocean iron fertilisation, was considered an appropriate analogue with respect to experiments being conducted within territories being subject to territorial regulation. An equivalent regime for the atmosphere was considered, but it was noted that such a regime should account for social and political impacts as well as physical ones. Moreover, the latter should account for novel environmental impacts, such as ozone depletion resulting from SAI. It was, however, unclear as to which organisation would be in a position to establish such a regime. Nevertheless, the group revealed little enthusiasm for giving the UN Convention on Biological Diversity (CBD) further powers in this regard.

Conclusions

The scenarios workshop effectively explored issues for the governance of particular geoengineering technologies and how they might unfold over time. Some of this effectiveness may have been because most of the participants, whether from research, policy or civil society, shared similar knowledge and assumptions about the possible contributions of geoengineering to the management of climate change. A more heterogenous set of participants might have led to less consensus within and between groups.

Three broad governance styles ran through the discussion: (1) 'top-down' relatively centralised global governance; (2) market mechanisms, which in this case were driven by the setting of a world price for carbon; and (3) a more decentralised, gradualist 'principles and protocols' approach. Yet, a number of assumptions made in the scenarios deserve to be challenged:

- The discussion of DACS at some points seems to conflate DACS and CCS. This is not only a disservice to the orders of magnitude greater difficulties and costs of capturing carbon from ambient air, but also ignores the different objectives of CCS and DACS - the former dealing with current emissions, the latter historic;
- At one point DACS is suggested as a possible exit strategy for SAI, compensating for the termination effect. That DACS could play this role would seem to be a heroic assumption, unless SAI was maintained over a very long period during which the effectiveness

of DACS could be increased and investment in it made at the massive scale that would be required for historic carbon emissions to be radically reduced;

- 'Coalitions of the willing' are invoked at some points as means to deployment that would not present the same governance challenges as unilateral action, yet would allow consensual action without the need for a global agreement. It is not clear why such a coalitions should not provoke similar challenges to international governance. Indeed, these possibly greater challenges might be greater in that a coalition, once established, would be more difficult to resist than the actions of an individual government to resist, should resistance be seen to be required.
- The bottom up 'principles and protocols' approach, most clearly applied here in group 2's discussion of BECCS, might benefit from global machinery for learning, and for the progressive development of norms and standards.

References

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Appendices: Timelines.

2014

An agreement is reached at COP21 to set a effective carbon price, e.g. \$50/t. *If this does not happen, or becomes ineffective during its ongoing evolution, desperation leads to consideration of alternatives, e.g. MCB.*

Agreement at COP21 has unlocked R&D funds for DACS, but there are regulatory planning issues.

Disenable climate change impacts occur, e.g. drought in US, Malaria in France.

Principles of payment mechanisms agreed, with costs passed onto consumers. *Rejection would postpone DACS R&D.*

A rush to develop CSS drives out DACS research.

Price /t CO_2 captured goes down. Success sends signals to put tax up, accelerating DACS R&D.

2034

Group 1, Direct Air Capture and Storage

2014

MCB appears to be cheap, effective, fast-acting, and better than SAI according to mostly desk-based research. It is a one-purpose technology posing risks of unilateral deployment.

International negotiations at COP21 fail to reach agreement on an effective carbon price. Unilateral investments in SRM begin, e.g. China. Governance of experiments begins with professional principles. There are definitional issues over intentionality.

There are difficulties in regulating experiments with sufficient specificity.

UNFCCC begins policing experiments.

A possibly militarised ‘coalition of the willing’ is established. Research into cloud albedo modification has been benignly occurring under different banners for some time.

Experiments carried out by the coalition create winners and losers. Questions of compensation, effective monitoring and democratic control arise. *Perceptions of risk may change, leading to consideration of alternatives, e.g. DACS.*

Large-scale experiments begin, with a moratorium placed on full deployment. The success or failure of these tests leads to an outright ban or deployment.

2034

Group 1, Marine Cloud Brightening

There is ongoing research. We are to some extent locked-in to using BECCS, as it features in the IPCC's emissions scenarios. 'Greenwash' drivers from exceeding 2°C, the CCS lobby and public health concerns in China.

2014

'Climate crisis' drivers e.g. tipping points, Arctic methane encourage further research

Questions over land-use conflicts, moral hazard, impacts and economics arise from BECCS research. There are hard limits to how much CO_2 can be sequestered.

Systemic shocks arise from post-BECCS implementation, e.g. food crises, accidental CO_2 leaks. There are moves to regulate BECCS. *Failure to regulate leads to local oppositional pressure groups.*

Shocks lead to stresses in Central Asia, with costs to global politics

World population exceeds 9 billion and more people live in cities.

2034

Group 2, Bio-Energy with Carbon Capture and Storage

MCB research is in its early stages, and is highly uncertain: *it may not even be feasible.*

2014

Desk-based research shows MCB to be a low cost and reversible option.

Triggers for MCB research: climate impacts, local impacts, Arctic ice reduction, or political pressures are felt.

Governance regimes establish questions of liability and politics of impact attribution. *MCB reaches 'dead ends' if it does not work in practice, or if its impacts are too harmful.*

If an economically viable model for MCB deployment is attained, deployment ensues. *If not, and if there is a failure to adequately govern the moral hazard and a slippery slope lead to a dead end for MCB.*

2034

Group 2, Marine Cloud Brightening

2014

There are several DACS projects to develop prototypes. Legal instruments for subsurface carbon storage already exist. There are no special governance issues.

Scientific research into DACS scalability to give an auditable evidence base. Social scientific research into certification and verification of capture and storage.

DACS becomes a 'boutique' interest, much like aviation emissions

An effective carbon price stimulates further DACS research

SAI development stimulates interest in DACS as a possible exit strategy

2034

Group 3, Direct Air Capture and Storage

2014

Computer modelling and particle research is underway, as is legal and governance research. UK Government has a 'watching brief'. UK Research Councils used stage-gates to pace SPICE. There are concerns about equity.

There is continued support for SAI climate modelling. Professional norms are established, with research protocols established for funders and science organisations.

Small-scale outdoor SAI experiments take place, e.g. similar to the SPICE balloon testbed. National regulations now oblige researchers to consult on trans-boundary effects.

There are demonstrations of SAI engineering feasibility or infeasibility. *In the latter case, this leads to a decline in interest.*

Better computer modelling would have to establish universal benefits of SAI and limited harms, e.g. minimal stratospheric ozone depletion.

A volcanic eruption demonstrates the cooling effects of SAI and provides data.

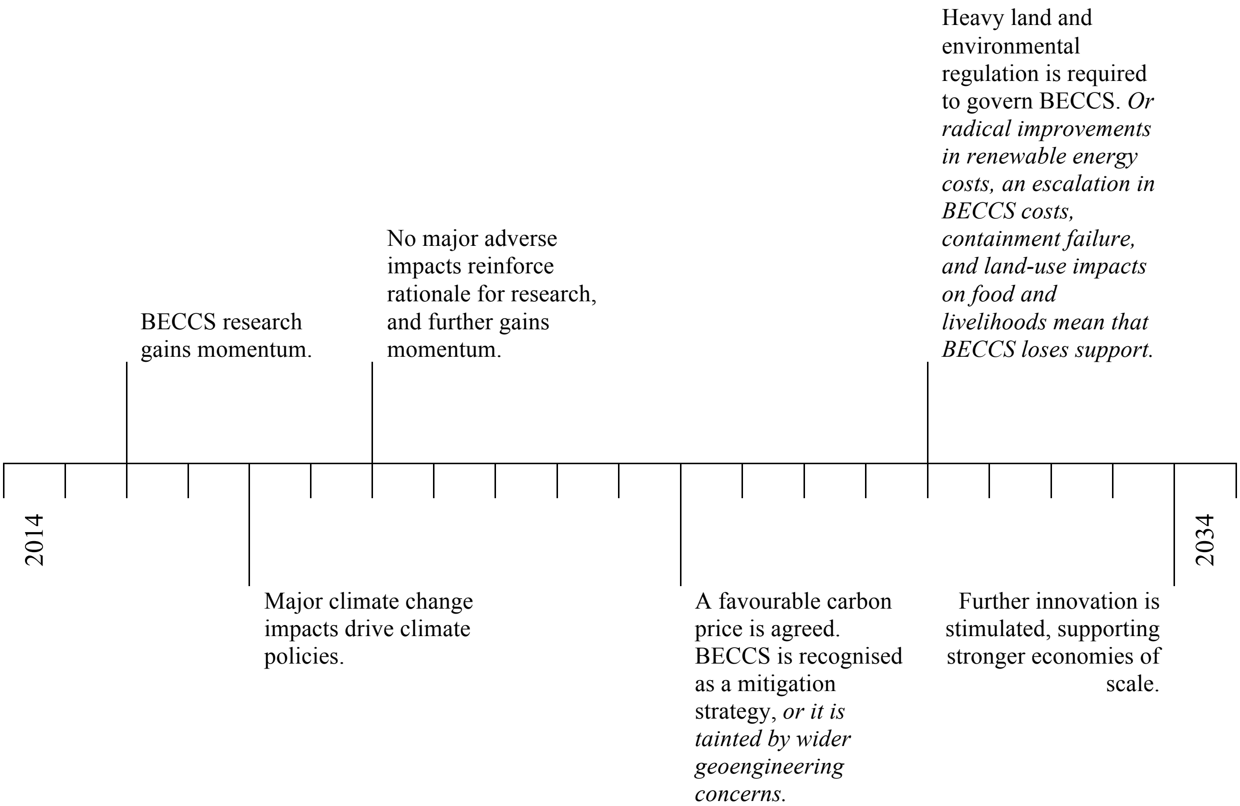
There is a major break-through in energy storage technology. A safe way of removing CO_2 from the atmosphere emerges that is scalable, cheap and politically feasible.

Three years of global crop failure ensues. *Evidence of the damage caused by ocean acidification becomes clear, leading to a decline in interest in SAI*; or trade-offs between climate change and SAI risks are made.

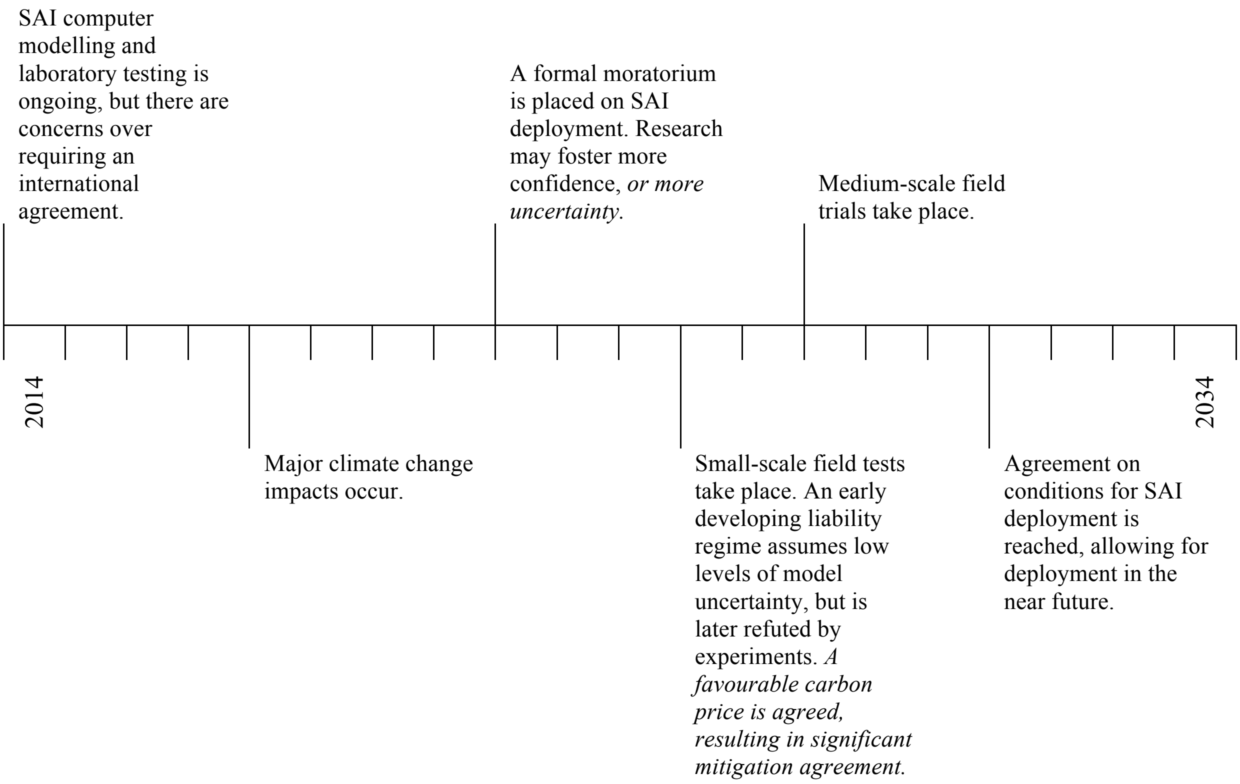
China adapts weather modification tools for climate control. An international science is set up, composed of a 'consortium of the willing' and existing treaty organisations.

2034

Group 3, Stratospheric Aerosol Injection



Group 4, Bio-Energy with Carbon Capture and Storage



Group 4, Stratospheric Aerosol Injection