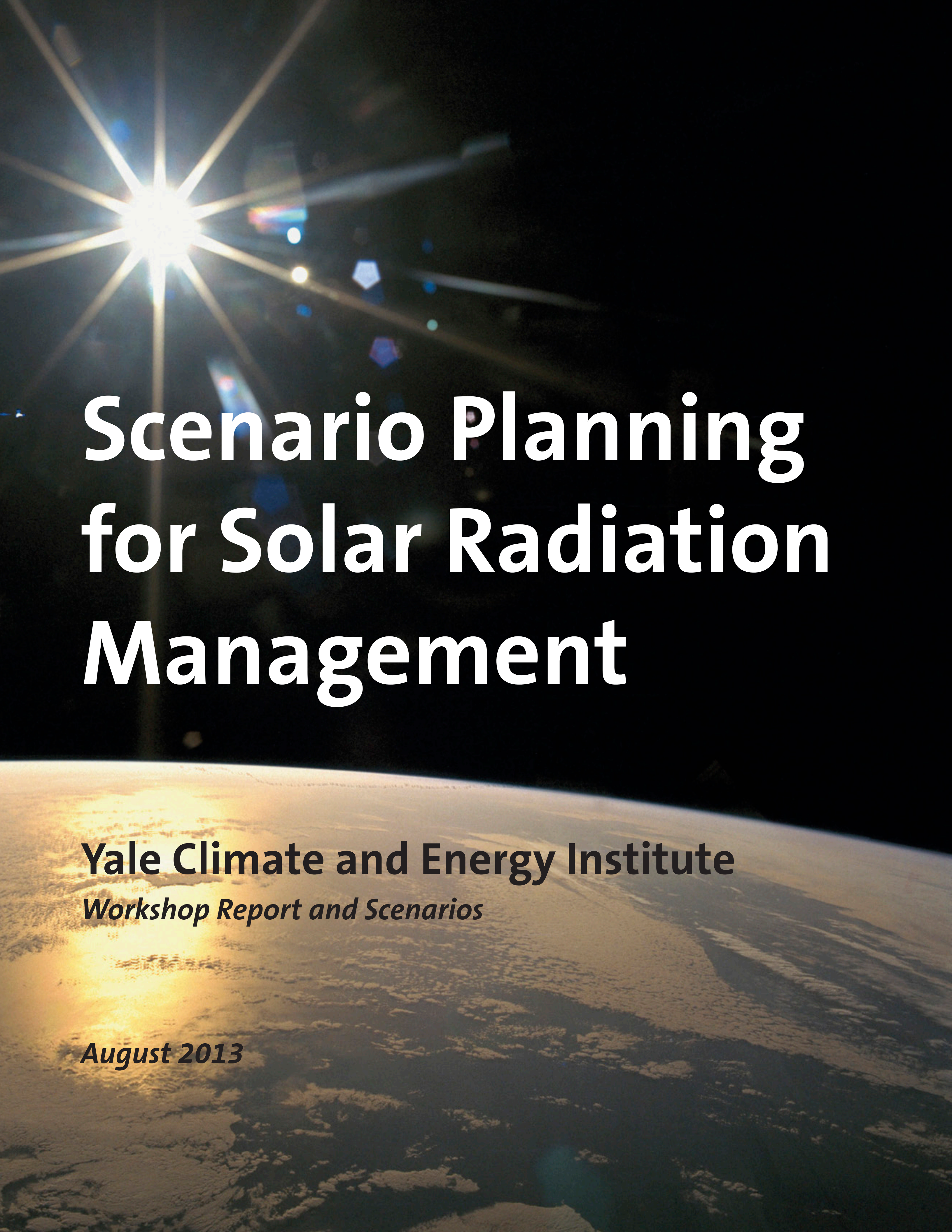

Scenario Planning for Solar Radiation Management

Yale Climate and Energy Institute

Workshop Report and Scenarios

August 2013

Yale Climate and Energy Institute

Centre for International Governance Innovation

CIGI would like to thank the Government of Ontario for its support of this project.

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Le CIGI a été fondé en 2001 par Jim Balsillie, qui était alors co-chef de la direction de Research In Motion. Il collabore avec de nombreux partenaires stratégiques et exprime sa reconnaissance du soutien reçu de ceux-ci, notamment de l'appui reçu du gouvernement du Canada et de celui du gouvernement de l'Ontario.

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The Yale Climate & Energy Institute (YCEI) seeks to understand Earth's climate system, ecological and social impacts of climate change, the strengths and weaknesses of current political and economic system's ability to respond to climate change, and to provide realistic, implementable solutions to societies and communities around the world.

The YCEI is an umbrella organization within Yale University, composed of all relevant departments, centers and faculty. Its mission promotes a multidisciplinary approach to learning, research, and the development of strategies that help societies contribute to solutions and adapt to the challenges of local and global climatic changes.

YALE CLIMATE AND ENERGY INSTITUTE

Scenario Planning for Solar Radiation Management

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Partner Institution

The Centre for International Governance Innovation (CIGI)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Solar geoengineering technologies have the potential to rapidly alter the global climate system. Under some circumstances, these technologies may allow the worst effects of emerging climate change to be avoided, or at least postponed. But important uncertainties also surround the climatic and social effects of these technologies, and their large-scale deployment thus carries significant risks.

Given the magnitude of the climatic and social change that solar geoengineering could induce, exploring ways that these technologies might evolve to shape the future is important for identifying early opportunities to nudge that evolution towards preferable outcomes. Scenario planning methods are powerful tools for identifying drivers that seem likely to influence the complex dynamics underlying such broad, society-level questions, even—or perhaps especially—given the breadth of uncertainties involved.

This *Solar Geoengineering Scenarios Workshop* drew together a multidisciplinary collection of 17 academic and practitioner experts for one and a half days to explore possible futures for solar geoengineering technologies using established scenario planning methods. This report outlines the methods that were employed, and documents in detail the products of each exercise conducted, including a wide range of drivers likely to shape the future, potential 'Black Swan' events, and key uncertainties that could notably reshape assumptions underlying the produced scenarios.

Most importantly, this report presents the six detailed scenarios that were written by the report authors based upon the central storylines generated during the workshop. As the scenarios themselves are the primary contribution of the workshop, only limited analysis of resultant insights and implications are included in this report. Instead, the short discussion section focuses on outlining the potential utility of these scenarios (and others generated using similar methods) for testing whether emerging governance proposals are able to effectively grapple with the array of issues manifest therein.

One general observation from the workshop process emerged as particularly notable. In the initial exercise, all four scenarios (one generated in plenary and three in independent small groups) included the large-scale deployment of solar geoengineering technologies. Such deployment was not an *a priori* assumption of the exercise and, in the opening workshop discussions, many participants had in fact expressed strong philosophical objections to solar geoengineering technologies being deployed or even seriously considered. Yet deployment emerged in every scenario, despite these foundational objections.

Reflection upon this outcome raised a variant of the 'slippery slope' hypothesis; i.e. that the propensity for technologies to be developed once conceived of, and then used once developed, might be at play in the exercise, and moreover that it may herald similar trends for the broader evolution of solar geoengineering technologies. (Alternative hypotheses include both groupthink and bias created by the premise of the workshop. However, the potential for both of these biases to be equally present in real-world decision environments was also noted.) To consider alternative possibilities, a second scenario exercise was conducted to produce two additional scenarios that were premised *a priori* on non-deployment. For at least one of the two scenarios, the group responsible found notable difficulty in generating what they considered to be a plausible non-deployment storyline.

INTRODUCTION

Technologies for intentionally modifying Earth's climate—commonly referred to as *geoengineering* or *climate engineering* technologies—have the potential to dramatically shape the future of our environments and societies. Attempts to engineer the weather, on a variety of scales, have had a long history, but the serious discussion of global projects aimed at the effects of climate change is comparatively new.[1] Either way, scientific and engineering research into geoengineering technologies is now quickly expanding. This trend is driven primarily by researchers concerned that global mitigation of carbon dioxide emissions is occurring too slowly to avoid potentially disastrous climate change during the coming decades.[2]

As a result, diverse stakeholders around the world are now starting to grapple with how emerging geoengineering research and technologies can be governed in ways most likely to steer the world towards positive future outcomes.[3] This question is frustrated by the fact that these technologies are shrouded in scientific uncertainty. (In fact, many remain largely in the realm of imagination.) Moreover, the future political and social contexts in which these technologies might operate are, if anything, more unknowable and unpredictable than the technologies themselves. Given all this, how can we begin to define a governance system which could achieve good outcomes, especially when each society, and each individual, may define their own 'best possible future outcome' differently?[4]

Scenario planning offers a way to start coping with this breadth of uncertainty.[5] Simply attempting to predict how the future will unfold can lead to dangerously myopic thinking about the situations we may face. Scenario planning methods, however, can help us to think methodically through a wide range of possibilities for the future. This process can be a powerful tool for identifying key drivers likely to shape the complex dynamics of our futures: issues that any geoengineering governance system will need to come to grips with.

This report presents the outcomes of a workshop whose participants used select scenario planning methodologies to explore how a specific set of emerging geoengineering technologies, and their environmental implications, might coevolve with social and political possibilities. The workshop focused particularly on *solar geoengineering* (*also known as solar radiation management or SRM*) approaches. Preliminary studies suggest that the most prominently discussed SRM method—stratospheric aerosol injection—may be able to alter the global climate system quickly (*within a year*) and dramatically (*by at least several degrees*). Direct implementation costs could be as low as a few billion dollars per year.[6] These 'high-leverage' characteristics make SRM a highly contentious and difficult-to-govern geoengineering method. The fact that stratospheric aerosol injection can be done largely through existing, widely accessible technologies creates an even more urgent need for considering near-term governance alternatives[7], especially given the wide variety

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1 Fleming (2010).

2 Shepherd *et al.* (2009); SRMGI (2011); Rayner, Blackstock and Viola (2011).

3 Victor *et al.* (2009); Blackstock and Long (2010); Keith, Parson and Morgan (2010); Banerjee (2011); SRMGI (2011).

4 Collingridge (1980); Rayner (2011).

5 Schwartz (1991); van der Heijden (1996); Ogilvy (2002); Verchick (2010); Ogilvy (2011).

6 Blackstock *et al.* (2009); Shepherd *et al.* (2009); Keith, Parson and Morgan (2010).

7 Victor *et al.* (2009); Blackstock and Long (2010); Keith, Parson and Morgan (2010).

of unpredictable ecological and social consequences that these technologies could have.[8]

The following subsection provides a brief introduction to prospective SRM technologies, including their potential environmental and societal implications. The next section outlines the scenario planning methods used for the workshop, while introducing some of the broad insights generated throughout the process. The detailed scenarios developed by the described workshop process are then presented, and the report concludes with a brief discussion of scenarios and possible follow-on activities.

An in-depth analysis of the lessons for governance that can be derived from these scenarios was beyond the scope of both the workshop and this report. Nonetheless, we consider the scenarios presented herein as an important set of possible futures against which proposals for an SRM governance system[9] can be compared, in order to evaluate how effective such proposals might be under widely varying conditions. At a minimum, this approach could identify potential weaknesses (and possible collapses) of specific governance frameworks. At best, it could spark new ideas for governance frameworks able to robustly secure better outcomes across a diversity of possible futures. We hope that the scenarios generated by this workshop, along with the recent outcomes of other similar exercises,[10] can provide a useful foundation for future research into geoengineering governance and contribute to the ongoing, multilateral conversation about it.

8 See e.g. Robock (2008).

9 For examples see: Bodansky(1996); Lin (2008); Victor (2008); Victor *et al.* (2009);Virgoe(2009); Banerjee (2011); Hester (2011); Humphreys (2011);Rayner(2011); Reynolds (2011). Blackstock and Ghosh (2011) provides a synopsis of most existing proposals.

10 Milkoreit *et al.* (2012); SRMGI Kavli (2011); Climate Engineering Summer School (2011).

Solar Geoengineering (SRM)

Solar geoengineering, also known as Solar Radiation Management (SRM), refers to technologies that aim to reflect solar energy back into space in an attempt to offset the increased retention of energy caused by the greenhouse effect. One commonly proposed method is the injection of sulphate aerosols or other reflecting particles into the upper atmosphere by using aircraft, but various technological strategies are possible.

SRM has been suggested primarily as a 'Plan B,' with research into geoengineering techniques proposed as a kind of insurance policy in case mitigation efforts prove inadequate or the climate system starts exhibiting signs of severe instability. However, SRM is often seen—both by those who support research and those who oppose it—as laden with physical and political risks and uncertainties. While SRM is expected to reduce global average temperatures, it would not necessarily serve as a perfect offset to the greenhouse effect; for example, it could alter regional temperature and precipitation patterns in complex and unpredictable ways. Some important ecosystem effects of high atmospheric carbon dioxide—particularly ocean acidification, which is a chemical process not driven by solar radiation—would not be ameliorated by a SRM approach. Deploying SRM could also affect a variety of other human activities and ecosystems, for example by reducing the effectiveness of photosynthesis and photovoltaic solar generation. These, in turn, could cause complex and unpredictable changes in human social and economic systems. Finally, certain forms of SRM could have tangible, experiential impacts—such as white skies and dramatic sunsets[11]—which could affect daily human life in a variety of ways.

SRM technologies could—from at least monetary and

11 Robock (2008)

technical perspectives—be deployed by an individual county (possibly even clandestinely), which could have complex repercussions for international security and climate governance. Even if unilateral action remains unlikely for geopolitical reasons, the potential for coalitions-of-the-willing to emerge in the face of protracted climate debates is quite real. The availability of SRM technologies—or even the promise of their availability—might reduce political will to mitigate or adapt to climate change. It is also possible that the prospect of SRM might encourage societies into aggressive carbon mitigation. If SRM were used as an alternative to serious reductions in greenhouse gas emissions, rather than as a supplement to them, temperatures would rebound almost immediately—with severe consequences—if the solar shield was inadvertently or intentionally removed.

For comprehensive reviews of the issues summarized here, along with detailed references to literature for all of the points made above, please see Blackstock *et al.*. (2009), Shepherd *et al.* (2009) and SRMGI (2011).

Scenario Workshop Method and Process

The development of the workshop process was heavily shaped by the experience of the facilitator, Dr. Jay Ogilvy, and drew upon the scenario planning methods pioneered by the Global Business Network.[12] Under ideal circumstances, these methods are deployed in an iterative, multi-stage process lasting many weeks. Given the significant time constraints under which this workshop took place, it used a streamlined approach in which the most essential components of the full methodology could be preserved. Specifically:

1. Exploration of extended time horizons, which in the case of our exercise extended to between 2050 and 2100.
2. Consideration of the broader context in which the primary subject of the exploration (*in our case, SRM technologies*) will evolve over this period.
3. The integration of a diverse set of perspectives and expertise, which in our case was reflected by the broadly interdisciplinary and intergenerational group of workshop participants. (Regrettably, a lack of resources made it impossible to assemble a robustly diverse international group.)

Prior to the workshop, the organizers and facilitator conducted advance research and interviews in order to set the agenda (*see Appendix 1*). In addition to the introductory and informational talks at the start, this preparation work also generated two additional inputs.

The first input was an initial question intended to launch the workshop: ***What key uncertainties need to be reduced before SRM research and deployment can be considered?*** While the workshop did not seek to directly answer this question, it was useful for defining the near-term challenges and decision points for which developed scenarios might be particularly helpful.

The second input consisted of initial suggestions for two critical uncertainties that could serve as the axes of a two-by-two scenario matrix that could be used to guide the scenario development process.

The Two-Axis Scenario Method

The *two-axis method*[13] is a commonly used tool in scenario planning. In brief, a variety of axes along which different futures might be characterized are identified. These axes could describe any physical, social, ethical, political, or economic condition, or combination thereof. Each axis is then dichotomized into two extremely opposing manifestations: for example, if the parameter is 'Per-

12 Schwartz (1991); van der Heijden (1996); Ogilvy (2002); Ogilvy (2011).

13 Ogilvy (2002, 2011)

ceptions of climate change', the opposing ends might be "*climate change is scientifically proven to be the result of human emissions*" versus "*climate change is a hoax*." Two of the possible axes are then selected (*in our case, on the basis of group preference determined by voting*), and used to form a two-by-two *scenario matrix*. A descriptive scenario is then developed for each of the four quadrants of the matrix, with the only constraint being that each scenario accurately reflects the characteristics of its quadrant.

The axes initially proposed as candidates for the workshop scenario matrix were: mitigation (*high mitigation vs. low mitigation*); climate sensitivity (*fast and severe climate change vs. slow and mild climate change*); and climate governance (*highly international vs. highly devolved*). These proposals were the starting point of a facilitated discussion that produced numerous other suggestions for candidate axes, all of which are described in Appendix 2.

Selection of the final axes proceeded in three steps. First, participants each voted for the axes they felt best represented dimensions of the future which they believed it would be important or productive to explore. The voting process narrowed the field to three final candidates (*tabulation of votes is provided in Appendix 3*): *Controllability of SRM Technologies* (Controllable versus Uncontrollable); *Equity of SRM Governance Regime* (Equitable versus Inequitable); and *Weltgeist* (Rational versus Spiritual conceptions of the world). Second, the facilitator than constructed two matrices based on these three candidates; these matrices are shown in Appendix 4, along with caricature labels for each of the quadrants. These candidate matrices formed the basis for an extended discussion and further honing by the workshop participants, which, during the third and final step, generated the matrix used as a basis for subsequent scenario development.

Workshop Scenario Axes and Matrix

The two axes chosen by the workshop participants were:[14]

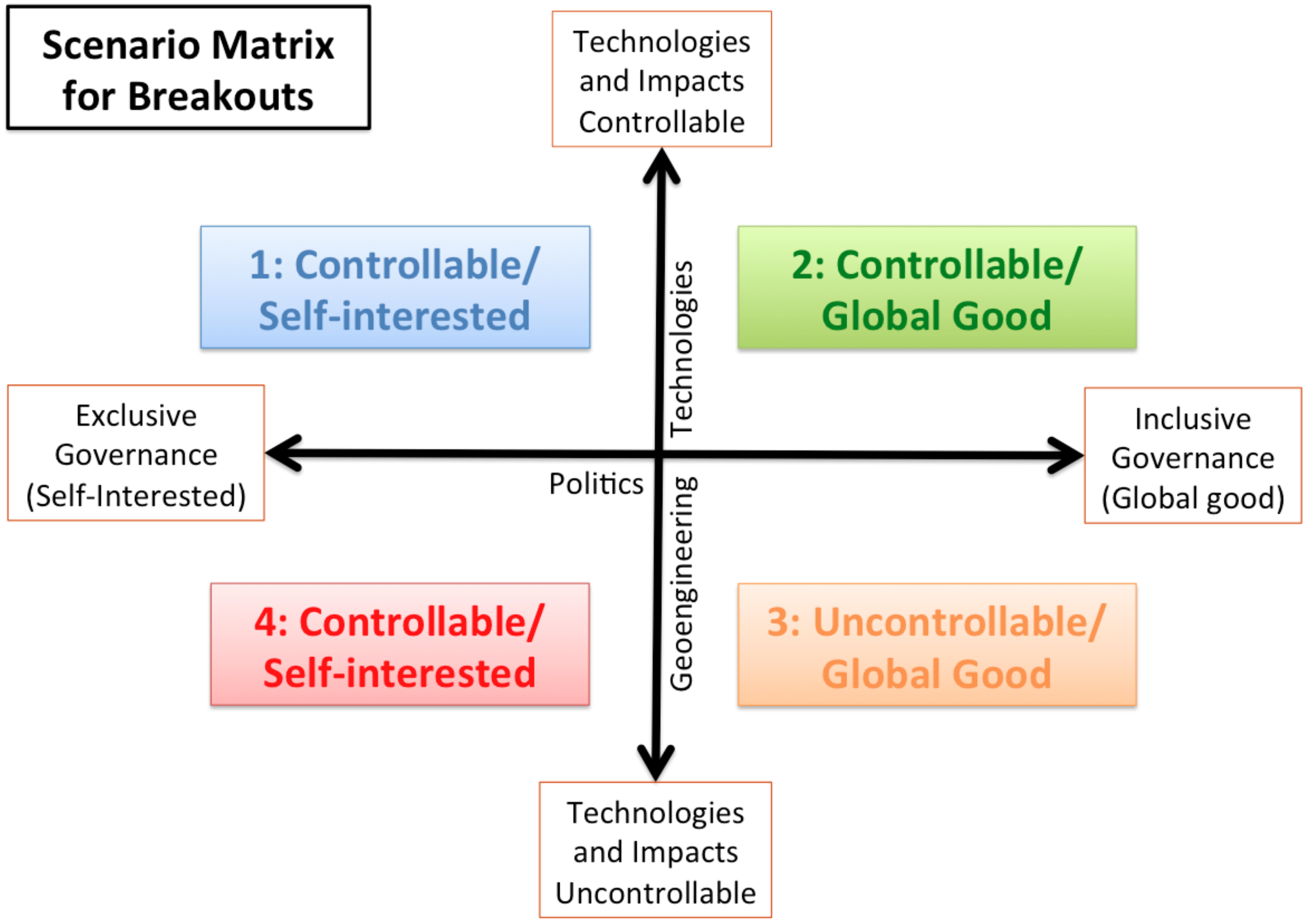
X-axis: Governance is Exclusive (Self-Interested) vs. Inclusive (Global Good)

This axis represents the self-interest of the world's politicized actors with regard to matters of global import. It is assumed that the term 'actors' refers not only to the traditional nation-state, but to non-state and sub-state actors as well: civil society and NGOs, industry, regional governments, minilateral clubs, etc. At the 'exclusive' end of the spectrum, these actors enact agendas that reflect only their own narrow self-interest in the impacts of SRM. At the 'inclusive' end, these actors have a more expansive conception of the 'global good,' and pursue agendas that reflect more collective interests.

Y-axis: Technologies & Impacts are Controllable vs. Uncontrollable

This axis represents the technical controllability of SRM technology – the degree of knowledge and influence over the direct *physical* impacts of deployment on the climate. It is assumed that such 'control' entails understanding of the technical aspects of geoengineering, as well as the uncertainties (sensitivities to intervention and potential tipping points) of the climate system. At the 'controlled' end of the spectrum, the physical climate system would respond accurately and predictably to a given deployment. At the 'uncontrolled' end, climate might display unexpected changes in response to interventions. These axes are depicted on the next page, along with initial proposed titles for the four quadrants.

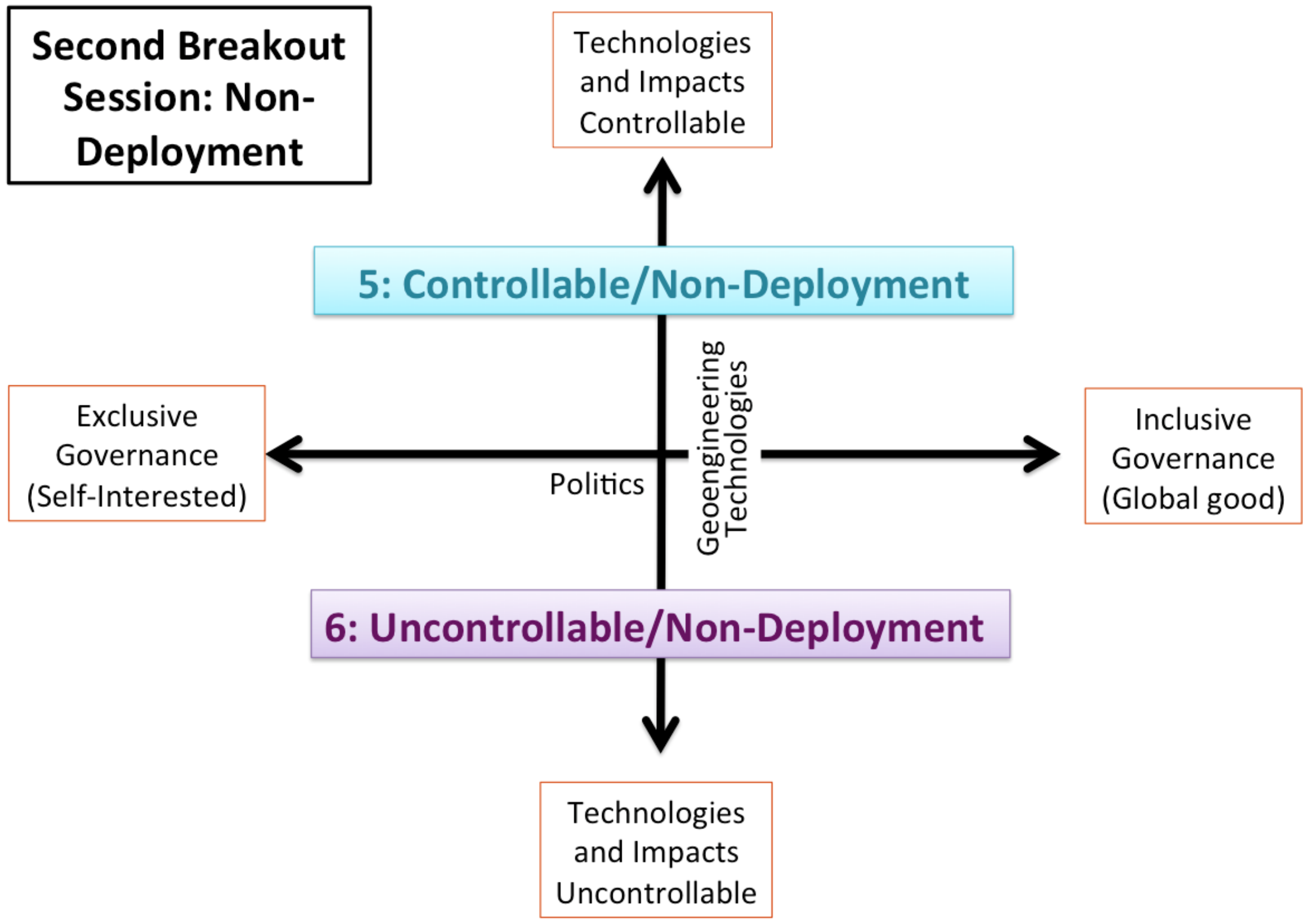
14 The 'control' axis, which eventually became the Y-axis, was not significantly changed during this discussion. However, many participants noted that the proposed 'equitability' axis was highly subject to differing value judgements that would make a common basis of understanding for scenario building difficult, and the group decided to modify it into the 'self-interested' continuum that was eventually used as the X-axis.



'Headlines Method' for Scenario Development

Given the limited time available during the workshop, complete development of scenarios was not possible. In order to efficiently capture the workshop participants' insights into each scenario quadrant, a *headlines scenario method* was used to identify core trajectories for each scenario. Before discussion began, participants were asked to spend five minutes independently crafting imaginary news headlines (generally one per participant) that they felt captured an important element of the scenario. These were then presented to the group, collectively discussed and honed to ensure meanings were clear, and sequentially ordered to create a rough narrative flow within the scenario. Throughout this process, headlines were significantly altered; the original headlines were sometimes discarded, and in some cases new headlines were added.

The first run-through of this headlines scenario method was led by Dr. Ogilvy, the workshop facilitator, and included all workshop participants. Subsequently, three breakout groups were created, which independently applied the same method to generate scenarios for each of the remaining three quadrants.



Additional Scenarios for Non-Deployment

Once rough scenarios had been created and reported back to the rest of the workshop participants, it was generally observed that all four scenarios had involved the large-scale deployment of SRM technologies, even though this had not been an explicit *a priori* assumption for any of them. Given the level of controversy surrounding the development, and especially deployment, of SRM technologies, this was an unexpected outcome, especially since at least several participants had raised categorical objections to SRM technologies ever being deployed. This in turn raised the question of whether the propensity for technologies to be developed once conceived, and then used once developed, might be likely to drive towards the long-term deployment of SRM technologies (as it had during the scenario planning process).

The participants discussed whether, since the workshop itself was premised on exploring SRM, the scenario outcomes may have been biased towards SRM deployment. Recognizing the potential for this bias, the group then decided to explore two additional scenarios (*in breakout groups*) premised upon non-deployment. It was decided that these should be separated along the *Controllable – Uncontrollable* axis of the scenario matrix, not the *Exclusive – Inclusive* axis. These outcomes, labelled Scenarios 5 and 6, were represented on the scenario matrix as shown above.

Additional Variables: Black Swans and Key Uncertainties

After all six draft scenarios had been roughly developed, Dr. Ogilvy led participants through two final conversations designed to identify variables that had remained under-considered due to the truncated scenario planning process.

The first conversation focused on identifying potential 'Black Swan' events—events that are rare, largely unpredictable, and highly disruptive to the social or physical conditions of the future.[15] 'Black Swans' are important to imagine separately, since they typically seem 'out-of-bounds' during scenario development because they tend to alter the foundational assumptions from which scenarios unfold. This ability to alter assumptions is exactly why 'Black Swans' are important, however. Had there been expanded time, the implications of these events for the developed scenarios would have been explored. As there was not time for such a comprehensive exploration, a list of representative Black Swan events was instead generated (*see Appendix 5*) so that future activities (*or governance analyses*) could take them into account.

The second conversation returned to the initial question for the workshop—*What key uncertainties need to be reduced before SRM research and deployment can be considered?*—and asked workshop participants for their concluding perspectives. The objective of this exercise was to spark ideas for new research that might reduce some of the uncertainties, potentially making the development of SRM governance frameworks somewhat easier. Participants' answers are documented in Appendix 6.

15 Taleb (2007)

Post-Workshop Scenario Writing

The final stage in the scenario development process took place after the end of the workshop. Based upon the rough scenarios developed during the workshop (*documented through flip chart sheets, PowerPoint slides, and audio recordings of conversations*), the authors of this report drafted expanded timeline and narrative versions of all six scenarios that had been developed in the workshop. These drafts were then circulated to workshop participants for review and comments. Final revisions—including an attempt to ensure scientific and social plausibility for the scenario storylines (to the extent possible)—were conducted by the authors of this report, and all remaining errors are the responsibility of the authors alone.

The time constraints which necessitated the use of the headlines scenario method meant that post-workshop scenario writing was inevitable for this exercise. Heowever, the process of converting headlines into prose, repeatedly circulating drafts, and then refining them proved to be extremely time-consuming. Future conveners may wish to consider whether scenario drafts can be created by small teams operating after the main sessions, allowing the non-author participants to review the text of the scenarios on the last day of the workshop (or immediately afterwards.)

SCENARIOS

The following section presents the six scenarios developed using the methods and process described above. The scenarios are numbered as per the two scenario matrices shown previously. Each scenario is presented using clips from future news sources, followed by a longer, more reflective piece. Both of these elements were written by the authors of this report based on the workshop discussions.

SCENARIO 1: CONTROLLABLE / SELF-INTERESTED

Climate Cools, But Rain Has Not Returned (2025)

Australian food production is down another 30% this year as terrible water shortages continue in spite of global climate stabilisation, which climatologists had hoped would reset regional weather patterns. Rumors suggest Australia has signed a multi-billion-dollar contract with Boeing for "cloud enhancement" technology supposed to divert atmospheric moisture...

Push and Pull: Weather (Tug-of-)War? (2032)

Ice reformation in the Arctic is frustrating Baltic oil drilling efforts, but recent cooling in Greenland and Antarctica provide the best long-term hope for stopping sea level rise, which still presents an existential threat for "nearly-drowned nations" such as Palau.

"You're Stealing Our Rain": African Farmers Sue Boeing in U.S. Court (2044)

Legal scholars expect the trial court to dismiss the case as a "political question," although some scientists are persuasively linking Boeing's newly deployed "cloud enhancement" project in India with the increased drought in central Africa. Cloud enhancement is widely understood to have saved millions of lives and trillions of dollars in Australia...

The World's An Oven, But Who's The Cook? (2065)

Residues of new rapidly degrading heat trapping molecules have been confirmed at dozens of sites worldwide. Chemically engineered to have shorter lifetimes and higher heat trapping ability than previous substances, these new molecules have already begun offsetting a significant amount of the cooling from SRM geoengineering in regions such as the Arctic, where the discovered concentrations are highest. Chemical tracing has still not yet identified the origins of these unique emissions due to their rapid chemical breakdown in the atmosphere...

Prominent Climate Engineers Note That the Politics of Geoengineering Have Been Less Controllable Than the Technology

NEW HAVEN, Connecticut (2067) – Fifty years after they were first deployed, the technologies of solar geoengineering have proven to be scientifically controllable. However, reaching geopolitical agreement on the use of these technologies has been far more problematic.

These were the conclusions of the 32nd Conference of the U.S. Climate Science and Engineering Association. As the CSEA's chairman noted: "There were good reasons to be worried in the early days, and perhaps some countries took action more quickly than was prudent, but, as it turned out, climate engineers were either very smart or very lucky. The managed injection of particles into the atmosphere did not shut down the monsoon, did not cause an irreversible ice age, and did not poison anybody. What the particles did was block the sun and reduce global warming. This meant that we at least delayed, and possibly avoided, the full price of filling the atmosphere with greenhouse gases. We're still emitting particles, and – so far, at least – we're not paying that full price."

At the outset of geoengineering deployment in the late 2010s, the technocratic management of the issue was not accompanied by political coordination. Throughout the previous decade, global temperatures had increased much faster than had been anticipated. China and its neighbors were hit particularly hard: by the end of the decade, rice-producing countries were suffering severe crop failure almost every other year. Unfortunately, this hardship prevented China from focusing resources on its low-carbon development trajectory, and other major emitters were unable or unwilling to transition their own economies away from greenhouse gases. Soon after this, sophisticated climate models done for the 6th IPCC report reiterated that even very dramatic reductions in carbon emissions—which many modellers considered necessary—would not improve the climate situation of severely affected countries for at least several decades. Shortly afterwards, the international climate negotiations collapsed.

In 2020, China officially admitted what had been an open secret for several years. Facing significant internal pressure to address rising temperatures, its central government had decided to re-inject, at high altitudes, a portion of the sulfates scrubbed out of coal stacks as part of its Clean Air Initiative. These sulfates spread across the globe and, although they fell to earth within a couple of years, while they were in the upper atmosphere they cooled the planet by several tenths of a degree centigrade.

Objections were immediate and widespread, with environmentalists, climate skeptics, solar power companies and astronomers (along with sufferers of Seasonal Affective Disorder) complaining loudly, and sometimes violently. However, China—whose rice crops were consistently succeeding for the first time in years—insisted on its absolute right to continue the program, and no international laws or treaties suggested otherwise. Eventually, China even sent cloud-forming ships into international waters north of Australia in a successful attempt to stabilize the "doldrums" (the low pressure are of that atmosphere known formally as the Intertropical Convergence Zone), which had been displaced by their sulphate release. A proposal by Singapore to add a liability regime for non-military climate engineering to ENMOD (the weather modification treaty passed after Vietnam) gained substantial traction, but was ultimately unsuccessful.

As global temperatures declined and the worst-feared disasters associated with geoengineering failed to happen, research funding for climate engineering soared to exceed the annual global expenditure on greenhouse gas mitigation and climate adaptation combined. Eventually, long-lived and controllable nanoparticles steered by magnetic fluxes replaced shorter-term sulphate injections.

It was this stage at which some argue that the geopolitical breakdown of solar geoengineering became entrenched. A retired State Department official, one numerous policy-makers present at the CSEA meeting, noted: "Was that the beginning of the real changes, when countries, all following their own interests, abandoned any pretence of returning the climate to how it was, and started to think about what kind of climate they would like to have?"

Thirty years of political competition have now passed—with increasing greenhouse gas levels and complex climate effects requiring a deeper and deeper commitment to more and more sophisticated global SRM technologies, along with a parallel array of regional to local weather modifications technologies to achieve 'finer tuning' of desired outcomes. Countries have struggled repeatedly to find common purposes, but—much like the carbon mitigation negotiations of the 1990s through 2010s—they have eventually pulled apart at the last minute. A new global treaty was almost passed in 2042 to deal with the acidification of the ocean due to carbon dioxide, but that process ultimately failed as well. As a result, regional attempts to preserve ocean marine life, ranging from massive localised 'ocean-liming' projects to genetic alteration of species, are now widespread.

The CSEA also discussed the possibility that the current degree of control over geoengineering technology would force the international system to seek better coordination of geoengineering deployment. Circumstances might indicate such a need, as predictions of weather wars are increasing in the American media. Atmospheric stations around the world have observed the chemical residues of a new kind of heat trapping molecule, apparently designed to create a rapid warming trend. These rapidly degrading molecules have clearly been manufactured and released on purpose, with their chemical volatility in the atmosphere making their origin difficult to identify. The former state department official challenged the CSEA plenary: "Will we respond by simply releasing more cooling particles of our own?"

SCENARIO 2: CONTROLLABLE / GLOBAL GOOD

US Navy Develops Green Ships, Inspires New International Maritime Standards (2019)

As the International Maritime Organization's stringent new ship emission standards come into effect, the U.S. Navy has announced that 90% of its ships are now running on biofuels derived from mustard-seed and seaweed…

U.K. and Russia Launch Small-Scale Geoengineering Experiments (2024)

During the planet's fifth consecutive hottest year on record, the U.K. completed a year-long cloud-brightening initiative off the coast of East Africa with inconclusive results. In May, with full support from its oil and gas industries, Russia launched nanoparticles equipped with RFID chips into the upper atmosphere…

U.S. Congress Embraces Geoengineering, Adds Momentum to Climate Talks (2032)

The impacts of geoengineering technology will be closely studied by the U.S. Department of Defense. The U.S. initiative breathed new life into the international climate negotiations, with the world's most vulnerable countries striking bargains with countries eager to geoengineer on their behalf.

Small Island States Saved from Drowning, but Oceans Continue to Acidify (2041)

Island state Presidents have thanked the U.K. and U.S. for lowering storm surge and deflecting hurricanes off the coasts of their islands, but in a parallel statement the World Reef Congress noted the near-total destruction of Pacific coral reefs through ocean acidification…

Anti-Geoengineering Protests in China and the U.S. Trigger Aggressive Mitigation (2047)

The jobs-oriented Carbon Mitigation bill has passed the U.S. Congress after a fourth month of anti-geoengineering protests rocked the economies of both the U.S. and China. Sparked by anger over the perceived influence of fossil fuel interests over climate control technologies, these protests have forced political parties to reconsider their support of now ubiquitous geoenginering technologies…

Global Earth Compact Elevates Indigenous People's Council (2051)

The Global Earth Compact signed yesterday includes the creation of an indigenous people's council and a coalition of green NGOs as part of the oversight for the Global Environmental Regulatory Agency (GERA). Dubbed the "Carbon Police" (or, more irreverently, the "Karma Police") by corporate detractors, GERA has been allocated unprecedented transnational jurisdiction to standardize carbon markets around the world.

Carbon Regulators Turned "Karma Police"?

***New Haven Reporter*, Editorial (2055).** Today, with every citizen on Earth subject to the carbon-constraining vigilance of the GERA—the so-called "Carbon Police"—we have to ask how we got here. Certainly, the increased powers given to the U.N.'s military—the humanitarian peace-keeping force—circa 2025 set a powerful precedent. And historians trace the seeds of these carbon regulating policies as far back as the carbon markets proposed in the 1990's. An even more more salient question now is: have these carbon regulators overstretched their mandate? The GERA's unofficial but widely adopted motto, "Carbon is karma," certainly seems to suggest a more pervasive social agenda than simply carbon-market restructuring!

Recall that global environmental governance attained maturity as late as 2030, when the U.S. Congress rapidly embraced geoengineering after the promising early field tests in the U.K. and Russia. Without the U.S.'s enthusiasm for geoengineering, many argue, the global climate negotiations—which had been stalled for almost half a century—would not have been revitalized. The flood-gates were finally open. Industrialized nations realized that they could assuage the fears of vulnerable countries at a fraction of the cost of signing a climate treaty. The United Nations Framework Convention on Climate Change suddenly became an international bazaar. Rich countries drove their own technological development by doing geoengineering on behalf of drowning small island states.

Large-scale solar geoengineering experiments and eventually deployment were cautiously mounted. Despite the success of geoengineering at stabilising global temperatures, water shortages and food crises continued in several areas of Africa and Asia. International scientific efforts strongly suggested that inevitable natural variability—and not the geoengineering activities—were the cause of these challenges. But disgruntled political leadership and public opinion in effected regions still argued that solar geoengineering was really being controlled by the "globally dirty" fossil fuel industry. The slogan of living in an "over-controlled world" struck a chord with purportedly disenfranchised publics world wide, sparking the unprecedented rise of new green politicians.

Governments of the time did not foresee the widespread protests of 2047 against the "global geoengineering complex," leading to the new global environmental compact in which many stakeholders previously on the fringe (indigenous people's groups, green NGO's, small developing countries, and the like) claimed formalised influence over the first ever global environmental regulator.

Given their international autonomy, large budget and strong PR arm, the GERA is well-placed to resist checks and balances on their authority. Their influence has gone beyond government to affect education. Although the global climate was already stabilising before 2045, many now inaccurately credit the GERA alone (rather than the geoengineering technologies still quietly in operation) with that achievement. This vast and complicated green bureaucracy should not go unquestioned.

For today's business communities in all but the most privileged enclaves it's a given that industrial-scale access to a carbon-intensive energy source will require filling out dozens of forms and waiting for up to ten years. Recently, the world's richest person, C.T. Looey, has debuted a new, popular social media platform that has made dealing with (or, as some might say, bribing) the GERA's bureaucracy far more efficient and transparent. Meanwhile, some of Looey's rivals have been running marketing campaigns about new, improved, geoengineering technologies that have great appeal for those who oppose the GERA's broad reach. Would these Carbon Police have accrued so much authority without the backlash against geoengineering? If we had solved climate change earlier, would we have needed them at all?

SCENARIO 3: UNCONTROLLABLE / GLOBAL GOOD

IPCC Unable to Predict Geoengineering Consequences (2019)

Based on the recent sulphate-based SRM field-tests conducted by U.K. and U.S. scientists in the Arctic and South Pacific, the IPCC's latest assessment report (AR6) has concluded that the global climate system is too unstable to predictably forecast the repercussions of large-scale solar geoengineering…

Security Council Meets over Methane Outgassing (2023)

The U.N. Security Council met today over recent and verified reports of large-scale methane outgassing from melting Arctic permafrost. Debate over exploring a solar geoengineering response was split, with China and the U.K. backing the proposal, but India firmly opposing on the grounds of uncertain effects for the South Asian Monsoon…

Multi-Billionaire Funds SRM Fleet to Save Drowning Islands (2025)

James Templeton of Long View Corp. pledged yesterday to fund a fleet of aircraft to deploy reflective aerosols within a month over international waters. The location of the fleet's base has yet to be announced, but there are early indications that Templeton has purchased an airfield in Nunavut—Canada's northernmost territory, and one of its most politically devolved. Some have immediately denounced the outspoken philantropist as an unaccountable Bond-esque 'Greenfinger'…

Indian Crop Failure: Geoengineering at Fault? (2035)

A few years after James Templeton's 'Bright Sky' solar geoengineering initiative, Arctic methane deposits have refrozen, Greenland's ice-sheets appear to have stabilized, and the IPCC has declared sea-level rise an 'issue in retreat'. But the IPCC has also noted decreases in precipitation from the Asian Monsoon and increasing crop failures…

Monsoon Fails for Second Year in a Row; 1 Billion Starving (2037)

The Indian government, in a national state of emergency for the past two years, is struggling to avoid the fall of the fifth government elected since the famines began. The slums of Mumbai, Kolkata, New Delhi, and others are filled with refugees…

'Greenfinger' Templeton Found Dead in His Cabin (2039)

… still unconfirmed whether Templeton, one of the century's most influential and notorious figures, was a suicide. Reception of the news was mixed, with several world leaders affirming his immediate legacy as the last decade's 'most necessary evil'…

Geoengineering internationalized; compensation for South Asia forthcoming (2040)

Today the U.N. Security Council has formally passed control of the Bright Sky Fleet of solar geoengineering aircraft to a new international agency, alongside a ban of any further unilateral geoengineering by nations, firms or individuals. The contentious UNSC decision states that climate cooling deployments will continue until a proper assessment of the risks of cessation is complete…

Bright Sky at Morning: Can We Take Warning?

NEW YORK CITY, New York (2041) – After a fortnight-long hiatus, the airships formerly known as the Bright Sky Fleet resumed their stratospheric deployments yesterday. Officially renamed the U.N. Solar Radiation Geoengineering Initiative (UN-SRGI) in a low-key pre-flight ceremony, James Templeton's fleet has now been brought fully under the auspices of the U.N. Security Council, with the political support of the UNFCCC and the Group of 32.

"We are now attempting to address this global issue with a global solution, and as a global community," said a UN-SRGI's spokesperson. "Acknowledging the concerns of South Asian states regarding the continued effects of solar geoengineering on their rainfall patterns, the United Nations is crafting an exit strategy which will stabilize our global climate to the benefit of all nations." This all but confirmed that the deployments would continue for now at the expense of India, Pakistan, and Bangladesh, where the South Asian Famine has left millions dead—and over ten million starving and dispossessed—in the last three years.

She went on to reveal that UN-sponsored studies on the impacts of a gradual reduction of solar geoengineering are well underway, and the UN-SRGI's intention is to scale down deployment as soon as impacts can be known with any certainty. Other elements of the 'exit strategy' are being coordinated at the highest levels of international governance. Carbon geoengineering and renewable energy technologies—long placed on the back burner—have received huge bursts of public and private funding. Large trade-and-aid packages have been offered to, and accepted by, the South Asian states.

The news that the global sun-block would continue was met with mixed reactions in the Indian capital of New Delhi, where relief efforts led by the U.N. High Commissioner for Refugees (UNHCR) and Red Cross/Red Crescent are coordinated. Spontaneous protests erupted all over the city when the news broke, but some international officials were more sanguine. A UNHCR administrator, speaking under conditions of strict anonymity, noted: "Would it have been better if solar geoengineering been prohibited because of theories about risks? If the methane outgassing from the Arctic had raised the global average temperature 6 to 10 degrees, we might all be dead. The moral mathematics baffle the mind, but don't we have to weigh this against the deaths and hardship in South Asia today?"

In the early 2000s, when solar geoengineering was first discussed as an insurance policy against catastrophic climate change by elements of the scientific community, such conundrums barely registered on the global agenda. Governments and societies had known about the greenhouse effect and the need for carbon cutbacks since before the UNFCCC's founding in 1992. Yet the potential for 'tipping points' was consistently ignored. Developed and emerging economies of the period had continued their reliance on carbon to fuel their growth, until the Arctic finally started to belch methane and global temperatures spiked precipitously.

With solar geoengineering seemingly the only solution on hand, governments proved willing to ignore field-tests showing that even limited deployments could trigger large and unpredictable changes in the South Asian Monsoon. Since the greatest risks of geoengineering appeared to affect only the equatorial Asian states, the majority of the developed, emerging, and small island governments continued to favour it, even when 'Greenfinger' Templeton decided to privatize climate security. When the government of oil-rich Canada used its tenuous political relationship with its northern territories as an excuse to grant tacit acquiescence to Templeton basing his fleet within its borders, those same states consistently defended Canada in international forums. They could free-ride off the vigilante billionaire's well-meaning crusade, with no moral or legal liability for the risks.

The Indian government has chosen not to dwell upon history. A statement from the Interior Ministry read: "The whole world must now take collective responsibility to amend for the choice our preceding generation of leaders and citizens did not make: to have comprehensively mitigated greenhouse gases when it was not too late to have done so. We did not take warning then. Perhaps we shall do better now."

SCENARIO 4: UNCONTROLLABLE / SELF-INTERESTED

Concerns Over Climate Uncertainty as Planes Soar in the Arctic (2019)

... the Daedalus Consortium, publically backed by a range of governments concerned about the severe climate disruptions of the last decade, have publically stated their intention to continue their nanoparticle deployments. Meanwhile, the IPCC has reiterated that the climate's sensitivity to human interventions remains highly uncertain...

Geoengineering Leads to Over Cooling (2024)

...climate researchers have blamed escalating cooling trends on unexpectedly strong cooling in the Arctic resulting from what some consider to be the overzealous and overshot geoenginering deployment of cooling nanoparticles by the Daedalus Consortium's. Other scientists have suggested that marked decrease in sunspots over the last five years has amplified the impacts of the Daedalus experiment...

Northern Migrants Clash With Southern Hosts (2032)

Weakened agricultural productivity and increasing severe winters are contributing to the increase in wealthy Canadians and Americans relocating to Central America and Mexico. Tensions continue to mount between these incoming migrants and local populations...

Stresses in U.N. as Geoengineering Blamed for Frigid North and Land Rights Issues (2035)

The U.N. Security Council has been unable to resolve, or even lessen, tensions between Northern migrants using their wealth to buy large tracks of land, and the increasingly displaced equatorial locals. Northern governments political protection for their expat citizens remains a key source of conflict...

Geoengineering Object of 'Terra' Attacks? (2038)

Four prominent nanotechnology facilities in the U.S. were taken off-line last night after a coordinated series of small-scale explosions. These institutions are widely believed to have contributed to the Daedalus Consortium's now defunct solar geoengineering initiative...

U.N. Tense on 100th Anniversary, as Tropical Countries Boycott Celebrations (2045)

Brazil, India, the Central American Federation, and the countries of the emerging Mediterranean Union coordinated their absence from the 100th Anniversary Celebration of the U.N. to protest the U.N.'s failure to address challenges surrounding Northern settlers in Southern states...

International Order Ending in Ice?

***Austin-Texas Sentinel*, Editorial (2045)**. As the Secretary-General of the U.N. remarked yesterday: "Most people in the pre-Daedalus years expected, like Robert Frost, that the world was more likely to end in the fire of global warming. But it is ice that now seems to be straining the era of international institutions to its breaking point. If the countries of the Mediterranean Union continue to question the legitimacy of the U.N., we risk descending into a world of fortressed and isolationist societies."

The challenge of resolving citizenship and land ownership rights in states like India and Brazil is now beginning in earnest. Wealthy citizens who left Northern countries when their climates warming trends first stalled, and then reversed, now own large tracts of land in several warmer states. Their influence on the legal systems of their new homes has made many native citizens afraid of losing significant rights, including the right to own agriculturally productive land.

We cannot look forward without looking back. For decades, initiatives to mitigate GHG emissions took a back seat to the imperatives of economic growth, with the dominant powers of the time—particularly China, the US, and the EU—unable to agree on the collective action necessary to comprehensively restructure the carbon-based economy. In the 2000's, solar geoengineering emerged as an idea, and in the 2010's as a realised response. There were many initial safety concerns, but in 2015, a comprehensive analysis of the most complex climate models available at the time—models that we now understand as regrettably simple—showed a near-absence of side effects. Global corporations, international powers, and some even some humanitarian groups immediately proposed SRM as a cheap and apparently safe alternative. They formed the Daedalus Consortium, which was the first to deploy sun-blocking sulphates and nanoparticles on a large scale. With "Fly farther from the sun!" as their slogan, Daedalus received the quiet support of the majority of the world's states, who were eager for a new solution to the quickly emerging climate crisis after the UNFCCC had imploded in failure in 2017.

The Daedalus Consortium, and the majority of the world's scientists, did not believe that solar geoengineering in the Arctic could overshoot its targets, triggering mild but persistent global cooling. Nor did engineers predict that, once deployed, their nanoparticles would stay lofted in the stratosphere far longer than expected, proving impervious to technical methods for removing them. Caused in part by the onset of an unexpected solar minimum that reduced the UV radiation meant to breakdown the nanoparticles, the consequence of these factors meant that temperature returned to near pre-industrial levels, straining a century's worth of infrastructure that had been built during a warmer period. This cooling was especially hard on agriculture, which had been adapted for more than a century to warmer climates, and was already being further adapted in anticipation of significant warming trends. Frost, wind, and altered precipitation patterns dramatically reduced global yields. While the possibility of counter-geoengineering to induce warming was widely discussed at the time, such ideas were ultimately rejected by societies unwilling to put themselves at further risk.

Now, with the United Nations feeling the strains caused by climate migration and agricultural insecurity, concerns about the future international order abound. Some Southern countries have partially suspended political and civil rights in order to contain the social instability caused by food and water shortages, combined with the new property regimes created by Northerners who were able to purchase wide tracts of rich agricultural land. Prospects for expanded cooperation between Northern and Southern nations currently appears low, and some Southern states are expelling large numbers of still-resident Northern migrants.

At the close of his speech, the Secretary General once again recalled the words of Robert Frost. "It seems strange," he lamented, "that the international order, concerned about an 'end in fire' by global warming only a few decades ago, risks finding itself frozen in the opposite. Yet, if we are undone, it will not be because of ice. It was lukewarm politics and wilful ignorance—ignorance of the risks of technology, the sensitivity of the climate, the self-interested fragility of the political system, and the hubris of our species—that brought us here."

SCENARIO 5: CONTROLLABLE; NON-DEPLOYMENT

Scientists Say That Sun-Block Will Have No Major Ill Effects (2018)

The IPCC's latest assessment report (AR6), has confirmed a tentative consensus that immediate impacts upon worldwide precipitation patterns of both climate change and proposed solar geoengineering are predictable with a reasonable degree of certainty…

Government Halts Geoengineering Plans as 'Solar-Gate' Escalates (2019)

A White House official has anonymously confirmed that the Air Force's first deployments of sun-blocking particles will be put on hold as popular furor over 'Solar-gate' reached new heights...

Geoengineering Not 'Silver Bullet' for Carbon Economy, Says Europa Report (2024)

Released by the Europa Group—a collaboration of the continent's top thirty universities—after a decade of innovative research, the 700-page report on the Economics of the Human Environment is, to date, the most comprehensive cost-benefit analysis (and endorsement) of a 'global green economy'. Accompanied by a popular outreach campaign unprecedented for such a publication, its prescriptions include…

'Environmental Gandhi' Denounces Climate Engineering (2028)

Dissident Chinese environmental philosopher Shen Feibi was given a standing ovation in Shenzhen in her first speech following the end of her house arrest. The soft-spoken Ms. Shen declared: "We could veil the sun; we could also pave every meter of forest, drain every lake, grow our food in test tubes, throw a concrete blanket over Mother Nature, and call it 'managing the planet.' Geoengineering can only lead us towards this grey dystopia…"

Rio+40 Shows Civic and Business Support For Global Green Economy (2032)

Forty years after its original incarnation, an Earth Summit in Rio de Janeiro has again broken new ground, overwhelmingly endorsing a reworked global green deal that has been hoped for since before Rio+20 two decades earlier…

Earth Compact to Green Global Economy

SHANGHAI, China (2033) – The European Union, the United States, and the China- and Japan-led Asian Economic Forum today announced a coordinated set of green stimulus packages designed to remake the global economy on a lasting, sustainable basis. The group of governments has been working on the plan for the last five years, and enjoys widespread support for the endeavor in their domestic publics. The agreement, unofficially termed "The Earth Compact", builds off years of patchworked green economy initiatives conducted by European, North American, and East Asian corporate, civic, and municipal networks.

"The ground has been shifting beneath our feet for years," the head of the Compact process remarked candidly. "Our governments were frozen for a time on the carbon economy, and contemplated geoengineering as a way of artificially extending the lifetime of that economy. But our young people, our captains of industry, our thinkers – they never let us deploy the technology, and they never let us forget the possibilities of green growth."

Movement towards this deal has been escalating since last year's Declaration on the Human Environment, signed by more than ten thousand of the world's civic and business leaders at the New Earth Summit (Rio+40) in Rio de Janeiro. Although the world's governments were unable to conjure a similar agreement at the time, global public pressure has, in retrospect, made the Earth Compact inevitable.

Yet this agreement would have seemed entirely impossible in 2018, when the IPCC Sixth Assessment Report (AR6) declared that while global average temperature appeared locked-in for at least 3-4 degrees of warming by century's end, the sun-block was, for all intents and purposes, controllable and predictable. However, as governments across the planet prepared to engineer the climate, waves of popular opposition emerged from disparate sources. The 'Solar-gate' scandal, which first broke in the US, made American deployment a political non-starter for years. Despite the eventual clearance of the charges of false data, the reputation of the climate engineering community never recovered. In Europe, the Europa Report established a new and credible metric for societal well-being, overturning decades of conventional economics thinking and providing fuel for a generation of young business and political leaders. The emergence of Shen Feibi, the 'Gandhi of her generation,' provided an eloquent voice against wayward anthropocentrism, and helped to galvanize support in China for a rational balance between humanity and the natural world.

Meanwhile, hybrid networks of subnational governments, the private sector, and civil society were creating 'facts on the ground', with regional carbon-pricing schemes, urban mega-region re-planning, and green energy incentives intensifying across Europe, Asia, and North America. The EU's decision to double down on nuclear energy in Northern Europe and solar energy in the Mediterranean, along with Korean and Japanese green stimuli made available internationally, set the early examples for state-led action in the late 2020s.

Early statements by the governments of Brazil, India, Australia, and Saudi Arabia indicate a tacit acknowledgement of the new state of affairs. Meanwhile, meetings at the World Economic Forum and World Trade Organization focused on the old issue of 'green protectionism'—tariffs raised by carbon-pricing states against goods from countries without similar standards—seem to be showing progress.

Shen Feibi herself was calm in victory. "In the beginning, we did not know what we were *for*—we only knew that we were *against geoengineering*," she said, in reference to the bottom-up global impetus that has led to the Earth Compact. "Now we are finding out what we are for: green tech, not grey tech."

Scenario 6: Uncontrollable; Non-Deployment

Coolest Summer in 200 Years (2018)

Thanks to exceptionally bad timing, several major solar geoengineeing experiments, mostly exploring nano-engineered particles, occurred the same year as two major volcanic eruptions. The net cooling the earth by 2-4 degrees Fahrenheit led to early frost onsets, wide-spread crop failures, and the coolest summer in 200 years…

Nanofukushima Movement (2021)

Ten thousand members of the self-labelled "Nanofukushima" movement went on hunger strike in subway stations in Japan, blocking transportation for millions of citizens. The movement calls for an immediate end to both nuclear power and geoengineering, and sympathetic protests are starting to emerge in other world capitals, particularly New York…

New Green Party Wins Seats in U.S. Election; Government Fears Geoengineering (2026)

The recently formed left-wing New Green party captured 21 seats in yesterday's U.S. Congressional elections. The party's most clearly-articulated position is its complete rejection of geoengineering, tracing it routes to the Nanofukushima protests earlier this decade.

Nanogeoengineering Leads to Birth Defects in Southwest U.S. (2030)

According to *The New England Journal of Medicine*, a longitudinal study in the Southwestern U.S. has concluded that nanogeoengineering experiments in the 2010's has led to birth defects affecting up to one in ten thousand babies born in the region over the past decade. Though leading medical authorities are calling for much more research before a conclusion can be drawn, several class action lawsuits are already being prepared…

Unep Bans Geoengineering After China-U.S. Threat of Military Retaliation (2036)

After the China-US declaration of military reprisal, wide-spread global demonstrations led an invigorated United Nations Environmental Program agreeing a global ban on geoengineering…

Depopulation and Biodiversity Loss (2050)

Since global warming has reached 4˚C, an unprecedented series of droughts, famines, tsunamis, and other catastrophic events has led to an estimated one billion deaths and the decimation of global biodiversity over the past decade…

Reflections on the Thirtieth Anniversary of the Fukushima Movement

***Kolkata Chronicle*, Editorial (2051)**. Today, on the thirtieth anniversary of what the Nanofukushima movement's members call "Day Zero," we should try once more to unravel the complicated series of events leading up to that day. Only a few months before Day Zero, the world had lived through the coldest summer in 200 years. The crop failures affected food prices everywhere, sparking riots and famines in Brazil, Indonesia, China, Russia, and Ireland. Only the wealthiest communities escaped without at least some hunger, with poor communities suffering severe, often fatal, malnutrition.

On "Day Zero," thousands of peaceful protestors chained themselves to subway turnstiles during an protracted hunger strike. They called themselves the "Nanofukushimites" and they were demanding a complete halt to all nano-geoengineering. Various sources agree that the mayor of New York City was sympathetic to copycat protestors, going so far as to issue them permits for the protests. The protests dragged on for days, then months.

Even as the Nanofukushimites staked out a meagre existence in the subway tunnels and catacombs of major cities, their supporters grew. Was it so surprising, then, that millions of Americans chose to vote for the New Green party, which promised to ban geoengineering? All the other issues we'd once cared about paled in comparison to our desire for having our children's futures protected.

Shortly after the elections, scientists linked nano-geoengineering to birth defects, confirming the Nanofukushimites' worst allegations. Spurred by this discovery, the U.S. and China threatened military action against anyone who geoengineered, the United Nations banned the activity altogether. Unfortunately, once planetary heating passed 3°C due to ongoing greenhouse gas emissions—which had continued to grow, essentially unabated, as the world's environmental-political attention was simply focused on stopping geoengineering—the social and ecological damage mounted fast. By the time it hit 4°C over the last half-decade, an estimated one billion people had died from droughts, famines, floods, wildfires, food-shortages, hurricanes, tsunamis, and sea-level rise that have caused conflicts worldwide.

Now, geoengineering is being debated again as the only hope to stop from crossing 5°C or even 7°C or 10°C… but the New Green and Neo-Nanofukushima movements remains a strong opposition base. Publics the world over are starting to ask whether the original movement might have been the cause of the World's worst suffering today. But of course, with next to no research on geoengineering since the 2020s, we have little idea whether new geoengineering technologies would really help, or just make things worse…

DISCUSSION AND FUTURE WORK

What do emerging technologies for intentionally modifying the Earth's climate mean for our environments and our societies? While the scenarios above certainly cannot provide a comprehensive answer to this question, they do provide insight into some of the dynamics that may shape how our world unfolds over the coming decades.

A comprehensive analysis of the drivers underlying these six scenarios was beyond the scope of the workshop, and remains beyond the scope of this report. Indeed, as noted above, even the scenario development process employed for this workshop was truncated, leaving no time for multiple iterations of the scenarios to ensure feasibility and self-consistency. Nonetheless, the above complex and original scenarios provide foundations upon which both further scenario development and subsequent analyses can be built.

The scenarios certainly reflected aspects of issues and concerns about SRM technologies that have been raised previously in the literature. These include the uncertainty about regional and global climatic impacts of SRM deployment;[16] potential for unilateral or minilateral deployment by states or even non-state actors;[17] the importance of non-state actors (including corporations, NGOs and grassroots movements) in shaping public perceptions of, and thereby future governance systems for, SRM technologies;[18] and the complex relationships between SRM and other societal governance issues that are likely to manifest over time.[19] A valuable agenda for future work might be examining whether deeper insight into such issues and concerns can be gained from studying and/or modifying the scenarios (perhaps making more 'realistic' variants thereof).

These scenarios also suggest new potential issues for further analysis, including potential relationships between future SRM governance regimes and trends in international governance;[20] and the question of whether future SRM deployment is indeed inevitable—or at least highly likely—based on the emergence of deployment in all four initial scenarios.[21] They also provide a set of possible futures against which existing proposals[22] for an SRM governance system can be evaluated for effectiveness across widely varying conditions. This creates the opportunity to identify potential weaknesses and failure modes for specific governance frameworks, and may spark new ideas for governance models that robustly ensure more positive outcomes across a diversity of possible futures.

Generated collectively by the workshop participants—an intergenerational group of experts spanning the fields of law, psychology, history, ethics, geology, engineering, climate science, physics and international governance—the scenarios in this report demonstrate the value of applying scenario planning tools to the exploration of emerging geoengineering technologies. Based upon the success of this initial workshop, along with the recent success of other similar exercises,[23] an important piece of future work will be the development and hosting of expanded, iterative and multi-workshop scenario planning exercises, incorporating additional expertise and experience.[24]

16 Blackstock *et al.* (2009); Shepherd *et al.* (2009).

17 Victor *et al.* (2009); Horton (2011).

18 Blackstock and Ghosh (2011); SRMGI (2011).

19 SRMGI (2011).

20 In some of the above scenarios, SRM technologies appear to have a catalytic effect on the transformation of the international order; sometimes positively, other times quite detrimentally.

21 Along with the difficulty the associated breakout group had in postulating a plausible Non-Deployment scenario in a World described as "Controllable" in the scenario matrix (Scenario 5).

22 For examples see: Bodansky(1996); Lin (2008); Victor (2008); Victor *et al.* (2009); Virgoe(2009); Banerjee (2011); Hester (2011); Humphreys (2011); Rayner(2011); Reynolds (2011). Blackstock and Ghosh (2011) provides a synopsis of most existing proposals.

23 Milkoreit *et al.* (2012); SRMGI Kavli (2011); Climate Engineering Summer School (2011).

24 A key objective for future exercises would be the incorporation of: (1) greater practitioner experience from the fields of (a) international environmental diplomacy, and (b) corporate and governmental research development and management; and (2) great international participation, particularly including academics and practitioners from the Global South.

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APPENDIX 1: WORKSHOP AGENDA

Friday, September 9

4:00 PM	**Reception**
4:20 PM	**Welcome** Bidisha Banerjee and George Collins, Conference Organizers
4:30 pm	**Introductory Remarks** Professor Douglas Kysar, Yale Law School
5:00 PM	**An Introduction to Scenario Planning** Dr. Jay Ogilvy, co-founder of the Global Business Network *What are scenarios? Why would we use them? How will we develop them? The cascade approach and our proposed decision-making standards.*
5:30 PM	A fifteen-minute **break**.
5:45 PM	**Dinner** is served.
6:00 PM	Over dinner: **Participant intros and opening thoughts** (1-2 min each)
7:00 PM	Over dessert: **A quick physical science briefing**. Trude Storelvmo, Yale Dept. of Geology and Geophysics. *The basics of climate change and SRM, and some important subtleties.*
7:20 PM	A ten-minute **break**.
7:30 PM	**Initial brainstorming**: we list and define important unknowns.
8:30 PM	**Temperature check**; early discussion on choice of key dichotomy.
9:15 PM	We conclude for the evening.

Saturday, September 10

8:00 AM	**Breakfast** is served.
8:30 AM	Time reserved to **add/rephrase/clarify unknowns** based on Night Thoughts.
9:00 AM	We choose a **key dichotomy**: by consensus if possible, by majority with a record of minority opinions if not.
10:00 AM	A fifteen-minute **break**.
10:15 AM	We develop **one scenario family** in plenary, flexibly considering the remaining unknowns and their interactions.
11:15 AM	In three small groups, we develop the **three other scenario families**.
12:00 PM	**Reports** from small groups.
12:30 PM	**Lunch** is served.
1:15 PM	We explore the **implications of one scenario** in the plenary.
2:00 PM	In three different small groups, we explore the **implications of the other three** scenarios.
2:30 PM	**Reports** from small groups.
3:00 PM	A fifteen-minute **break**.
3:15 PM	What **other unknowns** might we have missed? Was this a **good key dichotomy**?
3:45 PM	We **sketch** logics and storyboards **in plenary**.
4:30 PM	We **explore** these logics and storyboards **in small groups**.
5:00 PM	Small groups **report back**.
5:30 PM	**Open discussion**; approach to **workshop report**; **next steps**.

APPENDIX 2: CANDIDATE SCENARIO AXES FROM WORKSHOP

1. **Science of Atmospheric Concentrations, Locations & Lifespans**

This measures how the science of CO_2 and other greenhouse gases, as well as short-lived climate forcers, can influence a more nuanced understanding of geo-engineering technologies.

2. **Politics of Control**

This measures how much control nations, corporations, and wealthy individuals have in relation to each other vis-a-visgeoengineering.

3. **Meta-uncertainty**

A psychological factor that measures the amount of uncertainty policy-makers are willing to live with in deploying geoengineering; meant to capture the 'gap' between scientific aspects (what policy-makers understand about the technics and impacts) and political and institutional aspects (what policy-makers will do given other political pressures).

4. **Economics of Control**

Deploying geoengineering technologies feeds into economic systems (for example, deploying sulphates may intersect with the shipping industry). It may be that control (or lack thereof) of the economic systems upon which SRM technics are dependant may act as an uncertain proxy control.

5. **Reversibility**

This measures whether the physical deployment and consequences of SRM can be reversed, and with what degree of ease or possibility.

6. **Unintended Consequences**

Deployment may trigger unintended changes in the climate and in weather patterns, with uneven spatial effects. Such consequences have an ethical component—those with the capacity to deploy may impact those without the requisite capacity; as well as a political component—the capacity-deficient may be unable protect themselves from deployment by others.

7. **Detection and Attribution**

There may be uncertainty in establishing liability for the impacts of SRM deployment. Even if a (state) party's geoengineering attempts are detectable, it will be difficult to measure how much physical damage can be attributed to SRM relative to climate change itself.

8. **Definition of Optimal Climate**

There is uncertainty in how different (state) actors will define an optimal climate—an optimal temperature range—as this is relative to their interests (e.g. better temperature for agriculture, or tourism) or their moral and ethical beliefs. It is also uncertain how different conceptions of optimal temperature will conflict if propounded by actors with existing geopolitical rivalries (e.g. India and China). Finally, there is the question whether any such 'optimal' climate can be considered 'equitable'—and what metric might be used to determine this.

9. **Uncertainty over Human Will to Control Climate**

Humanity may display a variety of responses to the prospect of consciously intervening in planetary processes that have heretofore been seen as being 'in the hands of God'. Humans may display political and ethical reluctance to do so; they may also embrace the philosophy of Stewart Brand: "We are as gods, and we have to get good at it."

10. Public Response

General publics may respond in a variety of ways to the deployment of SRM—as a cheaper option to cutting carbon comprehensively, thereby creating moral hazard in mitigation; alternately, SRM may be seen as such an untenable risk that publics become more amenable to mitigation. It is noted also that 'public response' gauging in the climate problematique has historically been taken within Northern countries, and there is a need to better scope the public perceptions of the South.

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An intervention is made here by the facilitator to explain that uncertainties can be phrased as dichotomies—so as to fit onto an axis—in an effort to demonstrate to participants the end goal of the exercise. Accordingly, uncertainties generated hereafter reflected this knowledge.

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11. Harms vs. Benefits

This measures whether various demographics benefit, or are harmed, from the psychological and environmental impacts of SRM.

12. Ability vs. Inability to Predict

This measures the scientific and technical capacity to predict impacts of SRM.

13. Global vs. Decentralized Capacity for Action

This measures the societal and institutional capacity to act at a large scale (e.g. a global agreement) or only at via uncoordinated and localized mechanisms.

14. Reason and Science vs. Faith and Belief

Geoengineering—in the way it comes to be perceived globally—may come to represent a triumph of the principles of the Enlightenment (reason, empiricism, and individualism), as a rational and controlled manipulation of natural processes. Geoengineering may alternately cause a backlash against such thinking, and result in a more spiritual and collective understanding of the human relationship with nature.

15. Global Issue vs. National Security Issue

This measures whether scholarly and political communities come to see geoengineering as an issue of the global commons, or as one that reflect national (security) issues and agendas. This may determine whether geoengineering is managed cooperatively or fractiously.

16. Reflexive vs. Instrumental Technology

Reflexive technology was defined as technology with an inborn capacity to reflect on how it is being used in the world. In contrast, instrumental technology was defined as technology used to meet pre-defined ends.

17. Controllable vs. Uncontrollable

This assesses the controllability of SRM technologies and the impacts thereof; a compound between previously discussed uncertainties on different politicized usages of SRM, technical understanding and control of SRM, and understanding of the physical impacts on climate (and its physical and social offshoot effects).

18. Differentiated vs. Broad/Shared Impacts

The physical effects of SRM may vary across geographic regions (e.g. precipitation patterns), creating an uneven distribution of the harms and benefits.

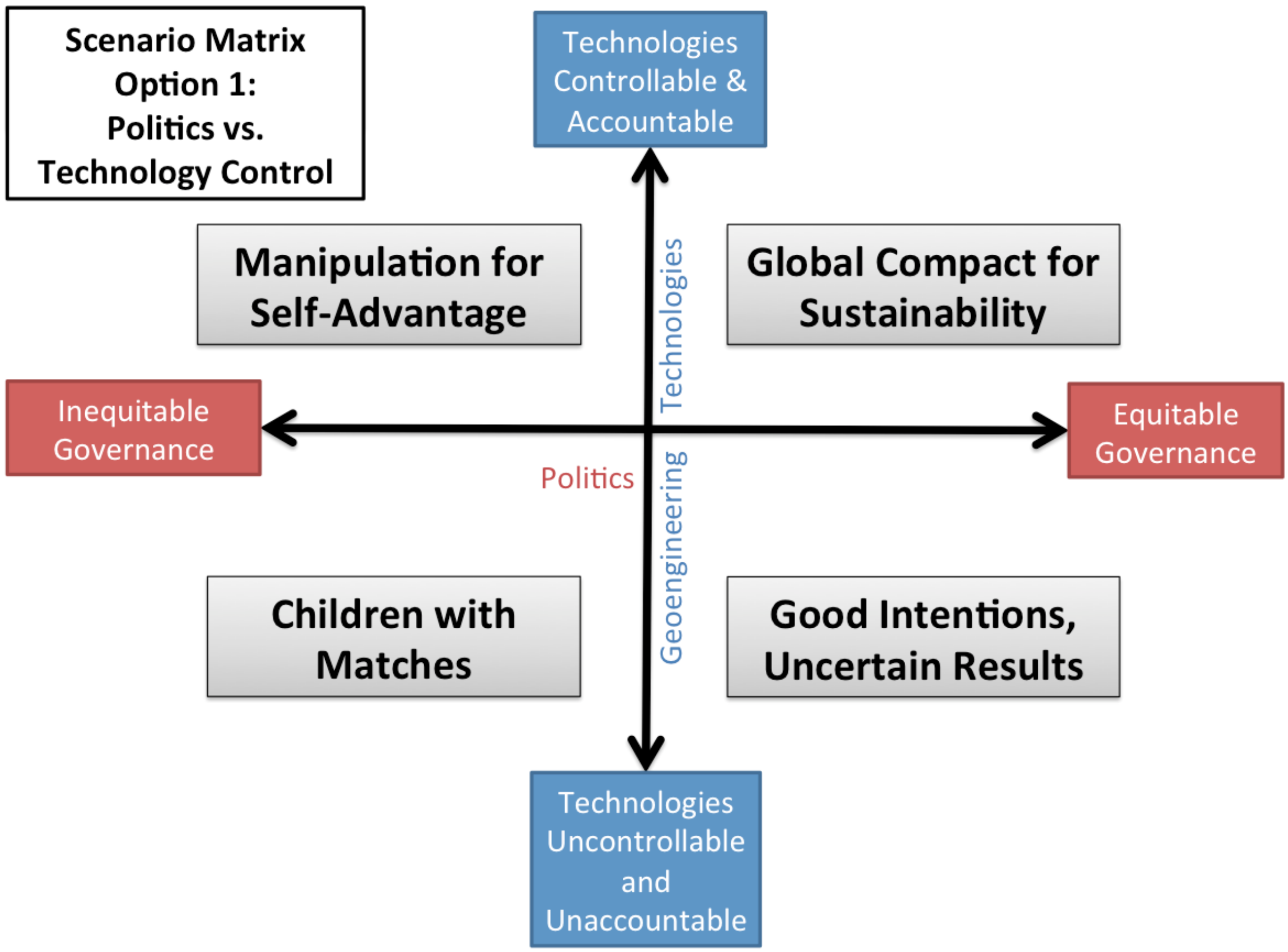
19. Equitable vs. Inequitable

This measures the relative harms and benefits done by SRM to different groups and the environment. This parameter is a catch-all encompassing previously mentioned and topically similar uncertainties (see #8, 11, 15, 18) that fundamentally reflects the possibility for 'privileged' actors—with capacity to deploy geoengineering or shape the governance thereof—creating uneven physical and social effects across all affected actors.

APPENDIX 3: TABULATION OF SCENARIO AXIS VOTES

NUMBER	UNCERTAINTIES AXES (PARAMETERS)	VOTES	SYNERGIES
1	Science of Atmospheric Concentrations, Locations & Lifespans	5	(6) Unintended Consequences
2	Politics of Control	0	
3	Meta-uncertainty	0	
4	Economics of Control	0	
5	Reversibility	0	
6	Unintended Consequences	2	(1) Science of (Technological) Concentrations, Locations, Lifespans
7	Detection and Attribution	0	
8	Definition of Optimal Climate	0	
9	Uncertainty over Human Will to Control Climate	2	
10	Public Response	3	
11	Harms vs. Benefits	0	
12	Ability vs. Inability to Predict	0	(17) Controllable vs. Uncontrollable
13	Global vs. Decentralized Capacity for Action	0	
14	Reason and Science vs. Faith and Belief	11	Brought up afterward: Managed vs. Wild conceptions of Managing the Planet
15	Global Issue vs. National Security Issue	11	
16	Reflexive vs. Instrumental Technology	3	
17	Controllable vs. Uncontrollable	18	(12) Ability vs. Inability to Predict (13) Global vs. Decentralized Capacity for Action
18	Differentiated vs. Broad/Shared Impacts	5	
19	Equitable vs. Inequitable	25	(11) Harms vs. Benefits (18) Differentiated vs. Broad/Shared Impacts

APPENDIX 4: CANDIDATE SCENARIO MATRICES WITH CARICATURE LABELS



APPENDIX 5: CANDIDATE 'BLACK SWAN' EVENTS

The following events were identified by workshop participants as examples of the kind of 'Black Swan' event that could significantly disrupt key assumptions underlying the scenarios developed during the workshop"

1. A new volcanic eruption akin to a "second Mt. Pinatubo"
2. Major climate tipping points (e.g. Arctic methane outgassing; thermohaline circulation halts)
3. Global pandemic (or similar event) drops global economic activity and thus carbon emissions
4. Collapse of global economy directly decreases carbon emissions (akin to collapse of post-Soviet economy causing carbon emissions to drop)
5. Collapse of international or regional institutions (UN, EU) or important global players (U.S.A) that dramatically changes the international political landscape
6. Breakthrough in 'game-changing' mitigation or renewable technology

APPENDIX 6: KEY UNCERTAINTIES

In the final session, participants were individually asked to name one or two uncertainties that they saw as especially important to the evolution of SRM research, technologies and governance. Their answers were:

1. How to build governance systems in an (far more) unstable future
2. The need for diverse (non-OECD) perspectives in scoping and governing geoengineering
3. Prior scoping may not illuminate the potential risks and options for deployment sufficiently; risks, and the manner of deployment, may emerge from unscoped, capricious events
4. What methods and mediums should the current (formative) research community use to engage the public?
5. Knowledge of the physical mechanics of tipping points and non-linear systems
6. Motivational structures for research communities—the need for humility and understanding of Man's relation with Nature
7. "Preservation of natural systems" as a prime factor in public perception and support of geoengineering
8. Capacity to create global, equitable, efficacious institutions to manage novel and risky technologies
9. Can global epistemic networks maintain authority and credibility when its recommendations threaten capitalism?
10. How exposure to the geoengineering debate will force global actors and demographics to alter their actions (e.g moral hazard; or added incentive to mitigate due to risks of geoengineering)
11. The role of popular movements in global environmental governance
12. Whether the international community will put together a credible mitigation/adaptation alternative to solar geoengineering in the face of rapid climate change
13. How existing economic, legal, political systems apply to unilateral uses of solar geoengineering
14. How confident can we be in our knowledge about the techniques of geoengineering, about the projected actions of future stakeholders, and about the shape of our response under conditions of genuine stress?
15. What variables make people change their behaviour?
16. How likely is it that we have already reached a 'state' (committed warming) in which geoengineering may be necessary to avoid suffering?
17. Whether the Westphalian/Liberal international order is capable of addressing the complexity of climate change and its interdependent issues
18. How audiences (civic or policy) with vested interests and inertial agendas interpret the recommendations and risk-assessments of the research community
19. What sorts of social dislocation and disruption will ensue as geoengineering puts stress on human relationships and on the human-nature interrelationship.
20. The sensitivity of the climate system to greenhouse gas buildup and solar geoengineering interventions..

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