Geoengineering,
the Anthropocene
and the end of nature
Geoengineering, the Anthropocene and the end of nature

Jeremy Michael BASKIN

ORCID # 0000-0002-5733-2271

PhD Thesis

December 2016

Department of Political Science, School of Social and Political Sciences, University of Melbourne

Submitted in fulfillment of the requirements for the PhD degree at the University of Melbourne
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Abstract

Solar geoengineering (SGE) is a controversial proposed technology which aims to address global warming by the ongoing injection of sulphate aerosols into the stratosphere, thereby reducing incoming sunlight and cooling the Earth. Once ‘taboo’, SGE has re-emerged since the mid-2000s as a proposal from a section of the climate science community. It has not yet been ‘normalised’ as an acceptable or accepted addition to the existing cornerstone climate policies of mitigation and adaptation.

I analyse SGE in an attempt to understand what travels with this emerging technology. I adopt an analysis rooted in traditions of critical thought, and focus on analysing the major institutional assessments of SGE and the ideas of SGE’s key experts and ‘knowledge-brokers’. In the process I analyse how SGE is imagined by both its opponents and proponents.

I address three main questions. Firstly, what is at stake in SGE’s re-emergence? Here I focus on understanding three things. These are SGE’s power effects and SGE’s insertion into existing relations and structures of power (geo-politically, economically and socially); the knowledge systems, epistemologies, assumptions and hierarchies which are brought to bear in developing and assessing the technology; and the competing values and worldviews which infuse the arguments of both its proponents and opponents. Secondly, I ask what are the differences and continuities between SGE now and geoengineering previously? Thirdly, I ask what is constraining SGE from being embraced and ‘normalised’ as a third leg of climate policy.

I argue that SGE is best understood as a sociotechnical project rather than as simply a technology to combat climate change. The widely-acknowledged ethical and governance issues which attach to SGE are not simply complications. They are intrinsic to the technology and wrapped up in the idea itself. I show how different sociotechnical imaginaries of SGE co-exist, none of them hegemonic. These are the oppositional ‘Un-natural’ imaginary, a conspiratorial ‘Chemtrail’ imaginary, and a ‘Power’ imaginary containing three narratives which co-exist uncomfortably – which I label the ‘Market’, ‘Geo-management’ and ‘Salvation’ narratives.

In choosing the unprecedented path of intentionally shaping the global climate (and thereby the locally-experienced weather), both new climates and new world/s will be made. I show how the material and the ideational will together shape whether, and if so when, SGE becomes normalised as an acceptable approach to climate change. Climate developments, power considerations and imaginations of the future are all critical. I show how an imaginary
of ‘Mastery’, predominant in early Cold War imaginations of geoengineering, is both essential for SGE’s normalisation, but also not easily available in the contemporary world. I argue that if SGE does emerge it will be as sociotechnical imaginary of the Anthropocene.

**Keywords**

geoengineering, climate engineering, solar geoengineering, Anthropocene, climate change, sociotechnical imaginary, Science & Technology, hubris

**Fields of Research (FOR) codes**

Broad Category: Studies in Human Society

160605 – Environmental Politics (50%); and

160808 - Sociology and Social Studies of Science and Technology (50%)
Declaration

This thesis comprises only my original work towards the PhD. Due acknowledgement has been made in the text to all other material used. This thesis is within the maximum word limit in length, exclusive of tables, maps, bibliographies and appendices.

Jeremy Michael BASKIN

1st December 2016
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Acknowledgements

I acknowledge, with gratitude, the contribution of my two supervisors at the University of Melbourne who provided critical commentary and essential feedback throughout the thesis process. My primary supervisor, Prof. Robyn Eckersley, gave me timely and challenging feedback through many drafts, reading each Chapter closely and generously. At all times she pushed me to refine and clarify my ideas whilst allowing me the freedom to pursue directions a less patient or tolerant supervisor might have discouraged. Her encouragement was crucial in getting me through the many conceptual roadblocks I inevitably faced and in keeping my focus. My second supervisor, Prof. Ghassan Hage, was especially helpful in pushing me to theorise better and challenging me with difficult questions at key moments. To both of them my heartfelt thanks. I also acknowledge the helpful comments from the two anonymous examiners.

I had the good fortune to be appointed a Fellow of the Program on Science, Technology & Society at Harvard in the last quarter of 2016. I acknowledge the role of Prof. Sheila Jasanoff and the STS Program in making this possible. Among other things this provided me with an excellent intellectual and physical space in which to finalise this thesis.

Thanks to Sylvia Seldon for helping proof-read at key stages, and to Anita Talberg, Melbourne Uni’s other PhD student looking at geoengineering, for her comments and commiserations at key stages.

Cover picture: Michael Portley – Emissions Offset

Dedication

To Sundhya for her love, friendship, wisdom and critical advice through six long PhD years. And to Ananya, our unique daughter, whose presence reminds me daily that it really does matter what world we pass on to our children.
## Contents

Abstract ................................................................................................................................. v
Figures and Tables ................................................................................................................... xiv
Abbreviations used ................................................................................................................ xv
Prologue ................................................................................................................................. xix

Chapter 1: Introduction .......................................................................................................... 1
Geoengineering and solar geoengineering .......................................................................... 5
The thesis questions and key concepts ............................................................................. 8
  What’s at stake? ..................................................................................................................... 8
  What’s different? .................................................................................................................. 13
  What’s constraining normalisation? .................................................................................. 13
Methodological approach ..................................................................................................... 14
  Theoretical orientation and mode of inquiry .................................................................. 14
Archive ................................................................................................................................ 17
  Other literature relevant to geoengineering ................................................................. 20
The argument in brief ........................................................................................................... 22
Chapter outline ....................................................................................................................... 24

SECTION I -- YESTERDAY

Chapter 2. The assumption of Mastery: geoengineering’s 1st wave .................................. 31
  Technophilia and hubris .................................................................................................... 32
  Geological engineering and climate modification ......................................................... 36
  Tempering hubris (slightly) ............................................................................................ 40
  Retreating from the era of Mastery ................................................................................. 44

Chapter 3. Becoming ‘taboo’: geoengineering’s hiatus ......................................................... 47
  The decline of the mastery narrative .............................................................................. 47
  Attempts at post-Cold War revival .................................................................................. 52
  Explaining the failed post-Cold War revival ................................................................. 56
  From weather to global climate ....................................................................................... 60
SECTION II -- TODAY

Chapter 4: The re-emergence of geoengineering .......................................................... 71
 The resumption of history ............................................................................................ 71
 The changing climate of climate change ................................................................... 75
 Foundations for geoengineering’s re-emergence ....................................................... 79
 Lifting the taboo ........................................................................................................... 83
 Officially respectable, but not quite acceptable ......................................................... 86
 Rationales, frames and representations ................................................................. 89
 Rationales ...................................................................................................................... 90
 Frames and metaphors .............................................................................................. 94
 Representing ................................................................................................................. 99
 An inability to normalise .............................................................................................. 103

Chapter 5. Knowledge, Power, Values ................................................................. 109
 Knowledge/s ................................................................................................................. 111
 Epistemic hierarchies and the elevation of the techno-scientific .................................. 111
 Managing uncertainty ............................................................................................... 117
 Counting without taking account ............................................................................ 120
 Power .............................................................................................................................. 125
 Emergency and Risk ................................................................................................. 125
 Capitalism .................................................................................................................... 130
 Global order ............................................................................................................... 134
 Values ............................................................................................................................. 137
 Conclusion .................................................................................................................... 142

Chapter 6: Competing narratives of solar geoengineering ..................................... 145
 Four competing narratives ......................................................................................... 147
 A brief detour into human engineering ....................................................................... 148
 Un-natural: the perils and injustice of geopiracy ....................................................... 149
 Market: a techno-fix to enable business-as-usual ..................................................... 151
 Geo-management: taking charge of the climate crisis ............................................. 155
 Salvation: saving the world from climate risk ......................................................... 158
Convergences and divergences in competing imaginaries................................................................. 162
Chemtrails: a shadow fifth imaginary............................................................................................... 166
Traces in the NRC report .................................................................................................................. 169
A sociotechnical imaginary struggling to be born ........................................................................... 176

SECTION III -- TOMORROW

Chapter 7: Future imaginings ........................................................................................................... 182
The climate of power ......................................................................................................................... 184
Climate ............................................................................................................................................... 184
A technology of the powerful ............................................................................................................ 188
... and yet subversive ......................................................................................................................... 190
Attaching to more ‘optimistic’ imaginaries ......................................................................................... 193
Development..................................................................................................................................... 194
Anthropocene .................................................................................................................................... 198
A sociotechnical imaginary of the Anthropocene ............................................................................. 203

Chapter 8: Conclusion ....................................................................................................................... 206
The argument.................................................................................................................................... 207
What’s different? ................................................................................................................................. 208
What’s constraining SGE? .................................................................................................................. 210
What’s at stake? ................................................................................................................................. 213
Some implications .............................................................................................................................. 219
The troubled nature of environmentalism ......................................................................................... 220
To conclude ... .................................................................................................................................. 223

Epilogue............................................................................................................................................. 226

Appendix 1: The science & technology of solar geoengineering.................................................. 228
The Earth’s energy balance ................................................................................................................ 228
The Sulphate Aerosol Injection (SAI) technique of solar geoengineering ...................................... 230
Assessing the effects of geoengineering ........................................................................................ 232

References.......................................................................................................................................... 236
Figures and Tables
Figure 1-1: A standard depiction of geoengineering................................................................. 6
Figure 1-2: Periodisation of interest in geoengineering post World War 2 ............................ 24

Figure 2-1: Summary periodisation of geoengineering context and associated imaginaries... 29
Figure 2-2: “Let’s Remake Nature According to Stalin’s Plan” ................................................. 34
Figure 2-3: “Weather made to order” ......................................................................................... 35

Figure 3-1: Iconic NASA images from space. ‘Blue marble’ (1972) and ‘Earthrise’ (1968)....... 49
Figure 3-2: Satirical cartoon of NAS 1992 report ................................................................. 54
Table 3.1: Schematic summary of reigning imaginaries............................................................ 67

Figure 4-1: AMEG strategic plan ................................................................................................. 92
Table 4-1: Typology of arguments in favour of solar geoengineering..................................... 94
Figure 4-2: Planet as patient, scientist as physician, political leaders as well-wishers. ....... 95
Figure 4-3a: Representations of geoengineering: BPC (above) & IPCC (below) reports....... 100
Figure 4-3b: Representations of geoengineering: Royal Society & German Federal Ministry. 101
Figure 4-4: Visualisations of SGE in ‘institutional’ reports ................................................... 103
Figure 4-5: Representations of the delivery of stratospheric aerosols. ................................. 104

Figure 5-1: Royal Society summary evaluation of geoengineering ........................................ 114

Figure 6-1: Cover of the ETC Group’s Geopiracy report (2010a) and the H.O.M.E. sticker.... 150
Figure 6-2: Richard Branson playing with planet Earth, whilst Al Gore looks on............... 154
Figure 6-3: Keith’s view of where geoengineering fits into ‘climate management’............. 160
Figure 6-4: Book cover images which encapsulate the ‘Salvation’ imaginary...................... 162
Table 6.1 – Summary of competing narratives of solar geoengineering.............................. 168
Figure 6-5: Typical image from chemtrail websites ............................................................... 169
Figure 6-6: Scientisation of SGE: representative sample of figures in NRC report (2015a). 171

Figure 7-1: Global average temperature probabilities associated with CO2e concentrations 185
Figure 7-2: Global temperature anomalies in °C, February 2016. Source: NASA GISS........ 186

Figure A1-1: The Greenhouse Effect. Source: GRIDA ............................................................ 229
# Abbreviations used

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AEI</td>
<td>American Enterprise Institute</td>
</tr>
<tr>
<td>AR</td>
<td>Assessment Report (used in conjunction with IPCC)</td>
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<td>ASO</td>
<td>Asilomar conference report on climate engineering</td>
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<tr>
<td>BPC</td>
<td>Bipartisan Policy Center</td>
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<tr>
<td>CCC</td>
<td>Copenhagen Climate Consensus</td>
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<tr>
<td>CCS</td>
<td>Carbon Capture and Storage</td>
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<tr>
<td>CDR</td>
<td>Carbon Dioxide Removal</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide (the most prevalent GHG)</td>
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<tr>
<td>CO₂ₑ</td>
<td>Carbon dioxide equivalent (a measure of the warming potential of various GHGs if considered as an equivalent of CO₂)</td>
</tr>
<tr>
<td>CoP</td>
<td>Conference of the Parties (annual meeting on climate change under UNFCCC auspices)</td>
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<tr>
<td>ENMOD</td>
<td>United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques</td>
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<tr>
<td>EuTRACE</td>
<td>The European Transdisciplinary Assessment of Climate Engineering (project)</td>
</tr>
<tr>
<td>GAO</td>
<td>United States Government Accountability Office</td>
</tr>
<tr>
<td>GEPA</td>
<td>German Environmental Protection Agency or Umbeltbundesamt</td>
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<tr>
<td>GeoMIP</td>
<td>The Geoengineering Model Intercomparison Project</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gases</td>
</tr>
<tr>
<td>IAGP</td>
<td>Integrated Assessment of Geoengineering Proposals (project)</td>
</tr>
<tr>
<td>INDC</td>
<td>Independent National Determined Contributions (used in conjunction with UNFCCC)</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>NAS</td>
<td>National Academies of Sciences (United States)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<td>--------------</td>
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</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NGO</td>
<td>Non-governmental organisation</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration (United States)</td>
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<tr>
<td>NRC</td>
<td>National Research Council (United States)</td>
</tr>
<tr>
<td>RCP</td>
<td>Representative Concentration Pathways (used by IPCC)</td>
</tr>
<tr>
<td>R2P</td>
<td>Responsibility to Protect</td>
</tr>
<tr>
<td>REAGIR</td>
<td>Reflections on Environmental Geoengineering (project)</td>
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<tr>
<td>SAI</td>
<td>Sulphate Aerosol Injection</td>
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<tr>
<td>SGE</td>
<td>Solar geoengineering. Used throughout to describe the technique also known as solar radiation management (SRM) by Sulphate Aerosol Injection (SAI)</td>
</tr>
<tr>
<td>SPICE</td>
<td>Stratospheric Particle Injection for Climate Engineering (project)</td>
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<tr>
<td>SRM</td>
<td>Solar Radiation Management</td>
</tr>
<tr>
<td>SRMGI</td>
<td>Solar Radiation Management Governance Initiative</td>
</tr>
<tr>
<td>STS</td>
<td>Science &amp; Technology Studies</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<tr>
<td>WG</td>
<td>Working Group (used in conjunction with IPCC)</td>
</tr>
<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
</tr>
<tr>
<td>W/m²</td>
<td>Watts per square meter</td>
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Prologue

Solar geoengineering, according to Harvard University’s Weatherhead Center where the largest group researching it is located, is ‘a particular form of climate engineering that aims to reduce the planet’s absorption of solar energy ... [and] involves introducing small particles into the upper atmosphere to scatter sunlight back to space’ (2016). It could equally and no less accurately be described less soothingly as the beginning of a millennial commitment to spray sulphuric acid aerosols into the stratosphere in order to counteract global warming.

When I describe solar geoengineering to those unfamiliar or only loosely familiar with the idea the typical response is: ‘Are you serious?!’ I too, when I first came across solar geoengineering in the mid-2000s, was inclined to regard it as both ‘mad’ and ‘bad’. It sounded like a crazily impractical idea seemingly drawn from the realm of science fiction, and embracing the least attractive features of modern techno-science. I soon discovered the idea was being taken extremely seriously, in part because the observed cooling effects following major volcanic eruptions was seen as proof that it could ‘work’.

* * * *

The devastating volcanic eruption at Tambora in 1815 in what is now Indonesia caused global temperatures to plummet and led, directly and indirectly, to a death toll likely in the millions (Wood 2014). In much of the Northern hemisphere, the following year was known as ‘The Year without a Summer’. The teenage Mary Shelley (daughter of the political philosopher and proto-anarchist William Godwin and the philosopher and early feminist Mary Wollstonecraft) spent that June in Switzerland with the young writers Percy Shelley, Lord Byron and John Polidori. Kept indoors by the unseasonably cold and inclement weather, they decided on a competition as to who could write the best horror story.

Mary Shelley’s contribution was *Frankenstein: The Modern Prometheus*, arguably the first work of science fiction. It tells of how Dr. Victor Frankenstein uses his knowledge of science and an obsession with simulating natural wonders, to impart life to non-living matter. In the laboratory, he aims for a beautiful creation but instead gives life to what he regards as a hideous Creature, Frankenstein’s monster. Repulsed by his creation Victor leaves and the abandoned monster flees, only to kill in rage as he is rejected by society.

One familiar reading of *Frankenstein* sees it as a cautionary tale about hubris and high technology. Dr. Frankenstein tried to act as God. He disrupted the natural order and created a monster leading to the ultimate downfall of both scientist and monster. But Bruno Latour
argues, in ‘Love Your Monsters’, that Frankenstein’s sin was rather ‘... that he abandoned the creature to itself’ and failed to take responsibility for his own creation. ‘Our sin is not that we created technologies but that we failed to love and care for them’ (2012:n.p.).

Perhaps Latour is correct when it comes to taking responsibility for technologies that ‘we’ (?) have created, that are already ‘out there’. It does not, of course, follow that it is permissible to create any new technology so long as we promise to ‘love and care’ for it through good times and bad. A dislike of techno-phobia does not make technophilia a virtue. This is relevant since, at the time of writing, solar geoengineering is still a nascent, imagined, technology for addressing climate change. It has not yet come into being as a deployed technology. Is solar geoengineering a ‘monster’? Is it one ‘we’ should create? Is it one we can ever love?

*******

These are complex questions, resistant to simple answers, and with normative values at their heart. In digging deeper, it has become apparent to me that geoengineering throws up more questions than answers, not just about climate and technology, but also about hubris and power. It troubles ‘common sense’ about environmentalism. It also raises profound, even existential, questions about both the human and the more-than-human.

My approach will aim to be scholarly and rigorous and to unpack solar geoengineering in all its complexity. I resist being simply subjective, whilst recognising, of course, that nothing is value-free and that there is never an objective ‘view from nowhere’. But complexity can sometimes be the enemy of clarity, and aiming for objectivity does not absolve the individual from ethical duty nor mean that they don’t have a subjective opinion. It is important to acknowledge the affect and the visceral and instinctive responses which so often accompany any reflection on geoengineering. I am still regularly pressed to give my view on whether solar geoengineering should be pursued and whether it will be pursued. For the record, my answer tends to be ‘No’ and ‘Probably’ respectively. This reflects the view I have come to, that solar geoengineering is ‘bad’ and ‘sad’, but imprudent rather than ‘mad’.

Importantly, these are not the questions posed in this thesis. In my quest to know how best to understand geoengineering I ask questions like ‘what work does the idea do and what is at stake in its adoption?’ , ‘for whose benefit is geoengineering imagined?’ and ‘what is constraining its emergence?’, rather than ‘is it bad?’ . These are the type of questions that need to be answered prior to making any decision about proceeding with solar geoengineering.
Chapter 1: Introduction

Climate change ‘represents an urgent and potentially irreversible threat to human societies and the planet’.

United Nations Framework Convention on Climate Change (2015:1)

‘Albedo modification techniques mask the effects of greenhouse warming; they do not reduce greenhouse gas concentrations’.

Reflecting Sunlight to Cool the Earth (National Research Council 2015a:1)

‘You are repulsed? Good. No one should like it. It’s a terrible option’

David Keith, prominent SGE proponent (quoted in Wagner & Weitzman 2012:n.p.)

The Paris climate agreement set a clear goal. To avoid dangerous climate change, global warming should be kept ‘well below’ 2°C above pre-industrial levels. Indeed, a threshold of 1.5°C should be pursued (UNFCCC 2015). It is difficult to see this goal being met. After all, average global surface temperatures are already about 1°C above pre-industrial in 2016 and the trajectory is not comforting.¹ The optimism manifest at the conclusion of the Paris talks in December 2015 does not alter the reality that the temperature goals set are generally held to be unachievable unless, the standard account goes, cuts in greenhouse gas (GHG) emissions are deeper, faster and sectorally-broader than those currently agreed (Clémençon 2016; Rogelj et al 2016). Politically, this suggests a need to make existing national climate targets, known as Intended Nationally Determined Contributions (INDCs), significantly more ambitious, thereby hastening the transition to a zero-emissions future. Technologically, it means assuming that a global energy transition of great magnitude can be achieved speedily over a few decades, despite much evidence to the contrary (Grübler 2012).

¹ In February 2016 average temperatures were 1.63°C higher than pre-industrial (NASA GISS). And this is after the cooling effect of anthropogenic aerosols in the atmosphere (much of which is caused by high levels of air pollution), which already masks as much as one-third of greenhouse gas-related warming (IPCC 2013a:Fig.10.5). Further warming would likely result from ‘clean air’ initiatives, especially in the developing world.
But there is another option, one that is being actively considered. It is the suggestion that, maybe, a cooler climate could be *engineered*. Maybe the Paris temperature targets could be met without the economic and political pain of cutting emissions quite so rapidly. Maybe climate engineering, “geoengineering”, could supplement (or even replace) the existing strategy of Mitigation and, with Adaptation, become a third leg of climate policy.

This proposal matters. Not only is it a risky ‘solution’ to the ‘problem’ of climate risk. Not only does it threaten to turn existing approaches to climate change on their head. But its adoption would also inaugurate a new era of actively-managed global climate, indefinitely. It would mean changing the climate to tackle climate change. Geoengineering raises many questions. What does making a global climate entail? And, in the process, what new world is being made and for whose benefit? Not surprisingly, geoengineering is a proposal that provokes deep unease and much opposition. Clearly, a great deal is at stake in its emergence.

Climate engineering begins as quite a simple idea. Since ‘we’ appear unable to adjust our emissions-intensive behaviour to avert serious climate change, maybe ‘we’ should instead adjust the climate system to adapt to us. By geoengineering, according to this account, humanity might avert increasingly serious, perhaps even catastrophic, climate change ... or at least it might buy more time to adjust our behaviour and pursue a less emissions-intensive path. Perhaps, so the thinking goes, we can remove GHGs from the atmosphere, say by fertilising the oceans with iron filings and changing their chemistry so that less CO$_2$ ends up in the atmosphere and more is captured in algal blooms, ideally sinking to the ocean floor. Or maybe, if we need to act more quickly, we can reduce incoming sunlight by deflecting some of it using mirrors in outer space, or by creating more and whiter clouds close to the Earth’s surface so more sunlight is reflected back into space, or by injecting the stratosphere with sulphate aerosol particles so that less sunlight gets through to the Earth’s surface.

This may appear to be the stuff of science fiction, but since the mid-2000s geoengineering has become part of mainstream climate policy discussions. It has been proposed by a number of prominent climate scientists (see for example Crutzen 2006; Schneider 2001), and been the subject of analysis by leading scientific institutions in the USA, the UK and elsewhere (see for example Royal Society 2009; NRC 2015a). Research into geoengineering has increased rapidly. Consideration of geoengineering now forms part of the work of the authoritative Intergovernmental Panel on Climate Change (see for example IPCC 2012).

In this thesis I focus on one specific proposed technique to engineer the planet: the attempt to reduce incoming sunlight through the *ongoing* injection of sulphate aerosols into the stratosphere, thereby enveloping the Earth in a fine, mist-like cloud of sulphur-dioxide. I will
call this ‘solar geoengineering’ (hereafter SGE). This is the technique which has generated the most interest, and which has a plausible claim to be able to cool the Earth rapidly and cheaply. It is also the most controversial geoengineering proposal.

Two initial observations are essential to understanding the direction my research will take. Firstly, SGE is being researched and imagined, but it is not yet an operating, deployed technology. Stilgoe has called it ‘... the figment of a particular technoscientific imagination’ (2015a:6). But it is no less real for that, given the significant research energy dedicated to making it a reality, and the effect that even the idea of geoengineering has on the existing verities and assumptions of climate policy. SGE is both an emergent technology, or at least the idea of one, and a putative climate policy solution. How these two things are imagined are central to its unfolding. It soon becomes apparent, on reading the geoengineering literature, that a range of visions of how the world is and what it should be are projected onto SGE. What the climate condition is understood to be, what values are assumed, what world/s aspired to, what is imagined to be possible and what not, all form part of the imagining of SGE and shape its emergence (or non-emergence).

The second observation is that SGE is a masking technology, and generally understood as such (NRC 2015a:1). Unlike geoengineering technologies aimed at Carbon Dioxide Removal (CDR), SGE is explicitly intended to mask the warming effects of growing GHG concentrations, not to reduce the concentrations themselves. But, in my argument, SGE masks much more than warming. It is insufficient to understand it simply as a controversial, but necessary, technical response to the risks of climate change. One must also ask in whose interests and for whose benefit is it intended, what it implies for the dominant economic and political global order, and in promising to shape the Earth and its climate, what world does it hope to shape too?

In its simplest form my research is animated by a quest to understand what is at stake in SGE’s emergence. I conduct my enquiry at the intersection of the field of critical political ecology (or critical environmental politics) and the tradition of critical scholarship known as Science and Technology Studies (STS). Critical Environmental Politics is attentive to the relationship between power in all its dimensions (material, rule-based, discursive, structural), and the more-than-human world and ecologies within which human societies operate (Eckersley 1992; Christoff & Eckersley 2013). STS is based on the insight that the social and the technological are always entwined (Bijker et al, 1987), that ‘science and society, in a word, are co-produced’, that they come into being together (Jasanoff 2004, emphasis in original). I make particular use of Jasanoff’s concept of the ‘sociotechnical imaginary’ to inform my analysis of how power, ‘visions of desirable futures’ and advances in science and technology are enmeshed (2015:3). I
aim to un-mask the sociotechnical imaginaries that animate solar geoengineering and are animated by it, and to consider what is at stake.

Understanding what is at stake, and the operative imaginaries, is also enhanced by applying an historical lens. What we are witnessing today is not, strictly speaking, SGE’s emergence, but its re-emergence. Ideas similar, often even identical, to SGE have been in circulation, often at the highest levels, since the conclusion of World War Two and for much of the Cold War. They have, at times, been embraced, and at other times been regarded as, in effect, ‘taboo’. By examining the sociotechnical imaginaries associated with previous incarnations of geoengineering, and both the continuities and discontinuities, I hope to illuminate both SGE’s present and its possible futures.

Geoengineering has entered mainstream climate policy consideration. But it, especially SGE, remains highly contentious and is not (yet) officially embraced. Indeed, it is widely viewed with distaste or embraced only as a ‘lesser evil’ or seen as a ‘bad idea whose time has come’. A key element of my central question, therefore, is to understand what is restraining the normalisation of SGE as a climate policy option: why is it struggling to move from mainstream policy consideration to full embrace. Any examination of SGE soon makes it apparent that SGE is a ‘troubling’ technology in all senses of the word. It troubles, of course, the existing verities of climate policy – mitigation as primary solution to the warming problem – even when it is offered up as merely a supplement to mitigation. But it also troubles by bringing to the fore existential questions grounded in competing social values such as what it means to be human, as well as questions about the place of science in thinking about climate, about ‘progress’ and about the human-nature relationship. It impels reflection on environmentalism, democracy, how expertise is engaged in the shaping of policy, and much else besides. It shines a light on the dystopic dimensions of contemporary life in the West, and on the dark side of ‘man’s mastery of nature’. I will explore whether the difficulty of normalisation may, in part, be related to the many unresolved ethical and political concerns, and even ontological and epistemological considerations, which are wrapped up in SGE.

In some respects SGE can be compared with other modern, ‘big’ technologies – such as nanotechnology, nuclear technology, and biotechnology – in that it raises comparable existential and values questions. But it is also distinct. Whilst these technologies can be understood as innovative, and as having entailed scientific and technical advances, the same is

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2 As we shall see, whilst further research into SGE is embraced by the mainstream, this is often conditional, and even conditional support for research and development has vocal opponents.
not true of SGE. Technologically it is a fairly mundane combination of pre-existing
technologies (balloons, aircraft, sprays, chemicals and so on), and scientifically it is largely
derivative of existing knowledge in the Earth sciences. But in its social and political aspects
SGE is revolutionary. Its aim to globally engineer key Earth systems makes it a totalising
technology and this has vast social, political and ecological implications. Contrast too, for
example, the pessimism which surrounds SGE with the techno-optimism attached at inception,
at least in some countries, to nuclear power providing electricity ‘too cheap to meter’, or to
the way in which biotech and nanotech have been able to associate themselves with a vision
of ‘progress’, the opening of new horizons, the enhancement of personal choice, and the
promise of plenty (Jasanoff & Kim 2009). It is different too in that whilst debate around
similar technologies has often been rapidly shifted to technical and risk questions, debate
around SGE shows few signs of being similarly constrained (Schäfer & Low 2014). If anything it
is opening up, as the centrality of the ‘social’ in assessing SGE becomes increasingly
acknowledged.

In the remainder of this introduction I introduce geoengineering more fully, and draw out the
main features of solar geoengineering in particular. I then state precisely the questions this
thesis will address, and discuss the method of inquiry which will be relied upon. I conclude by
giving a brief outline of my overall argument, and provide a brief overview of each of the
subsequent Chapters.

Geoengineering and solar geoengineering
Geoengineering goes by various names: ‘climate engineering’ is widespread (for example GAO
2011), but ‘climate intervention’ (NRC 2015a), and ‘climate remediation’ (BPC 2010) can also
be found. Various IPCC reports use both ‘climate engineering’ and ‘geoengineering’ (for
example 2012). Other terms that can be found in the literature include ‘planet hacking’
(Kintisch, 2010) and ‘geopiracy’ (ETC Group, 2010a) with its clearly negative connotations. I
generally stick to the term ‘geoengineering’ but where ‘climate engineering’ is used the two
terms can be understood interchangeably.

Scale (regional or global) and the deliberate intention to counteract climate change are
common elements in most definitions of geoengineering. The most commonly-cited
definition of geoengineering is the ‘deliberate large-scale manipulation of the planetary
environment to counteract anthropogenic climate change’ (Royal Society 2009:1). Almost all

3 This also distinguishes geoengineering from environmental engineering (such as dam building), also
sometimes called geoengineering.
accounts typically state that there are two variants of geoengineering: Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM). The former category comprises techniques at the marine or at the terrestrial levels for CO₂ to be “captured and stored away from the atmosphere so that it cannot act as a greenhouse gas” (Fox & Chapman 2011:3). The latter category, SRM, aims to “reflect a fraction of incoming solar radiation back into space before it enters the Earth system, effectively shading the planet” (Fox & Chapman 2011:2).

Figure 1-1, a typical example of the graphic representation of geoengineering in major reports, depicts some of the key technological interventions which geoengineering is understood to embrace. Since I am focussing on only one technology, SGE, these definitions, distinctions and depictions are adequate for now. However, I will cast a more critical eye on them and the work they do, later in this thesis.

![Figure 1-1: A standard depiction of geoengineering.](http://reilly.nd.edu/assets/133832/original/geoengineering_diagram_big.jpg)

I elaborate on the proposed SGE technique and the science underpinning it in Appendix 1. Here it is sufficient to note that SGE entails the injection of significant quantities of very small sulphate particles (aerosols) into the stratosphere to reduce incoming sunlight by a small amount. The aim is to mask the warming effect of increased GHG concentrations and induce a counter-acting cooling effect, essentially mimicking a major volcanic eruption on a global scale… and injecting repeatedly to maintain the cooling effect, or at least until there is no

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4 This particular illustration can be found at [http://reilly.nd.edu/assets/133832/original/geoengineering_diagram_big.jpg](http://reilly.nd.edu/assets/133832/original/geoengineering_diagram_big.jpg)
longer a need to reduce global temperatures. Geoengineering, and SGE, are typically conceived as a third leg of climate policy, a supplement to the existing policies of Mitigation and Adaptation.  

SGE is the most researched, most discussed, and most controversial of the geoengineering techniques. It also raises the most challenging questions for society. Is it really better than non-intervention? How risky is it and for whom? How would it be agreed upon and by whom? Whose hand would be on the global thermostat? Wouldn’t it provide an excuse to do less mitigation? Is it legal? Would it disrupt the Asian monsoon and increase droughts as observations of volcanic eruptions, and some models, suggest? What weather patterns would follow in each region, and how would it be known what weather effects stemmed from the SGE intervention and what from normal climate variation? Might it increase geo-political instability? Would it help or hinder food production? What would be the effects on other species and on biodiversity? How much would it cost? Once commenced, what effects would follow if it were stopped? Does ‘humanity’ have the right, or maybe the duty, to intervene in nature like this? And so on. As we will see, there is now a vast literature which attempts to address such questions.

Importantly, as volcanic analogs suggest, and its proponents argue and opponents largely acknowledge, SGE is likely to ‘work’ (in the sense of inducing planetary cooling) and work rapidly (useful if emergency cooling is the aim or if there is a perceived need to keep within set temperature limits). The argument that it is relatively ‘cheap’ (with costs purported to be in the low billions of dollars), whilst contested, is plausible at least in comparison to the cost of steep emissions cuts or unconstrained global warming. More controversial is the claim sometimes made (see for example Keith 2013) that SGE is capable of being ramped up or down as needed to ‘shave the peaks’ off warming (and hence a useful supplement to traditional mitigation). Critics of this view emphasise the ‘termination effect’ and suggest that winding down any aerosol injection process risks climate ‘bounces’ and accelerated warming and, therefore, that embarking on SGE is a ‘millennial commitment’ not easily stopped (see for example Pierrhumbert 2015:n.p.; NRC 2015a:36).

As a leading SGE proponent puts it: ‘deployment is neither hard nor expensive’ even with already existing technologies (Keith 2013:95).  

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\(^5\) Compensation (for loss and damage) is sometimes held to be another leg of climate policy. Since the Paris Agreement treats this largely as assistance for Adaptation (UNFCCC 2015:Article 8), I have not included it as an additional leg here.
deployment, concluded that SGE, alone among the geoengineering technologies, could be assessed as both highly effective and highly affordable as well as fast-acting (2009). Not surprisingly, this makes solar geoengineering appealing to economic rationalists, potentially attractive to policymakers and seductive for politicians. In short, SGE brings many of the generic questions surrounding geoengineering into sharp focus, and in a way that, say, the CDR technique of ocean fertilisation, with its much longer time horizons, does not.

Like geoengineering more generally, SGE goes by a variety of names. It is sometimes called ‘Solar Radiation Management’ (for example IPCC 2013b, the 5th AR summary for Policymakers), although strictly speaking the sulphate aerosol approach is only the most commonly imagined technology for reducing incoming solar radiation, and ‘management’ suggests something far more administrative, practical and achievable than may in fact be the case. Others have attempted to rebrand it as ‘sunlight reflection methods’ (referred to in SRMGI 2012:22) which sounds more benign. The NRC report adopts the dull but descriptive label of ‘stratospheric aerosol albedo modification’ (2015a). The term ‘Pinatubo option’ is also found, especially in popular accounts, since the idea’s proof of concept is based on replicating natural volcanic analogs such as Pinatubo (see for example Kintisch 2009:n.p.). All these terms refer to same technique, which I label ‘solar geoengineering’ (SGE).

The thesis questions and key concepts
I have already foreshadowed the questions this thesis aims to address. My core concern is how best to understand SGE and to explore what travels with SGE as it emerges. Here I outline my thesis questions more formally.

What’s at stake?
The thesis is animated by a quest to understand what is at stake in SGE’s re-emergence, since the mid-2000s, as an object of mainstream climate policy consideration? I aim to understand what is at stake by uncovering the socio-technical imaginaries that accompany SGE and by

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6 When I use the word ‘proponent’ it is important not to read ‘cheerleader’, but rather understand it as those who think SGE is a path down which we need to be willing to go, and for which we must actively prepare. Although a minority of SGE’s proponents are enthusiastic, many are tentative and embrace it reluctantly as ‘unavoidable’ or a ‘lesser evil’. Tellingly, one of the leading participants in the SPICE project calls his blog ‘The Reluctant Geoengineer’ (http://thereluctantgeoengineer.blogspot.co.uk).
7 To reiterate: whilst the focus of this thesis is on solar geoengineering, I sometimes use the more general term ‘geoengineering’. Depending on context this is either because the authors/documents being cited do not always make such clear distinctions, or because I wish to suggest that the insights may be relevant for a wider range of geoengineering technologies than SGE, especially large-scale interventions which involve manipulating the Earth’s chemical balance. If the context leaves room for doubt, then the reader should assume the reference is to solar geoengineering.
examining the nexus of knowledge, values and power that they presuppose. This is unpacked in terms of the following three subsidiary questions.

Firstly, **which knowledge systems and epistemologies, and which ‘epistemic communities’ (Haas 1992), have been engaged with in the process of SGEs re-emergence, and which have been relegated to a subsidiary role?** The hierarchy of knowledge to date has prioritised the sciences, and the climate sciences in particular, with other disciplines clearly seen as unnecessary or supplemental (see Szerszynski & Galarraga 2013). My assumption is that it matters who shapes debates around geoengineering, who the key knowledge-brokers (Stone 2002) are, and what is assumed to count the most when assessing geoengineering. What is at stake can change significantly if SGE is understood as primarily a technoscientific project rather than a sociotechnical intervention.

Secondly, **what ontological orderings and values are contested in the process of SGE’s re-emergence?** To address this implies exploring what existential and normative concerns are driving SGE’s re-emergence, and resistance to it. It also entails investigating how the idea of SGE relates to some of the hegemonic ideas and value systems of our time, such as progress, development, the global, democracy and human limits.

The debate on SGE shines a light on, and is a concentrated instance of, a major re-thinking of environmental politics that is currently underway. As a global intervention to moderate the planet’s climate, it invites engagement with the variety of ontologies and cosmoologies about ‘Nature’. It compels reflection on whether we are now at the ‘end of nature’, whether ‘Nature’ and its protection is a credible foundational concept for environmentalism, and the implications of the insight that ‘nature is always already social’ (see for example Descola 2013 [2005]; McKibben 1989; Vogel 2015; Latour 2013; Swyngedouw 2011:259). Contestation over SGE is intimately bound up with the widespread reimagining of environmental politics that has been variously labelled ‘post-environmentalism’, ‘neo-green’ or ‘eco-modernism’ (see for example Ecomodernist Manifesto 2015). As an extreme example of technological intervention into the Earth system, SGE shines a light on these new interpretations of environmentalism, and they, equally, may act to legitimate geoengineering (see for example Lynas 2011; Brand 2009). There is also, as we will see, some evidence that it is the perceived ‘un-naturalness’ of SGE, and a sense that it crosses a line of what it is ‘proper’ for humans to do, which are among the biggest obstacles to SGE’s embrace.

Thirdly, in relation to power, **what material and geopolitical interests are served or might benefit from the adoption of SGE as a component of climate policy?** In ambition SGE is itself clearly a powerful technology, one which aims to re-shape key components of Earth systems.
Here I want to understand if it is also a technology of the socio-economically and geo-politically powerful, and what this means for the relationship between SGE and the political-economy of contemporary capitalism.

Part of my enquiry therefore entails exploring the relationship between SGE and the dominant global economic order with its systems of extraction, production, consumption and trade. Central too, is the relationship between SGE and the existing geo-political order. Despite challenges to its hegemony, the United States remains the dominant global power and it is also the prime locus of consideration and research into SGE. The geo-political and the economic are, of course, connected. Geoengineering, even as an idea and certainly if it becomes a practice, has power effects and implications. I explore my intuition that some of these effects may function to stabilise the dominant order, whilst others threaten to de-stabilise it.

Although some have imagined a small island state faced with rising sea-levels embarking on SGE, in reality one cannot expect solar geoengineering to be embarked upon other than by, or with the approval of, a major global power. SGE can be associated with the increasing securitisation of climate and environmental policy more generally (Dalby 2013). One of the drivers that led to the commissioning of the NRC report into climate intervention (2015a) was an anxiety by the US security establishment as to whether they would be able to detect if another country was embarking on geoengineering. Further, any deployment of SGE would presumably make assumptions about, for example, what global average temperature to aim for, and be informed by the expected and different effects on, say, India or Pakistan or Indiana. Healey & Rayner are not alone in pointing out that it is not difficult to see SGE provoking interstate conflict (2015).

Equally when it comes to the relationship between SGE and capitalism, the connection is not straightforward. SGE would seem to be compatible with facilitating ‘business-as-usual’ and the dominant economic order. Indeed, this is a key reason why the economically neo-liberal, anti-statist American Enterprise Institute (2013) or Bjorn Lomborg’s Copenhagen Consensus Centre (2009) are so enthusiastic about solar geoengineering. But deploying SGE would appear to centrally involve massive state and military involvement. The level of centralisation implicit in its deployment and ongoing operation would appear to run counter to many existing democratic practices. Further, and distinct from comparable modern technologies such as nuclear, biotechnology or nanotechnology, SGE’s trans-boundary and uncontainable effects makes it hard to imagine how the proposed technology might be marketised or turned
into an opportunity for profit. If SGE is compatible with capitalism, it is with an especially statist, imperial version of it.

In short, to understand what is at stake it is necessary to locate SGE in the socio-economic and geo-political order within which it is struggling to emerge. Broadly, for understanding the global order and who and what is powerful, I draw on Manfred Steger’s account in Globalisms (2009) of competing global ideologies in the contemporary world. Steger argues that neoliber al ‘market globalism’ is currently hegemonic, and notes how the securitisation of this ideology since the early 2000s (post September 11) means it has also assumed an imperial character. The soft power of markets has been supplemented by hard power discourses of intervention. Steger’s approach emphasises competing ideologies and this is helpful since SGE is still operating mainly as a contested idea. I share his observation that imperial ‘market globalism’ is hegemonic economically and geo-politically, and I use the phrase, ‘market globalism in an unequal world’, as shorthand to describe this.

Jasanoff’s concept of ‘sociotechnical imaginaries’ provides a fruitful vehicle to hold together the components of this contested knowledge-values-power nexus and to help understand what is at stake in solar geoengineering’s re-emergence. The concept is elaborated most fully in her edited book Dreamscapes of Modernity (2015), which builds on the rich pre-existing vein of thinking about imaginaries (for example Anderson 1983; Taylor 2002, 2004). She notes, however, the ‘… omission in classic accounts of social imaginaries … of modernity’s two most salient forces: science and technology’. She is concerned too with the under-theorisation of ‘the domain that connects creativity and innovation in science, and even more technology, with the production of power, social order, and a communal sense of justice’ (2015: 6-7). As Jasanoff defines it, the concept of the ‘sociotechnical imaginary’ refers to:

‘collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology’ (Jasanoff 2015:3).

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8 This is not to suggest that there are no vested interests promoting geoengineering or likely to emerge, only that it is hard to see a for-profit industry interest at any great scale. Hamilton (2013a) has pointed to the role of patents, ultra-rich benefactors (including Bill Gates), and the interests emerging from elements of the security establishment in promoting pro-geoengineering perspectives (see also Long & Scott 2013).

9 In addition to ‘market globalism’, Steger identifies two other competing global ideologies: ‘justice globalism’ associated with the global justice movement in its myriad forms, and ‘jihadist globalism’ attached to the ideology of radical Islam.
A key part of this thesis is precisely to understand the ‘visions of desirable futures’ which animate solar geoengineering. Jasanoff notes that whilst ‘multiple imaginaries can coexist within a society’, some are elevated to ‘... a dominant position for policy purposes’ (2015:3). Further, ‘sociotechnical imaginaries can originate in the visions of single individuals, gaining traction through blatant exercises of power or sustained acts of coalition building’ (2015:3). Whilst sociotechnical imaginaries are ‘typically grounded in positive visions of social progress’, there is an ‘interplay between positive and negative imaginings – between utopia and dystopia’ (2015:3). The resonance of the concept to analysis of SGE is apparent: utopia and dystopia do indeed co-exist, no single imaginary is yet dominant for policy purposes, and the ‘Earth-shaping’ and ‘world-making’ dimensions of geoengineering are entwined.

The major institutional analyses and assessments of geoengineering (such as Royal Society 2009; IPCC 2012; NRC 2015a), even as they acknowledge the relevance of the social, typically treat geoengineering as an object of scientific and technical expertise. That is, it is understood mainly as an exercise in shaping and re-shaping the climate system of the Earth. I turn this emphasis on its head, and explore how geoengineering seems to act as a screen onto which competing visions of the world are projected. Imaginaries and the ideational are therefore central to my analysis. This is appropriate too, given that SGE is not yet an operational technology, and is currently more idea than operational ‘thing’, and that the transition from the former to the latter is at the heart of its contestation.

The ‘sociotechnical imaginary’ concept goes beyond the well-established connection between power and knowledge. Values, or ‘visions of desirable futures’, are also central. And the resultant imaginaries, which are both prior to and concurrent with knowledge, are connected to power too. It is especially resonant when thinking about geoengineering because of the importance it attaches to how the projected visions of a technology both shape it and help bring it into being. It emphasises the importance of the normative, the ideational and of material power in the emergence and stabilisation of imaginaries, and to the materialisation or actualisation of that power in the world. It brings power more centrally back into the study of science and technology, and in a way which is attentive to both material and discursive power. It illuminates and gives greater theoretical precision to my argument that solar geoengineering is a technology of both power and the powerful. It also has the potential to reveal commonalities and contrasts between geoengineering and other existentially controversial technologies.

I do, however, adapt the understanding of sociotechnical imaginary outlined above in one key respect. In my usage of the term I expand it to include not only how people imagine they fit
with other people, but also how they fit with the more-than-human world. It is hard to conceive a ‘social existence’ which lacks at least an implicit understanding of the environment: the ‘natural’ and material places within which that social existence is located. Geoengineering, of course, relates to activities at the intersection of the human and the ‘natural’ world, and the boundary (or its lack) between the social and the natural is central to this thesis. Analysing geoengineering reinforces the need to go beyond an understanding of power which focuses on interactions between people and social structure and material interests, to one which includes interactions with the ‘lively’ more-than-human world (Latour 1993).

What’s different?
The second question posed in this thesis is historically focussed: **In what ways does geoengineering’s re-emergence today differ from earlier iterations and imagined interventions?** In some respects this question can be understood as preliminary to the first question. Indeed, in the thesis I deal with it first both because it provides a foundation for understanding SGE’s re-emergence in the mid-2000s, and in the hope that understanding earlier imaginaries may help illuminate what is at stake today. I develop a periodisation of geoengineering post-World War Two based on the changing geo-political and socio-economic conditions, and linked to the shifting societal and climate-specific imaginaries of the times. My aim is to understand both the continuities and discontinuities between the past and the present, in the belief that understanding the past may help one make sense of the present and perhaps of SGE’s likely future.

What’s constraining normalisation?
A third and final question is: **What is currently restraining the normalisation of SGE as a legitimate third leg of climate policy, alongside mitigation and adaptation?** This question arises from the realisation that whilst the taboo on geoengineering may have been lifted in the mid-2000s, SGE cannot yet be said to have been embraced by climate policy makers and become something normal and respectable. As will become apparent, there are a number of contested framings and narratives of SGE, expressed in a range of competing imaginaries, none of them currently hegemonic. Exploring these will help in understanding what might be restraining – or, increasingly, what might be enabling – SGE’s normalisation. In the process I will link these imaginaries to the knowledge-values-power questions already discussed. This thesis question is not a normative one, although I am enquiring into norms from a critical standpoint.

In addressing the three questions outlined above I hope to emerge with a more complete understanding of solar geoengineering today.
Methodological approach
Any methodology must be appropriate to the type of questions being asked. It must make clear both the theoretical orientation and mode of inquiry adopted, and the archive or source materials which comprise and inform the object of analysis; and these must be a good ‘fit’ with the research questions. As I will shortly describe, my archive consists primarily of documents that contain accounts of geoengineering which are closest to the centres of political, institutional and organised scientific power.

Theoretical orientation and mode of inquiry
In a general sense I am working with traditions of critical thought and inquiry. I conceive of this as a theoretical orientation which seeks to interpret and make sense of a particular assemblage of texts in their historical and institutional context, guided by certain critical concepts, rather than a “Theory” per se, which would seek to develop explanatory rules and to fit things into prescribed frameworks. Critical thought, as Hoy (2009) notes, is an ‘unmasking’ type of orientation and is particularly concerned with the relationship between ideas and practices, and established power.

Discourses of geoengineering take place in a world where the reality is one of uneven power. This makes itself manifest, to varying degrees, at all levels of society and geo-politically, including individual, community, state, or regional level, and even epistemic communities within the sciences. I hope to be alert, at all times, to the broader realities of power, even when emphasising ideas and their productive power to generate both meaning and effects.

As outlined above, in exploring geoengineering I am especially interested in the relationship between ideas and power: in the ensemble of scientific statements, philosophical and moral perspectives and institutions; in the link between ideologies, imagined futures and the existing socio-economic order; in the disruptive effects of geoengineering on existing environmental and climate discourses; in geoengineering’s ability to generate new approaches to addressing the climate challenge; and it being ‘not-yet-a-thing’, an entity in transition from being an idea to being a practice. The methods I adopt are designed to assist in the task of ‘revealing’ and ‘unmasking’ meanings and implications in their changing historical and institutional context. I aim to understand how and why thinking about geoengineering has changed over time and how it has been situated in the dominant imaginaries and power relationships of the time.

10 Power is uneven across a number of dimensions. Apart from discursive power, Barnett and Duvall also identify the inter-related dimensions of material power (which flow from the assets and resources available), compulsory power (the ability to enforce an outcome on others), as well as structural power and institutional power (2005).
And I need to do this whilst cognisant that the ideational and the material are always already entwined.

In this orientation towards ideas and power I am informed by discursive traditions and their insights regarding the importance of language. How geoengineering is analysed, discussed and constructed; the terms and metaphors used; the framings; the assumptions and judgements relied upon... all this has productive power in constituting meanings and positioning subjects in particular social and ecological relationships. So too does the context within which words are used. As Wachterhauser (1986) has put it: ‘human understanding is never “without words” and never “outside of time”’ (cited in Kinsella 2006: 6). In this thesis, in short, I pay particular attention not only to how ideas are expressed but also in what time and context.

To these traditions of thought I connect other, related traditions: in particular genealogical approaches and elements of critical Marxist thinking. But I do so indirectly, tailoring my own particular mode of critical thought and inquiry to suit my own particular object of enquiry.

As Koopman (2012) describes it, the genealogical approach entails the critical problematisation of submerged problems of the contemporary condition: critique as a precursor to judgement. Contingency, complexity and critique inform this approach. The genealogical tradition also typically pays attention to historical origins, which is the focus of my early Chapters and the second of my thesis questions. It is critical-historical, and indeed has been described as “a backward looking history of the present” (Allen 2013). As we shall see, the role of contingent factors is especially significant in understanding geoengineering’s emergence.

My debt to critical Marxist traditions of thought can be found, for example, in my allusions to the Gramscian notion of ‘hegemony’, especially when addressing my third thesis question exploring the difficulty in normalising SGE. It can also be seen in my close attention to questions of inequality, particularly the rich-poor divide and that between the global North and the global South. This is a focus, at least in part, of my first thesis question, and also relevant when looking at imaginations of the future of SGE in the final Chapters. My debt to this tradition is also evident in my use of the term ‘ideology’ which I use to mean a ‘shared worldview’ or set of ideas, values and goals that structure a group’s notion of reality, and not in the classical Marxist sense of a false set of ideas that has been perpetuated by the ruling class. Ideologies, as I use the term, can therefore be part of a particular sociotechnical imaginary (we will see how at least one of the imaginaries of SGE incorporates a great deal of ‘free market’ ideology). But the concept of sociotechnical imaginaries is both narrower (in its focus on the achievement of future visions through science and technology) and broader (in its
inclusion of norms and assumptions which may lack the coherence or be insufficiently general to be thought of as ideologies).

The integration of the foregoing critical traditions enables me at times to unearth power relations, at other times to unpack some of the discourses of climate and ‘nature’, for example, which inform any consideration of geoengineering, while also enabling me to emphasise how geoengineering is located in the context of other concurrent developments both material and ideational.

Working at the intersection of the material and the ideational, it is necessary to be alert to both the discursive and ‘real’, and their entanglement. Norms and facts are co-produced, especially in climate policy and environmental politics generally (Jasanoff & Martello 2004). This is especially important given that one of my key questions is how to understand why SGE has not been normalised. On the one hand I adopt an approach which is common in the social sciences and central to critical thought: that the concepts that inform our worldviews – ‘climate’, ‘environment’, ‘globalisation’, ‘emergency’ and so on – are socially constructed and shaped. On the other hand I accept that the methods and instruments of science reveal real, physical phenomena – there really is an increasing concentration of GHGs in the atmosphere; there really is a warming trajectory; extinction rates are rising and globally biodiversity really is diminishing, and so on. In practice this means I have an obligation to understand the scientific literature sufficiently to use it accurately before critically commenting on it. But it also means being alert to the normative currents within scientific thought and to the reality that ‘facts’ are never simply facts, and that what facts are uncovered by science, when, where and by whom are socially situated.

In disciplinary terms, as already indicated, I am working at the intersection of critical environmental politics (Death 2013) or ‘critical political ecology’, and science and technology studies (STS). However, geoengineering as it is emerging ranges widely across disciplinary boundaries. Inevitably, therefore, I draw on literature from many disciplines: the Earth sciences, political science more generally, geography, philosophy, economics, ecology, environmental humanities, history, political economy, anthropology, international relations, theology and more. I examine these through the lens of environmental politics and STS. Where I draw on concepts and terminology used across disciplines – terms such as ‘risk’, ‘precaution’, ‘emergency’, ‘governance’ and so on – I endeavour to make the meaning clear.

In short, the cross-disciplinary nature of the subject of my enquiry requires the tailoring of a hybrid methodological approach that is appropriate to the core thesis questions. This approach emphasises problematisation, contingency, contextualisation, power and unmasking.
Archive

In asking, as my central question does, what is at stake in the re-emergence of SGE, considerations of power and the existing social order become essential to the enquiry. This has shaped my archive and led me to focus on analysing the ‘institutional’ and the ‘policy-influential’ literature surrounding SGE. Together these make up my central archive.  

What I call the ‘institutional’ literature on geoengineering comprises reports or other documents on geoengineering from authoritative institutions, or ‘official’ bodies in some sense. They are generally institutions, domestically and internationally, which influence the overall settings of climate policy: both current policies and potential future ones. They are typically close to one or more centres of institutional or governmental power and they accordingly help frame discourses of climate change. These reports are critical for understanding how a powerful technology is understood in the “corridors of power”. Most commonly they are examples of what Jasanoﬀ has called ‘advisory science’, a hybrid activity combining ‘elements of scientiﬁc evidence with large doses of social and political judgement’ (1990:229). They have typically been produced collaboratively and then ﬁnesed and signed-oﬀ by the participants prior to release. As such they can be said to reﬂect some sort of collective, negotiated, perspective. In some instances they operate at the intersection of elite science, government, the policy elite, and even the military (with the NRC 2015a report being the most prominent example of this).

Table 1-1 lists the key ‘institutional’ documents produced since SGE’s re-emergence. The most notable, and arguably inﬂuential, are documents, or parts of documents, emanating from the IPCC (especially associated with the Fifth Assessment Report), the UK’s Royal Society (2009), and the US National Research Council (2015). Other institutional literature emerges from various international initiatives focussed on governance (such as SRMGI and Asilomar), government agencies (such as NASA, the US Government Accountability Ofﬁce, and the German Environment Agency), and legislatures (most notably in the UK and the USA). Reports on geoengineering from advocacy groups or think-tanks are not generally included in this listing of ‘institutional’ reports. However, the Council on Foreign Relations (CFR), RAND

11 By ‘archive’ I mean a bounded set of documents that are the focus of my close reading.
12 In the more historically focussed chapters in Part I, I jump more freely between ‘institutional’ and other literature since the literature rarely has a singular focus on geoengineering and coming to grips with the changing imaginaries of that time requires a less rigidly deﬁned archive.
13 These include major reports by, for example, the Copenhagen Consensus Center (CCC), the American Enterprise Institute (AEI) and The ETC Group. I do not treat these as having the same ‘official’ status as
Corporation and Bipartisan Policy Center (BPC) reports are included because their well-known closeness to the US foreign policy, security and political establishments respectively gives them something verging on “official” status, and at the very least an insight into thinking that is close to the US establishment.

The ‘institutional literature’ is often politically cautious in its phrasing and limited by mandate as to what it can discuss: the NRC report (2015a) is one prominent example. Therefore the second component of my central archive is what I term the ‘policy-influential’ literature. These are works – journalistic, popular and academic – by individual authors, often but not always scientists, who have been closely associated with a number of the institutional reports. These are the key knowledge-brokers and scene-setters of SGE. They have generally played a central role in framing the institutional debates around geoengineering and presenting the ideas to the public. They frequently assess specific geoengineering proposals, recommend funding, and occasionally advise ultra-wealthy individuals with an interest in geoengineering (Hamilton 2013a: 72ff). They often referee reports where they have not been panellists, and are repeatedly cited in press articles on the topic, thereby helping frame opinion. Their writings are less constrained than the ‘institutional’ literature, and more likely to engage with the implications of geoengineering, or address non-scientific issues that are causing disquiet, whilst still carrying authority. Their views matter.

Not all the policy-influential literature is supportive of geoengineering: Alan Robock, for example, a leading expert in volcanos and atmospheric science, is a key knowledge-broker but also sceptical of SGE (2008). But much of it is. Identifying whose work to include as ‘policy-influential’ is more art than science, but it is not entirely random. Those supportive, or reluctantly accepting, of geoengineering have been labelled the ‘geo-clique’ by Kintisch (2010a:8), a term which has gained traction elsewhere (see Hulme 2014:14; Nerlich & Jaspal 2012). Key names include scientists Ken Caldeira and John Shepherd, engineer David Keith, and policy specialists David Victor and Jason Blackstock. Oldham et al (2014) analyses bibliometric data and co-authorship of scientific papers related to SGE and adds names like Ben Kravitz, Peter Irvine, Andy Jones and Philip Rasch to those already mentioned: the last of these has been involved in more than one of the institutional reports.

those listed, but do of course draw on them where needed to understand the perspectives they represent.
Table 1-1: Key institutional texts, since mid-2000s, relevant to SGE (most influential marked in bold)

<table>
<thead>
<tr>
<th>Locus</th>
<th>Institution</th>
<th>Year</th>
<th>Brief Title</th>
<th>Abbrev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>International</td>
<td>IPCC</td>
<td>2013</td>
<td>5th Assessment Report</td>
<td>IPCC-5AR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>Report of 2011 expert meeting on Geoengineering</td>
<td>IPCC-EXP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2007</td>
<td>4th Assessment Report</td>
<td>IPCC-4AR</td>
</tr>
<tr>
<td>UK</td>
<td>The Royal Society</td>
<td>2009</td>
<td>Geoengineering the climate</td>
<td>ROYSOC</td>
</tr>
<tr>
<td></td>
<td>SRM Governance Initiative</td>
<td>2011</td>
<td>Solar radiation management: the governance of research</td>
<td>SRMGI</td>
</tr>
<tr>
<td>UK/USA</td>
<td>Tyndall Centre &amp; Cambr-MIT Inst.</td>
<td>2004</td>
<td>Macro-Engineering Options for Climate Change Management &amp; Mitigation</td>
<td>TCM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2015</td>
<td>Climate Intervention: report in brief</td>
<td>NRC15-SUMM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>Advancing the Science of Climate Change</td>
<td>NRC10</td>
</tr>
<tr>
<td></td>
<td>Novim</td>
<td>2009</td>
<td>Climate Engineering Responses to Climate Emergencies (cited as Blackstock et al)</td>
<td>NOVIM</td>
</tr>
<tr>
<td></td>
<td>Asilomar</td>
<td>2010</td>
<td>Principles for Research into Climate Engineering Techniques</td>
<td>ASOC</td>
</tr>
<tr>
<td>US – Govt &amp; Political establishment</td>
<td>US Senate</td>
<td>2007</td>
<td>Senate Committee on Environment &amp; Public Works (various)</td>
<td>SEN-EPW</td>
</tr>
<tr>
<td></td>
<td>US Congress</td>
<td>2010</td>
<td>Congress Science &amp; Technology Committee</td>
<td>CONG-S&amp;T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2013</td>
<td>Congression’s Res. Service: Geoengineering: Governance &amp; Technology Policy (various)</td>
<td>CRS</td>
</tr>
<tr>
<td></td>
<td>RAND Corporation</td>
<td>2011</td>
<td>Governing Geoengineering Research: a Political and Technical Vulnerability Analysis of Potential Near-Term Options (cited as Lempert &amp; Prosnitz 2011)</td>
<td>RAND</td>
</tr>
<tr>
<td></td>
<td>Bipartisan Policy Center</td>
<td>2011</td>
<td>Geoengineering: a national strategic plan for research on the potential effectiveness, feasibility &amp; consequences ...</td>
<td>BPC</td>
</tr>
<tr>
<td>Germany</td>
<td>German Fed. Min. of Educ. &amp; Res’rch</td>
<td>2011</td>
<td>Large-scale Intentional Interventions in to the Climate System? (cited as Rickels et al 2011)</td>
<td>GFME</td>
</tr>
<tr>
<td></td>
<td>Umweltbundesamt (German EPA)</td>
<td>2011</td>
<td>Geoengineering: Effective Climate Protection or Megalomania? (cited as Ginzy et al 2011)</td>
<td>GEPA</td>
</tr>
</tbody>
</table>
Any listing should probably also include names such as Andy Parker, Scott Barrett and Michael MacCracken. Not yet published research (as at August 2016), using social network analysis, and aiming to identify the key knowledge-brokers at the centre of debates around geoengineering, largely concurs with these names (Möller forthcoming). Where I use the work of particular knowledge-brokers I will identify why they can be considered particularly influential.\(^{14}\)

**Other literature relevant to geoengineering**

My central archive constitutes the core of my close reading. I also go beyond this archive and make use of a wide range of secondary academic literature analysing one or another aspect of geoengineering, and other popular or journalistic accounts. I generally use these to enhance analysis and understanding, and because they provide insight or knowledge into a particular issue, but I do not treat them as institutionally authoritative or policy-influential.\(^{15}\)

There is a large and rapidly growing literature on geoengineering. The reference list alone of the NRC report runs to 37 small-font pages (2015a; see also Irvine *et al* 2016), and this mainly covers peer-reviewed scientific literature. There are now hundreds of articles emanating from the social sciences. A number of significant edited collections have also been published in recent years, in particular focussing on the scientific and engineering issues associated with different techniques (Launder & Thompson eds. 2009; Harrison & Hester eds. 2104); or reflecting on the ethics and governance of geo-engineering (Preston ed. 2012 and 2016 forthcoming; Blackstock, Miller & Rayner eds. 2015).

There are also a number of monographs. Two journalistic accounts provide anecdote-rich introductions to the people, issues and technologies associated with the re-emergence of geoengineering (Kintisch 2010a; Goodell, 2010). They touch on many of the themes of this thesis, although not in great conceptual depth. Some monographs on climate change contain weighty chapters on geoengineering, such as Jim Fleming’s *Fixing the Sky* (2010a) which locates geoengineering historically, Stephen Gardiner’s *A Perfect Moral Storm* (2011), which analyses the ethical issues, or David Victor’s *Global Warming Gridlock* (2011), which argues that in a ‘climate emergency a well-designed geoengineering plan will be better than doing

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\(^{14}\) It may be relevant sociologically that almost all are pale, male, first world scientists.

\(^{15}\) It is, perhaps, a symptom of the failure of SGE to be normalised, or contained as a predominantly technoscientific object, that some of the authors of the secondary literature are beginning to influence policy directly. One thinks here of Oxford’s Steve Rayner, as well as two academics known to be hostile to SGE, Clive Hamilton and Jim Fleming, both of whom had some involvement with the NRC report (2015a).
nothing’ (2011:166). Clive Hamilton’s Earthmasters: Playing God with the Climate (2013) stresses the Promethean hubris of the drive to geoengineering and finds few if any reasons which can justify even research into geoengineering. His book draws particular attention to the small handful of scientists and engineers leading the geoengineering charge, the so-called ‘geo-clique’, and the involvement in geoengineering of private capital and the ultra-rich (including Bill Gates), the patenting of certain technologies by key scientists, and the interest in geoengineering from the military-industrial complex. He is particularly concerned about the danger of such players becoming established and having a vested interest in the continuing pursuit of geoengineering.

In 2013 Harvard University’s David Keith, the most active of the knowledge-brokers, published a short monograph entitled A case for climate engineering, specifically a case for solar geoengineering. This elicited a sharp response from Mike Hulme, a well-known UK-based climate scientist and now geographer in the form of a book entitled Can Science Fix Climate Change? A case against climate engineering (2014). Hulme, also talking about solar geoengineering, takes issue with hubristic techno-fixes and argues that climate engineering is undesirable, ungovernable and unreliable (2014:xii). I discuss both books at length in this thesis as exemplars of strong, contrasting, perspectives on SGE.

Two important books on geoengineering were published as this thesis was being written up. Jack Stilgoe’s Experiment Earth (2015) examines solar geoengineering, including the Stratospheric Particle Injection for Climate Engineering (SPICE) project, and is inspired by the sociology of expectations.16 With an ethnographic eye he takes a critical and revealing look at the Royal Society report, the subsequent SPICE project experiments, and the disciplinary tensions that have emerged between the engineers and various other scientists, and the many ways in which the scientific and the social are entangled both in climate change science generally and in SGE in particular. He is especially interested in rethinking experimentation and exploring what responsible innovation might look like. These concerns neatly complement the focus of this thesis. They also occasionally converge since, like Stilgoe, I too draw on the lens of science and technology studies (STS) in thinking about SGE. Stilgoe’s characterization of solar geoengineering as ‘the figment of a particular technoscientific imagination’ has much in common with my own approach. But where he is concerned with how good and

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16 The SPICE project was a UK-based project looking at candidate particles that could be used in SGE, the feasibility of a balloon delivery system, and related modelling. Launched in 2010, it was suspended for a period amidst controversy regarding its implications. See [http://www.spice.ac.uk/](http://www.spice.ac.uk/)
democratic experimentation might emerge, my focus is largely different in that I concentrate on what is at stake and what is restraining SGE’s normalisation.

Well-informed science journalist Oliver Morton’s book, *The Planet Remade: how geoengineering could change the world* (2015), examines geoengineering in general whilst devoting a significant part of his book to SGE. For Morton the seriousness of the climate problem combined with the sheer difficulty, indeed impossibility, of making the needed energy transitions in time, means geoengineering will probably be inevitable. His argument has some similarity with those made in this thesis: ‘the way a society imagines its future matters. Who gets to do the imagining matters’ (2015:30). Utopian thinking ranks high in his project, but not because utopias are attainable. ‘[l]imagining geoengineered worlds that might be good to live in, in which people could be safer and happier than they otherwise would be, is worth doing’ (p.30). His goal is what he calls ‘a deliberate planet’ (p.344). It is one in which, following Latour’s Frankenstein comment already referred to in my Prologue, people ‘take care not control’.

*

I have endeavoured to create a tight and appropriate ‘fit’ between the research questions I pose, the theoretical orientation and conceptual resources I draw upon, the archive I have crafted and my critical mode of interpreting this archive. By adopting an approach grounded in traditions of critical thought I facilitate the ‘unmasking’ task at the heart of my central research concern. By focusing on the ‘institutional’ and the ‘policy influential’ literature, I select approaches with the closest proximity to power and climate policymaking, again a central concern. The theoretical orientation and the archive, taken together, enable me to outline and understand the range of sociotechnical imaginaries at play.

By reading the archive closely, through the lens of my chosen theoretical orientation, and examining both what is said and what is not said, I am able to reveal much of the implicit, often paradoxical, thinking which animates SGE. I am able to explore what ideologies, assumptions and dreams underpin it and therefore reveal what is at stake in SGE’s re-emergence, what its past reveals about its present, and what is constraining its normalisation as a respectable component of climate policy and its deployment as a technology.

**The argument in brief**

My argument, briefly stated, is that there are clear continuities with earlier attempts at geoengineering, but also clear differences. These differences include a decline in the valency of previous notions of Mastery and expectations of Progress, not least within the epistemic
community of climate science. SGE today is intended as a masking technology which aims to contain the warming effects of climate change. I argue that it should also be understood to mask the systemic socio-economic drivers of our climate predicament. In this sense it is a doubly-masking technology. This double-masking is not commonly understood: at most, an objection to SGE on the grounds of so-called ‘moral hazard’, that it will discourage mitigation efforts, occasionally acts as a partial stand-in for such concerns.

Whilst SGE is both (developing) technology and (emergent) climate policy, it is also an idea-information. This is why I argue that it is most usefully understood as a “sociotechnical imaginary”. The ideologies, assumptions and dreams projected onto SGE, the effects SGE as technology is expected to have and the work it is expected to perform, entail a world both disrupted and stabilised. It is ontologically disruptive, and particularly challenging to many traditional understandings of the human relationship to the more-than-human, to ‘nature’. SGE is imagined as a powerful technology; it is also a technology of the powerful. It is both Earth-shaping and world-making. It is simultaneously compatible with ‘business-as-usual’ and the pursuit of endless economic growth, and yet also implies pushing the existing global order in a substantially more autocratic and securitised direction than it is currently.

A range of competing imaginaries swirl around considerations of SGE, none of them yet hegemonic. Something is constraining a single narrative from emerging, and restraining SGE from becoming fully normalised as an acceptable climate policy and fully developed as a technology able to be deployed. According to the major ‘institutional’ assessments to date, what is holding SGE back is primarily a lack of information and knowledge, including a lack of clarity regarding the likely effects on rainfall, agriculture and regional weather patterns, and on existing mitigation efforts. And so, the standard story goes, more research and more detailed modelling are needed. I argue that the inability to normalise is better understood as a function of the ideational. This includes a widespread distaste for the Earth- and climate-shaping envisaged and a sense that it is ‘un-natural’; the location of the case for geoengineering within discourses of climate crisis and climate emergency; and a disconnect between the dominant norms of the ‘epistemic community’ of climate scientists and those of ‘market globalism’. To date these restraining ideas have proven more significant than the fact that the technology is, in many respects, compatible with the dominant global order and the
interests of the powerful. To the extent that SGE is able to break these restraints it will be, I argue, because it has been re-imagined as a sociotechnical imaginary of the Anthropocene.¹⁷

Chapter outline
The Chapters following this Introduction are divided into three sections: Yesterday, Today and Tomorrow.

‘Yesterday’ comprises Chapters 2 and 3. There I explore the history and understandings of geo-engineering in the period prior to 2005. I identify three phases in geo-engineering’s history prior to its re-emergence: Mastery, Unimaginability and Taboo. Figure 1-2 depicts this and the associated contexts and imaginaries of the times. The aim in the first section is to sketch a genealogy for geoengineering and to draw out the continuities and discontinuities between how geoengineering, and especially SGE, have been understood and imagined at different times.

<table>
<thead>
<tr>
<th>Cold War</th>
<th>Market globalism</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASTERY</td>
<td>UNIMAGINED</td>
</tr>
<tr>
<td>1945 – early ’70s</td>
<td>early ’70s – 1990</td>
</tr>
<tr>
<td>TABOO</td>
<td>NEW OPTION</td>
</tr>
</tbody>
</table>

Geoengineering’s 1st wave | Geo-engineering’s Hiatus | Geoengineering’s 2nd wave

Figure 1-2: Periodisation of interest in geoengineering post World War 2

Chapter 2, ‘The Assumption of Mastery’, examines geoengineering’s first wave, and tracks its enthusiastic embrace as an idea after 1945 and during the height of the Cold War. It will show how geoengineering formed part of a larger Cold War imaginary involving, in the West, the triad of modernity: a belief in ‘progress’, the invention of ‘development’, and a faith in ‘science’ and the technologies it could generate, and with all three underpinned by an assumption of human entitlement, even obligation, to mastery over nature. These had almost identical counterparts in the Soviet sphere. Geoengineering was embraced because it was possible, and as part of US-Soviet Cold War techno-rivalry, and not because there was a climate problem needing a solution.

Chapter 3, ‘Becoming “taboo”’, examines the hiatus period, an inter-regnum in which geoengineering was seen as unnecessary and no longer imagined, before coming to be regarded as Taboo. It was a taboo that persisted even during an unsuccessful attempt by

¹⁷ The idea that, since about 1950, humanity is now the dominant Earth-shaping geological force (Zalasiewicz et al. 2015).
some scientists to revive the idea in the early 1990s. This Chapter seeks to understand the reasons for geoengineering’s effective disappearance from the climate policy table. And it reveals some of the specific thinking about science, climate and nature that made geoengineering essentially unimaginable.\(^\text{18}\) The relationship between the idea of geoengineering and the rise of neo-liberal globalisation is also considered.

The section ‘Today’ contains three chapters and aims both to describe and critically analyse geoengineering since its re-emergence in the mid-2000s. In Chapter 4, ‘The re-emergence of geoengineering’, I analyse the institutional literature in depth, and chart the re-emergence of SGE into mainstream consideration as a policy option from the mid-2000s, and link it to growing concerns about climate. I trace the primary rationales that accompanied its revival, and analyse the various ways in which it is framed, understood and imagined today. I also show how geoengineering has been unable to be normalised as a concept and as a respectable third leg of climate policy. It is researched and imagined but it lacks legitimacy and traction.

In Chapter 5, ‘Knowledge, Power, Values’, I dive more deeply into understandings of SGE today, in an effort to understand attempts to stabilise and normalise it as a concept. I focus on epistemological and knowledge choices, questions of values and ontological ordering, and the relationship of SGE to power and the powerful. In particular I examine the elevation of the “techno-scientific” in institutional assessments of SGE, the invocation of ‘emergency’, the elevation of cost-benefit thinking, the narrowing of ethical debates, and the implications of SGE for capitalism and geo-political ordering. In each case I show how paradoxes and contradictory forces and imperatives cohabit, in ways which restrain normalisation.

In Chapter 6, ‘Competing narratives of SGE’, I analyse four competing narratives and their associated logics, assumptions and imaginaries. Each of these engages with SGE beyond the technoscientific framing, but none has managed to emerge as hegemonic. Without a hegemonic narrative it becomes difficult for SGE to be officially embraced and normalised as both applied technology and climate policy. I examine the implicit and explicit values, worldviews and ontological orderings in the competing narratives. Three of these are largely favourable towards SGE. I label them the ‘Market’, ‘Geo-management’ and ‘Salvation’ narratives respectively, and I interpret them through a close reading of the work/s of a key ‘policy-influential’ proponent. These three narratives can be thought of as uncomfortable bedfellows, strands of what I call the ‘Power’ imaginary. The fourth narrative analysed is

\(^{18}\) Geoengineering was, of course, not literally unimaginable. Rather it became unrespectable and fell off the table of things which governments might consider doing.
essentially an oppositional ‘Un-natural’ imaginary. I also touch on, but do not comprehensively analyse, another oppositional narrative, which I label the ‘Chemtrail’ imaginary.

The final section, ‘Tomorrow’, consists of a single Chapter examining the prospects for SGE and its possible deployment. In Chapter 7, ‘Future Imaginings’, I examine the implications for SGE of various ways in which climate change might unfold. I also examine the relationship between SGE and the currently powerful in the world and suggest that power in many dimensions needs to be thought of as intrinsic, rather than extrinsic, to SGE. Finally, I explore how paradigms of ‘development’ and the Anthropocene have begun to be mobilised in support of reframing SGE as a project of modernity. I conclude by suggesting that if SGE does materialise as an operational technology, it will do so as a sociotechnical imaginary of the Anthropocene.

The conclusion, Chapter 8, pulls the key strands of the argument together and reflects on whether the thesis questions – what’s different, what’s constraining, what’s at stake – have been answered. I conclude by looking at a number of implications of my analysis for thinking about climate policy post-Paris and about environmentalism, before considering whether SGE will ever come into being as a deployed technology and a third leg of climate policy.
Section I – YESTERDAY
Geoengineering entered the public and climate policy domain around 2005. But this contemporary interest in geoengineering is not new. There are clear precursors in the period from 1945 until the early 2000s.19 I explore these in this section. By analysing contemporary geoengineering’s pre-history and exploring its genealogy, I hope to show both continuities and discontinuities in personnel, ethos, accompanying vision, and association with the dominant order. This should enhance our understanding of the contemporary geoengineering imaginary.

The changing shape of the geoengineering idea during this period (1945 - 2005) is, of course, intimately connected to the times. Understanding the social, economic, geopolitical, scientific and ideological context is therefore crucial. I focus in particular on the changing nature of the Cold War, the understandings of science in this period, the emerging understanding of global warming, the rise of environmentalism, the hegemony of neo-liberal globalisation at the Cold War’s end, and the transition from ‘weather’ to ‘global climate’ as an object of concern.

I identify three phases in geoengineering’s pre-history. A first phase, which emerged in the wake of the Second World War, ran concurrently with the first period of the Cold War, and could be found in both the East and the West. Running for almost three decades (from 1945 until the early 1970s), this phase was grounded in a manifest confidence in the idea that ‘we can and should’ geoengineer. I label this the Mastery phase, since it was characterised by dreams and assumptions of mastery.

In the second phase (starting in the early 1970s), scientific and policy interest in climate engineering rapidly dissipated and the idea largely disappears from sight. As global warming is increasingly understood to be anthropogenic, mitigation is adopted as the required response. By the late 1980s, as potentially serious climate effects are recognised, geoengineering is

19 Fleming’s major monograph Fixing the Sky (2010a) provides a detailed history of meteorology and of attempts at weather and climate modification. Elsewhere he writes about the many ‘deceptional and delusional attempts to control nature’ (2006:25). I exclude from my account one manifestation which he includes in his study: early local efforts at rainmaking. From the 1840s, so-called ‘pluviculturalists’ focussed on what they claimed to be ‘scientific’ rainmaking, for example by lighting large fires. And there are traditional attempts across millennia to make rain. These are too remote from the focus of this thesis although there are some continuities. Indeed, I will touch on some of the Cold War efforts at weather modification which, as we shall see, involved trying to create rainstorms over enemy territory. It could even be argued that ‘scientific’ rainmaking, given its dubious efficacy, has much in common with long-established shamanic efforts across many cultures, only with scientific ‘power over’ rather than magical ‘alignment with’ powers being claimed as the underlying force. But this is beyond the scope of this thesis.
neither imagined nor, it seems, imaginable by those thinking climate policy. I label this the Unimagined phase.

In the third phase, from shortly after the end of the Cold War (1989-90) until the early 2000s, there are unsuccessful attempts to revive interest in geoengineering as a policy option. In a tone redolent of the Mastery phase, and at a time when neoliberal globalisation is becoming hegemonic, the emphasis is on geoengineering’s cheapness. The idea floats around, and even appears in an “official” report, but there is little enthusiasm for it and it is barely discussed. Its previous unimaginability persists as Taboo, the label I give this phase.

These three phases should be seen as a broad-brush periodisation of geoengineering, largely from the perspective of elite interest in the idea. From a larger historical perspective, both phases 1 and 2 take place against the backdrop of the Cold War, although the shift to the Unimagined phase coincides with a tempering and redirection of the Cold War during the so-called ‘détente’ period.

A further continuity exists between phases 2 and 3. In contrast to the Mastery phase, little work on or advocacy of geoengineering takes place in either the Unimagined or the Taboo phases. In this sense both phases together can be understood as a hiatus between the Mastery phase and the contemporary post-2005, second wave of interest in geoengineering.

To assist in reading the following chapters, Figure 2-1 below summarises the periodisation I have adopted, and the associated historical contexts.

<table>
<thead>
<tr>
<th>Cold War</th>
<th>Market globalism</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASTERY</td>
<td>UNIMAGINED</td>
</tr>
<tr>
<td>Geoengineering’s 1st wave</td>
<td>Geo-engineering’s Hiatus</td>
</tr>
</tbody>
</table>

Figure 2-1: Summary periodisation of geoengineering context and associated imaginaries

This section contains two chapters. The first of these will examine geoengineering’s first wave, Mastery. It will show how geoengineering formed part of a larger Cold War imaginary involving, in the West, the triad of modernity: a belief in ‘progress’, the invention of ‘development’, and a faith in ‘science’ and the technologies it could generate, and with all

20 Although geoengineering was, of course, literally imaginable it seems in reality to have been barely imagined.
21 In reality, of course, there are overlaps in any periodisation, and it is not suggested that each period starts and ends neatly on the stated dates.
three underpinned by an assumption of human entitlement, even obligation, to mastery over nature. These had almost identical counterparts in the Soviet sphere.

The following chapter will examine the Hiatus period, an inter-regnum when geoengineering was unnecessary and Unimagined, and then came to be seen as Taboo. It will try to understand the reasons for geoengineering’s effective disappearance from the climate policy table. And it will aim to show some of the specific thinking about science, climate and nature which made geoengineering essentially unimaginable. The relationship between the idea of geoengineering and the rise of neo-liberal globalisation is also considered.

* * * * *
Chapter 2. The assumption of Mastery: geoengineering’s 1st wave

“We would be unfaithful to the tradition of Western Civilization if we shied away from exploring what man can accomplish, if we failed to increase man’s control over nature ....”

Edward Teller (1962:56)

The beginnings of the Cold War can be found in the closing months of the Second World War. In Europe there was a race between the nominal allies (mainly Britain, the US and the Soviet Union) to ensure that Hitler’s defeat left them in control of the largest possible swathes of territory. Churchill (and de Gaulle’s Free French) were committed to regaining control of those colonial possessions they had been forced to abandon, and re-asserting their diluted authority over those they had retained throughout the War. National resistance movements, of various stripes but generally communist in orientation, were advancing in a range of places including China, French Indo-China, Korea, Indonesia and elsewhere.

There was concern in Washington about future US influence in the Pacific and a desire to conclude the war there on favourable terms. Fearful of the possibility of the Soviet Union and Japan concluding a separate peace, and wanting to set down a marker for the future, the US decided to deploy its newly-invented atomic bomb to force Japanese surrender. The Soviets, whose infrastructure and population had been hardest hit by the war, would soon devote vast resources to science and military technology to ensure they would not be left behind. They emerged from the War as the second global superpower, after the United States. Competition between them was central to what would soon become known as the ‘Cold War’. Ideology played a key role in shaping this competition and how it played out globally. America, as Westad puts it, cast itself as an ‘empire of liberty’, whilst the Soviet Union cast itself an ‘empire of justice’, and both thought of themselves as the true bearers of Western modernity (Westad 2007).

Over the following decades, the United States developed its military power and global presence, whilst the Soviet Union attempted to keep up with it and, occasionally, surpassed it. The connection between scientific production, government funding, and military application was generally substantial throughout the Cold War (Oreskes & Krige 2014) and was integral to the arms race (see also Masco 2010). The period saw enormous investment, in both the US and the USSR, aimed at advancing both climate control capability and the science of meteorology more generally, with both believed to be centrally important to the military and to their nuclear weapons programmes in particular. Fleming (2010) has labelled the Cold War
proponents of climate engineering as the ‘weather warriors’, since their scientific work, proposals and even their fantasies were deeply enmeshed with the military.

In the United States, perhaps because of the role of that country’s scientific and technological achievements in winning the war, what emerged was a belief that almost any problem, natural or man-made, could be fixed. Almost identical views could be found in the Soviet Union, underpinned in that case by the Stalinist belief in the power of the socialist order to overcome all obstacles to ‘progress’. In hindsight what is most striking is that, after the most destructive and technologically sophisticated war (and genocide) in history, both East and West embraced a highly hubristic vision of ‘progress’, science and technology. Indeed, as I will now show, this seemed to be a central component of the early Cold War zeitgeist.

Technophilia and hubris

Julian Huxley, a well-known British physicist and self-declared humanist (and soon to be founding head of UNESCO), flew to New York in December 1945, in the aftermath of the bombing of Hiroshima and Nagasaki. According to a New York Times report on the 20,000-strong gathering he addressed, he called for international control of atomic energy, something then being strongly resisted by the US military. Better, argued Huxley, to use atomic power to help “regions which are still no better off than they were a century and more ago.” It could be used as “atomic dynamite” for “landscaping the Earth”. ‘Dams could be built in a fraction of the time’. Arctic pack ice and snow could be melted.

When challenged about the Arctic proposal Huxley admitted, said the reporter, that the exact consequences were unclear. ‘He would not blow the Arctic cap away all at once ... A beginning would be made with “only a little bit of ice, north of Labrador, say”’. Huxley was equally enthusiastic about atomic power. It might distil seawater and flood the Sahara so that it might “again blossom”. ‘Atomic power could make an old dream come true’, ‘opening regions which are now uninhabitable or economically uninteresting’, and be ‘a safeguard against the social danger of overdeveloping densely populated industrial regions’. Huxley’s vision, said the reporter, involved ‘international control of atomic energy and ... social planning on a worldwide scale’ (New York Times, 9 Dec 1945).

I cite Huxley’s stance at some length because his views capture both technological hubris and the desire to impose a certain type of developmentalism upon the world – literally blasting the

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22 Huxleys’ own biography is fascinating with combinations of interests virtually unthinkable today. He was an influential scientist, a committed eugenicist, a colonialist, an old-style conservationist (and
backward and ‘uninteresting’ regions into modernity. This was before the term ‘development’ had been invented (Sachs 2010).

Highly influential US public intellectual Arthur Schlesinger Jnr., remarked in his 1949 book The Vital Center: The Politics of Freedom, that:

… no people in the world approach the Americans in mastery of the new magic of science and technology. Our engineers can transform arid plains or poverty stricken river valleys into wonderlands of vegetation and power (cited in Bonnheim 2010: 892).

Similar thinking could be found in the Soviet Union. In 1948 Stalin had announced his plan for ‘The Great Transformation of Nature’, what Brain has called ‘the world’s first state-directed effort to reverse human-induced climate change’ (2010: 671). Shaw cites the editors of Voprosy Geografii, published in 1952 to address The Tasks of Physical Geography in Connection with the Great Construction Works of Communism: “Whilst remaining natural scientists, geographers must at the same time become in their own way ‘builders’ of new, transformed landscapes, or ‘engineers of nature’” (Shaw 2015:127).23

Arkadii Borosovich Markin’s 1956 book Soviet Electric Power emphasised the imagined future role of nuclear power:

New islands and colossal dams will be built and new mountain chains will appear. Atom explosions will cut new canyons through mountain ranges and will speedily create canals, reservoirs, and sea, carry[ing] out huge excavation jobs.... Science will find a method of protection against the radiation of radioactive substances” (cited in Fleming 2010a:199).

These perspectives were a continuation of longstanding Soviet interest in subjugating nature, and opening up the Arctic and Siberia in particular, with science and technology seen as the key to this (Josephson 2011: 420). And they had almost identical counterparts in the US government’s ‘Operation Plowshare’ initiative of the 1950s, a geological engineering programme to “… research, design, and implement the ‘constructive’ uses of nuclear explosives” with its initial focus on opening up Alaska (Kirsch & Mitchell 1998:101).

Igor Adabashev, in his 1966 book Global Engineering, also echoed some of Huxley’s developmentalist dreams but he attached them to the Soviet self-identification as bearer of justice. He envisaged diverting rivers and creating a vast inland sea in the Sahara, thereby allowing crop production to flourish. This would enhance ‘the struggle of African people’s for

23 These plans either failed or were completed at great ecological cost, with the tragic story of the Aral Sea being one of the widely-known examples (Micklin 2007).
national liberation’. Such projects had been delayed by capitalism which was like ‘a ball and chain hampering man in his progress towards a happier lot’ (cited in Fleming 2010a:200).

Propagandist and popular imagery also convey a sense of the times. Figure 2-2 reproduces a 1949 Soviet poster. This portrays Stalin as fatherly leader explaining his plan for the ‘Transformation of Nature’ to two heroic-looking workers. Behind Stalin, the ‘forest breaks’ (like wooded barriers) described in the plan and surrounding the collective farm fields, are already in place. The slogan reads “Let’s Remake Nature According to Stalin’s Plan”. Figure 2-3 comes from a 1954 cover of a popular US magazine, *Collier’s*. It is suggestive of popular perceptions at that time regarding the promise of engineering the weather. It also directly alludes to the military interest in this.

![Figure 2-2: “Let’s Remake Nature According to Stalin’s Plan”](image)

In short, from the outset, on both sides of the Cold War, the dominant imaginary was one of Mastery. It involved overcoming Nature, in the name of ‘progress’ and ‘development’, by mobilising science and technology, and in the most hubristic combination imaginable. It was an overwhelmingly optimistic vision. The technoscience imagined was state-driven, envisaged

* Cited in Brain (2010), which credits Viktor Semenovich Ivanov, 1949.
only ‘big’ technologies, and the purportedly ‘socialist’ and ‘capitalist’ (or ‘justice’ and ‘liberty’) visions of what ‘progress’ and ‘development’ entailed sounded remarkably similar.

Edward Teller, a leading US scientist, and an influential figure in both the technosciences and politics of the era (and, later, in solar geoengineering), captured the mood of the time in his 1962 book The Legacy of Hiroshima.\textsuperscript{24} The quotation which opens this Chapter conveys this, and other quotations are also typical:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2-3}
\caption{“Weather made to order” \textsuperscript{*}}
\end{figure}


\textsuperscript{24} Teller was a key figure in the practice and politics of ‘big science’ throughout the Cold War and beyond. US President Eisenhower, in his 1961 farewell speech, famously warned against both the ‘military-industrial complex’ and the hijacking of public policy by the ‘scientific-technological elite’, and he let it be known afterwards that it was Teller and von Braun that he had in mind (Goodchild 2004:xxiii).
“... the demands of the world's needy must be met and can be met, and they will be met through science” (p.81)

“Science brings progress; progress creates power; power is coupled with responsibility” (p.93)

“The ancient story of Prometheus has ceased to be a legend. It has become a fact. There are among us those who are frightened by such progress, those who would turn back. This we cannot do.” (p.299)

**Geological engineering and climate modification**

This vision of Mastery was widely held not only by the political and military elites, but also by leading scientists and large swathes of the scientific community. In this section I give examples and major milestones relevant to climate modification and drawn from the early decades of the Cold War. These cover leading scientists and scientific institutions, and political and military leaders talking about science, and come from both sides of the East-West divide. The aim here is to highlight the climate engineering component of the wider imaginary of Mastery already described. In this period the focus was on three related practices: geological engineering, climate/weather control (the distinction was blurred at this time), and the development of meteorology (and associated computing, rocket/satellite and space capabilities), and cognate disciplines such as oceanography.

To avoid an ahistorical account, it is important to note that for much of this time whilst the warming physics of CO₂ concentrations had been theorised, the trend of actual warming was not yet known nor was ‘climate change’ a framework of understanding. Hence, the fantasies and proposals covered both weather control and climate control, and the boundaries between these objectives were never clear. Indeed, says Miller, in this period ‘... climate and weather ... were essentially identical’ (2004:50). Because solar geoengineering is the focus of this thesis, the account below will give greater emphasis to proposals aimed at atmospheric engineering, although in practice these were not always clearly distinguished from other interventions.

In October 1945, two months after the dropping of atomic bombs on Japan, Vladimir Zworykin’s “Outline of a Weather Proposal” raised the need for more exact, scientifically-based weather knowledge. Better data, and the ability to compute, might allow for effective weather control. Zworykin, a research director at the RCA Laboratory in Princeton, imagined a future where “[l]ong-term climatic changes might be engineered by large-scale geographical modification projects...” (Fleming 2010a:192-3). Zworykin imagined an international organisation to both study and channel the weather and thereby ‘improve’ the climate, in the hope that its “... eventual far-reaching beneficial effects on the world economy may contribute to the cause of peace” (cited in Fleming 2010a:193).
Zworykin’s proposal was immediately endorsed by the influential John von Neumann, who had been central to developing the atomic bomb, even helping select the Japanese cities to be targeted (Macrae 1992). In von Neumann’s endorsement he envisioned ‘altering the reflective properties of the ground or the sea or the atmosphere’ and he noted that the proposal fit well with his overall philosophy: ‘All stable processes we shall predict. All unstable processes we shall control’ (cited in Fleming 2010a:194). Zworykin’s proposal was also endorsed by oceanographer and US Army major, Athelstan Spilhaus: ‘In weather control, meteorology has a new goal worthy of its greatest efforts’ (cited in Fleming 2010a:194).

In January 1947, with the Cold War now clearly part of the new global reality, Zworykin and von Neumann both addressed a joint session of the American Meteorological Society (AMS) and the Institute of the Aeronautical Sciences. Measurement and calculation resulting in management and control were once again themes in their presentations. von Neumann spoke about high-speed computing in meteorology, and Zworykin spoke about weather control (Fleming 2010a:195). Using militarily-resonant and mechanistic language, Zworykin envisaged that ‘trigger mechanisms’ to divert a hurricane might include covering an island with carbon black to absorb heat or generating white smoke to reflect it. ‘Pity the poor Caribbean islanders’, comments Fleming, ‘whose tropical paradises would be invaded and possibly brutalized each hurricane season by paramilitary forces trying to save Miami’ (2010a:196).

From the start, climate intervention was of great interest to the US military. Fleming cites, as “the classic cold-war pronouncement on weather control”, the commander of the Strategic Air Command, General Kenney stating in 1947 that “[t]he nation which first learns to plot the paths of air masses accurately and learns to control the time and place of precipitation will dominate the globe” (2010a:195-6). A telling indication of the priority given to this by the

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25 Von Neumann was a Hungarian-born, Jewish refugee, mathematician, physicist and polymath. He has become famous for his brilliance, his right-wing and militaristic views, his pivotal role in developing the H-bomb, and his foundational role in computing, amongst many other achievements. He was extremely well-connected to the military and political establishment even at the time he endorsed Zworykin’s proposal.

26 In the early 19th century Laplace had argued that the world was ‘wholly knowable’, at least in principle. von Neumann’s comments have roots in this aspect of the European Enlightenment. Similar views pervaded the Soviet bloc. As Czech dissident and President Vaclav Havel, talking about communism, put it in 1992: communism displayed the extreme, arrogant and proud belief that “… man, as the pinnacle of everything that exists, was capable of objectively describing, explaining and controlling everything that exists” (1992). In short, in the period examined here, both West and East subscribed to the Promethean belief that Mastery was not only desirable but that the knowledge which underpinned it was also attainable.
military can be seen in the fact that by 1965 the US military had 14,300 meteorologists working for it, compared to 4,500 working for the Weather Bureau (Fleming 2004: 185).

In the Soviet Union, interest in weather modification also grew after the Second World War. This was possibly in response to US initiatives and was similarly linked to a general interest in subjugating nature and opening up the Arctic zone. These efforts generated a significant scientific literature: Zikeev and Doumani (1967) provide a listing covering the two decades after 1946. In the 1950s various proposals emerged to position a sunshade over the equatorial regions to cool the planet or, more commonly, to place reflective particles in space to warm the planet, melt the permafrost and enable Siberia to flourish (Fleming 2010a:207-8). Some of these ideas appear to have been largely speculative.

From the early 1950s Mikhail Budyko, a leading climatologist and director of the Geophysical Observatory in Leningrad (now St. Petersburg) led research programmes into the heat balance of the Earth and surface-atmosphere interactions (Fletcher 1968). There were also significant research programmes at the Institute of Geography and the Institute of Applied Geophysics, both in Moscow (Fletcher 1968:16). Their research output is not easily accessible and some of it may have been classified. We know of at least one conference on climate modification which was held in Leningrad in April 1961 and involved all these institutes and other leading figures in meteorology (Fletcher 1968:17).

In the USA, in 1953, a President’s Advisory Committee on Weather Control was established, and in 1958 the US Congress passed Public Law 85-510 and gave the National Science Foundation (NSF) the responsibility to ‘initiate and support a program of study, research and evaluation in the field of weather modification’ (Byers 1974:35). Of the NSF initiatives, Harper notes that “[a]lthough such projects were couched in terms of research, their ultimate purpose was operational weather control’ (2008:22-3).

In 1958, US Senate majority leader and later President, Lyndon B Johnson gave a major speech after the Soviet launch of Sputnik and shortly before the launch of the first American satellite. Johnson is worth quoting at some length:

‘Control of space means control of the world ...From space, the masters of infinity would have the power to control the earth’s weather, to cause drought and flood, to change the tides and raise the levels of the sea, to divert the Gulf Stream and change temperate climates to frigid ... If, out in space, there is the ultimate position – from which total control of the earth may be exercised – then our national goal and the goal of all free men must be to win and hold that position’. (cited in Fleming 2010: 209)
The idea of climate control was overwhelming understood as a space of contestation between the two superpowers. The Program of the Communist Party of the Soviet Union at its 22nd Congress in 1961 included the following:

“...the progress of science and technology under the conditions of the Socialist system of economy is making it possible to most effectively utilize the wealth and forces of nature for the interests of the people, make available new forms of energy and create new materials, develop methods for the modification of climatic conditions and master space.” (cited in Rusin & Flit 1962:3)

In the above two quotations we see the dominant imaginary of the times: mastery over nature is assumed to be possible, desirable and necessary; with science and technology at the heart of the drive for mastery and control. And the dominant global ideologies of each superpower, identified by Westad (2007) in their crystallised forms – liberty and justice respectively – are also visible. For the US such mastery is “the goal of all free men”. For the Soviets it is “the Socialist system” and “the interests of the people”.

Climate control was occasionally also seen as a terrain of global co-operation in that only co-operative efforts would generate the weather surveillance and data needed to advance understanding of the atmosphere. The World Meteorological Organisation (WMO) was formed in 1950 and became a specialised agency of the United Nations shortly thereafter. In September 1961 President John F. Kennedy, in a speech to the United Nations, proposed “further cooperative efforts between all nations in weather prediction and eventually in weather control” (Kennedy 1961). This was only months after the Soviets had put the first man into space. That same year, Kennedy’s nemesis and Stalin’s successor, Soviet Premier Kruschev, raised the issue of weather control in a report to the Supreme Soviet (Fleming 2010a:213). A United Nations resolution the following year called for “greater knowledge of basic physical forces affecting climate and the possibility of large-scale weather modification” (cited in Fleming 2010a:214).

An important 1962 lecture by Harry Wexler, ‘On the Possibilities of Climate Control’, noted that Kennedy and Kruschev had made it ‘respectable’ to talk about climate modification. Wexler was the leading meteorologist in the US and chief of scientific services at the US Weather Bureau. He played a key role in advancing the use of climate modelling and the deployment of meteorological satellites, and much of his work explored some of the consequences of trying to adjust the Earth’s heat budget. Wexler concluded his lecture by listing, albeit not necessarily endorsing, four potential techniques for re-ordering the

27 For information on Wexler I rely heavily on Fleming (2010a) and Fleming (2010b).
atmosphere. These were to increase global temperature by 1.7°C by detonating ten H-bombs in the Arctic; to cool global temperature by 1.2°C by putting dust particles into equatorial orbit (essentially what we would today call ‘solar geoengineering’); to warm the lower atmosphere and cool the stratosphere by injecting substances into space; and to destroy stratospheric ozone and cool the stratosphere by up to 80°C (Fleming 2010a:218). Noteworthy is that the proposals had no common climate objective. Some aimed at cooling, others at warming.

Note too, in all the instances cited above, the shared language and vision of Mastery held by the political leaders, the military and the scientists. The focus on climate modification emerged from the hubristic technoscientific imaginary of the times, but clearly the scientists helped to generate and sustain that imaginary. And military patronage in physics and related fields, as Forman has noted of this period, fostered a science focussed on technical mastery and obsessed with gadgeteering (1987). In short, the scientific side of the many projects was inseparable from their social, political and ideological context. Research did not take place in a vacuum, and the research focus and the imaginary itself are best thought of as co-created. As Fleming has put it, in describing the link between the Cold War and the emergence of modern meteorology as a discipline: “... [S]cientists seek support from the state and access to political power, while the state (especially the military) seeks power over nature as promised ... by scientists. ... [T]ranscending this dichotomy is the co-production of the military-scientific-industrial state” (2010:166).

**Tempering hubris (slightly)**

With hindsight we can also see signs of emerging doubts and of a developing awareness of a climate problem. Wexler’s lecture noted that inadvertent modifications were already happening and that rising CO₂ emissions might have serious effects on the heat balance. And he was alert to growing public anxiety that, as he put it, ‘Man, in applying his growing energies and facilities against the power of the winds and storms, may do so with more enthusiasm than knowledge and so cause more harm than good’ (cited in Fleming 2010a:218). Indeed, by 1963 US President Kennedy issued a secret memorandum directing that large-scale technological and scientific experiments be reviewed in advance for potentially adverse environmental effects (Harper and Doel 2010:120-1).

Similar awareness was cautiously emerging at this time in the Soviet Union. At the 1961 Leningrad conference on climate modification already mentioned (Fletcher 1968:17), Budyko warned that ‘the waste heat produced by human energy generation could, in two hundred years, rival that of the Earth’s radiation balance, rendering life on Earth “impossible”’ (cited in Fleming 2010a: 236). To address the issue another scientist, M. Ye. Shvets, proposed to inject
36 million tons of particles into the stratosphere to reduce solar radiation by 2 to 3 degrees C—essentially what we would now call solar geoengineering. This was contrary to the still dominant ‘unfreeze the Arctic’ thinking in the Soviet Union with its implied aim of warming.

Active work on weather modification continued throughout the 1960s and early 1970s and generated a variety of published reports. A pitch for the importance of meteorology, and the need to keep funding it, can be detected in comments by the chair of meteorology at MIT frequently cited in these reports: “Basic research in meteorology can be justified solely on the economic importance of improved weather forecasting but the possibility of weather control makes it [the research] mandatory” (see Keith 2000:252). The National Science Foundation-funded programme on ‘Weather Modification’ (Fletcher 1968; Byers 1974) resulted in a number of studies, papers and reports. These, increasingly, drew attention to the distant possibility of what was called ‘inadvertent climate modification’, which today would be called “anthropogenic climate change”, associated with rising CO₂ emissions.

Some of these ideas were considered at the highest policy level. In 1965, in one of the earliest official considerations of global warming, US President Johnson’s Science Advisory Committee issued a report entitled Restoring the Quality of our Environment. The rise in CO₂ “... could be deleterious from the point of view of human beings”, it stated in a corner of the report (in Appendix Y4), and urged the need to explore ways to restore the radiation balance, by raising the Earth’s albedo. Examples cited included “… injection of condensation of freezing nuclei ...” to cause cirrus cloud formation at high altitudes; and spreading small reflective particles on the surface of the oceans, at a “not excessive” cost (‘rough estimates’ of about $500m per year), a technique perhaps useful also in inhibiting hurricanes (White House 1965:127). Intriguingly, therefore, one of the earliest official considerations of potential global warming recommends only what we would today call geoengineering! The idea of mitigation was absent.

A report by J.O. Fletcher entitled ‘Changing Climate’ (1968) is a revealing account of both the continuing hubris (and military linkages) within scientific meteorology and atmospheric science, but tempered by an emerging awareness of both uncertainty and the possibility of climate change. The report was produced for the US military-linked RAND Corporation as part of a larger review of weather and climate control. For Fletcher, global climatic variations “… seem to be associated with variations in the vigor of the whole global atmospheric circulation, but why the global system varies is still a mystery” (1968:6). He tentatively notes that “man is probably inadvertently influencing global climate” (p.12) and that “some time during the next century heat pollution, like CO₂, will indeed become important on a global scale” (p.11). This
message was, in short, beginning to be made, if not heard, in the corridors of power in the US – the government, the military and, even, the oil industry.  

Assessing research largely conducted by Soviet scientists, Fletcher concludes that intervention in particular cyclone and similar events “involve actions that we do not know how to produce efficiently”. “On the other hand, various ways of influencing thermal losses and inputs to the atmosphere [the heat balance] ... are much more achievable with present technology” (1968:14). In short, and in today’s terminology and using a distinction not then commonplace, climate intervention will likely be more effective than weather intervention. Fletcher states that “… to avoid undesired planetary warming, ways must be found to drain additional heat to space” (p.15-6). And he examines, for example, ways to create high cloud over the Arctic to increase reflectivity: “… sixty C-5 aircraft, operating from Eielson AFB [Air Force Base] and Thule AFB could deliver 1kg per km2 per day [of seeding materials] over the entire Arctic basin” (p.14). Fletcher concludes his report by drawing attention to the lack of understanding of climate systems:

“With environmental problems, it is convenient to think of progress in four stages – observation, understanding, prediction, and control ... Much progress is needed in all four areas in order to achieve the degree of control over climatic processes that is becoming necessary” (p.20).

Similar developments are apparent on the Soviet side. A remarkably prescient account for its time can be found in a paper presented by Y.K. Federov in the early 1970s, probably 1971, but translated and published in an edited collection in 1974, and entitled ‘Modification of Meteorological Processes’. At the time, Federov was Director of the Hydrometeorological Service in Moscow. After recounting efforts at weather, rain and hail modification he turns to climate modification: “… modifying processes on a significantly greater scale – regional, and perhaps even global” (Fedorov 1974:398). He stresses the complexity of the processes and

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28 See, for example, a 1968 Stanford Resource Institute report for the American Petroleum Institute. Drawing on the work of the President’s Science Advisory Committee it noted that exploiting all fossil fuel then thought to be recoverable would lead to concentrations of 830ppm. The report warned that rising CO2 would result in increases in temperature at the earth’s surface, which could lead to rising seas and increasing temperatures. It has been suggested the oil industry suppressed this report (see Guardian 12 April 2016, ‘Oil industry knew of “serious” climate concerns more than 45 years ago’) and it would certainly have been in its interests to do so. But a more charitable explanation can perhaps be found in the uncertainty in the report itself, still common at that time. The report concludes by arguing that ‘there seems to be no doubt that the potential damage to our environment could be severe’. But it then goes on to say: ‘Whether one chooses the CO2 warming theory as described in detail by Revelle and others or the newer cooling prospect [from smog and industrial pollutants] indicated by McCormick and Ludwig, the prospect for the future must be of serious concern’ (Robinson & Robbins 1968:110).
gaps in knowledge, and casts doubt on earlier engineering proposals (such as the proposal to dam the Bering Strait) as “not, unfortunately, scientifically well-founded” (p.399). He then moves onto climate change: “[i]n the not too distant future, therefore, we shall be faced with the problem, if not of global change, rather, of stabilizing the present climate, to which the economies of all the nations of the earth are geared ...” including compensating for “inadvertent modification” or “channel it in the direction we desire” (p.400). Alongside limiting emissions he suggests geoengineering:

“... Theoretically, limiting the additional heat generated by human activity is not the sole means of avoiding undesirable changes in the heat budget of the planet; it is also possible to increase the other parts of the budget, such as radiation or reflection” (p.400).

And his focus includes albedo modification and intervention “... in processes as they evolve in the stratosphere ... substantial artificial changes in the properties of the upper layers of the atmosphere, changes so great as to change the nature of the lower layers”. He notes that this has been repeatedly considered by Soviet scientists (p.399-400). He may have been thinking of Budyko who, in his 1971 book Climate and Life (1974), according to Alan Robock and Philip Rasch, “proposed that if global warming ever became a serious threat, society could counter it with airplane flights in the stratosphere burning sulphur to make aerosols (small particles), similar to those found after a volcanic eruption” (IPCC 2012:20).

By the early 1970s the US was spending tens of millions of dollars annually on weather modification research and development (Hess 1974:v). Much of the research conducted was substantially oriented to military application. The military had tested such technologies extensively throughout the 1960s as part of Projects Stormfury and Popeye.29 From 1967 to 1972 the US military engaged clandestinely in extensive weather modification activities, using cloud-seeding, over the jungles of Laos and Vietnam. As part of US involvement in the wars in South-East Asia, the aim was to dramatically increase rainfall in certain areas and thereby disrupt the supply lines of the nationalist communist, guerrilla enemy. Leading US meteorologists would undoubtedly have known about such activities. Operation Motorpool, ...

29 There is also an intriguing instance of the technology being offered clandestinely to India’s Indira Gandhi in 1966, as a form of development assistance but also to pressure her to change certain policies. W.W. Rostow was a key intermediary between Johnson and Gandhi in this process. The US goals, at a time of conflicts and tension involving China, India and Pakistan, concurrent with a failed monsoon and famine in Bihar, were threefold: to enhance Indian self-sufficiency in food rather than reliance on dwindling US supplies; to keep non-aligned India from drifting into the Soviet orbit; and to pressure for devaluation and other economic reforms. Project Gromet, as it was known, failed to deliver rain and was terminated early in large part because the Pentagon thought Soviet detection of it would reveal what was being implemented over Vietnam and Laos (Harper and Doel 2010).
as it was known, only became public knowledge in 1971-2 after details were leaked to the media (see Fleming 2010:177-182), and its exposure had significant consequences, as we shall see.

Retreating from the era of Mastery

By the early 1970s some shifts in thinking were becoming apparent. The 1971 NAS-NRC report “The Atmospheric Sciences and Man’s Needs: Priorities for the Future” reflects some of the changes in thinking among US meteorologists and atmospheric scientists. Significantly, this was a year after a significantly strengthened Clean Air Act was brought into force. The report notes that CO₂ increases might lead to an increase in surface temperatures of 0.5°C by 2000. “This is comparable to the natural variability of climate over 30 years; consequently, the CO₂ problem is not likely to be critical in the next few decades” (1971:46). In addressing the ‘Man’s Needs’ of the Report’s title it specifies four: Atmospheric quality, Weather Modification and Control, Prediction, and Information Service (p.iv) – see Figure 2-4. In short, it retains an attachment to weather control but adds ‘atmospheric quality’ as a human need. The implication, and the shift in register from earlier reports, becomes clearer further on in the report as the following quotations suggest:

“In the past decade we have had to recognise that the environment can be seriously and dangerously impaired by steadily increasing industrial production and individual consumption ... Young people, especially, are scornful of a society that seems to place affluence above environmental quality” (1971:13).

“Environmental problems will not be solved and disposed of; they will have to be managed by men and institutions that combine a wide range of technical skills with an understanding of society’s needs and desires” (p.54).

“The public-policy issues that have been outlined here have much in common with similar issues arising out of such problems as management of the use of the electromagnetic spectrum or nuclear power generation or the use and control of pesticides. Problems like these, in which the technological and sociological aspects are intimately combined, are becoming more numerous and more urgent” (p.56).

Intriguingly the report’s recommendations include the need to “establish mechanisms for the rational examination of deliberate and inadvertent means for modifying weather and climate” (p.78), and for the US to put forward a resolution to the UN “dedicating all weather-modification efforts to peaceful purposes…” (p.79). It is hard not to conclude that the report’s authors knew about and were uncomfortable with the still secret Project Popeye and Operation Motorpool.
When Operation Motorpool was exposed it was widely condemned. In the US, concludes Fleming:

‘The dominant opinion was that seeding clouds – like using Agent Orange or the Rome Plow, setting fire to the jungles or bombing the irrigation dikes over North Vietnam – was but one of many sordid techniques involving war on the environment that the military used in Vietnam’ (2010a:182).

The public exposure of the United States’ weather warfare, combined with pressure from the Soviet Union, resulted in the United Nations adopting, in 1977, a Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD). The ENMOD story is revealing of the times.\(^30\) The US government under President Nixon, and the US military, were hostile to any constraints on weather modification activities. But amidst growing hostility within the US and internationally to the Vietnam War, Nixon was


\(^{30}\) Fleming (2010a:183-6) is the most detailed account I have been able to find and is relied upon here.
under pressure from a combination of leaks of information and a 1973 Senate resolution, supported by leading meteorologists, to present a resolution against hostile weather modification to the UN. In September 1974, with Nixon by now embroiled in the Watergate scandal, the Soviet Union seized the opportunity and proposed a far-reaching draft convention at the UN to forbid the use of

“meteorological, geophysical or any other scientific or technological means of influencing the environment, including weather and climate, for military and other purposes incompatible with the maintenance of international security, human well-being and health, and furthermore, never under any circumstances to resort to such means of influencing the environment and climate or to carry out preparation for their use.” (cited in Fleming 2010a:184)

The US watered down this proposal. The final ENMOD convention that was adopted prohibited intentionally hostile weather and climate modification, but only at scale, and expressly permitted its peaceful use.

By the mid-1970s, three decades of enthusiasm for climate modification, geoengineering and solar geoengineering was coming to an end. For the next three decades, as we shall see in the following chapter, it largely disappeared off the public policy agenda and very little scientific research into it was funded or undertaken. The instinct towards Mastery may have persisted, and indeed many of the individuals and institutions continued to operate in the environmental and climate space. But the explicit embrace of the dream of mastery was becoming socially unacceptable. Why the vision of Mastery went into retreat, and the link between this and the rising environmental movement, will be explored in the next chapter.
Chapter 3. Becoming ‘taboo’: geoengineering’s hiatus

“How much can we push the balance of nature before it is seriously upset?”

Report of the Study of Man’s Impact on Climate (SMIC 1971:26)

"I think of it as designer volcanic dust put up with Jules Verne methods"

Robert A. Frosch, author of geoengineering chapter in NAS 1992 (cited in Fagin 1992)

From the early to mid-1970s until the middle of the first decade of the 2000s geoengineering basically disappeared from the policy agenda. It became effectively ‘taboo’, or at least unimaginable as a policy option. One can think of this three decade-long period as a Hiatus or ‘Inter-regnum’, dividing the first wave of interest in geoengineering covered in the previous Chapter from the second wave of interest when it re-emerged around 2005. This Hiatus comprised two distinct phases. First, from the early 1970s to the end of the Cold War, when geoengineering was essentially not thought about and was Unimagined. Then, during the 1990s until the early 2000s, when attempts to revive the idea of geoengineering were unsuccessful, and what had been unimagined became unimaginable and, in effect, ‘taboo’.

This chapter begins with an examination of the reasons why interest in climate modification evaporated in the 1970s. I will then look at the limited, but unsuccessful, attempts to revive the idea in the 1990s following the ending of the Cold War. The disappearance of geoengineering ran parallel to the emergence of contemporary climate science with its attendant climate policy focus on mitigation through greenhouse gas abatement. I will discuss the shift in thinking from weather to climate and the attendant globalising of climate science and climate policy discourses. Finally, I will outline the shape of the climate imaginary during this hiatus, which made geoengineering first unimagined, and then unimaginable, and reflect on its continuities and ruptures with the Mastery narrative.

The decline of the mastery narrative

Why did interest in climate modification evaporate so rapidly and completely in the early 1970s? Certainly there was widespread global condemnation of US climate modification activities, and use of environmental warfare more generally (notably Agent Orange), as part of the Vietnam war. The ENMOD convention was simply the culmination of that outrage. The

31 I exclude here initiatives such as reforestation. At the time, these were generally not presented as geoengineering and they are not regarded as geoengineering in this thesis.
Soviet Union was diplomatically astute in riding the wave of this outrage. It was also opportunistic: with lower computing capabilities and fewer resources than the US, and with less need for it militarily (its allies in the Third World mostly adopted guerrilla strategies), the climate modification race was more useful for the Soviets to constrain than to pursue. For the US, ENMOD was understood to be a restraint, hence its efforts to water down the proposed convention. But ENMOD was the aftermath, not the prime cause of geoengineering’s evaporation.

Perhaps more significant was that from the early 1970s there was growing awareness within the scientific community of the complexity and inter-relatedness of the various components of natural systems, and hence the practical difficulties of climate modification. There was also increasing knowledge about the extent and nature of the emerging climate problem. I will return, later in this Chapter, to an examination of the importance of changing thinking about, and framing of, climate change.

But the primary explanation for the end of the first wave of geoengineering can be found in a number of major shifts in the political, cultural and economic landscape. As Bob Dylan had prefigured in his famous ballad: “The times they are a-changin’”. In the early 1970s the global context changed so significantly, and so rapidly, that the idea of geoengineering, rooted in an imaginary of Mastery, could no longer be sustained. We can point to the confluence of three broad developments. Firstly, the economic and fiscal crisis of the early ‘70s and the end of the period of plenty in the West and much of the world. Secondly, a range of crises in the ‘Third World’ (as it was then known) and a shift in the axis of competition between West and East, from direct confrontation to indirect, and an increasing focus on gaining and retaining the loyalty of nations in the ‘global south’. And thirdly, a growing environmental awareness in the United States, the Soviet Union and much of the world.

Wallerstein has noted that “[w]hat had seemed in the 1960s to be the successful navigation of Third World decolonization by the United States – minimizing disruption and maximizing the smooth transfer of power to regimes that were developmentalist but scarcely revolutionary – gave way to disintegrating order, simmering discontents, and unchanneled radical sentiments” (Wallerstein 2002:n.p.). This was the period of military coups in most of Latin America and Africa, left-wing and anti-colonial wars in parts of central America, Africa and south-east Asia, and Soviet efforts to contest US influence. This hardly cast a positive light on the ‘development’ and ‘progress’ aspects of the Cold War imaginary. Neither did the economic situation where the oil shock, petrol shortages, and sharp economic slowdown in the West
heralded the end of the so-called ‘Golden Age’, and prompted calls to end the reliance on oil and the need for alternative, more humble, technologies.

An emergent environmental awareness also accelerated during this time growing from popular accounts of the 1960s such as Rachel Carson’s *Silent Spring* (1962). 1970 saw the first ‘Earth Day’. As Gilman has put it, ‘a radicalized environmentalist movement emerged that envisioned nature as an end in itself rather than as a standing reserve of resources to be tamed and harnessed to human ends’ (2003:245). Ironically, given they were products of ‘big’ science and technology, the iconic images of this time of Earth suspended in space were widely understood to suggest a need for greater stewardship and humility. As Poole has put it: “[a]n ‘eco-renaissance’ took place during the Apollo years of 1968–72, framed almost exactly by the ‘Earthrise’ and ‘Blue marble’ photographs four years apart” (2008:13) – see Figure 3-1.

![Figure 3-1: Iconic NASA images from space. ‘Blue marble’ (1972) and ‘Earthrise’ (1968).](https://en.wikipedia.org/wiki/File:NASA-Apollo8-Dec24-Earthrise.jpg)

This was a period when the so-called ‘proxy’ Cold War was emerging with East-West contestation increasingly played out in the Third World. Debt and conditionality became increasingly evident as mechanisms of governance, structuring relations with the Third World. There was a battle for the soul of the states of the Third World. This was the period too when economic instability, Cold War concerns and environmental concerns became intertwined. Third World countries were challenging the West in particular and pushing, ultimately unsuccessfully, for a New International Economic Order. Desertification and droughts in the Sahel were held responsible for creating an environment leading to the overthrow of the

Ethiopian Emperor in 1974 and his replacement by a pro-Soviet, purportedly Marxist, military regime. In April 1974, in a speech to the United Nations, US Secretary of State Henry Kissinger, pushed for increased research to counter the threat of climate change (Behringer 2010:188).

In short, key elements of the Cold War imaginary – progress, development, science and technology (at least in its ‘big’ and militarised form), and the embrace of mastery over nature – lost much of their purchase, their “taken-for-grantedness”. Gilman, borrowing from Raymond Williams, has written of ‘a shift in “the structure of feeling” in the United States” (2003:244). This was no longer a context in which deliberate climate modification could thrive, be funded, or even be respectable.

An early sign of this mood-shift can be found in the 1971 MIT-led *Study of Man’s Impact on Climate*. This was largely a study of ‘inadvertent’ weather modification, the term then used to describe impacts flowing from human economic activities. The shift is immediately evident in the dedication at the front of the book. It is taken from a Sanskrit prayer: “Oh, Mother earth, ocean-girdled and mountain-breasted, pardon me for trampling on you” (SMIC 1971: frontispiece)! The study noted the increasing demands being placed on “fragile biological systems”. It asked “how much can we push against the balance of nature before it is seriously upset?” (1971:26). By the late 1970s federal funding of climate modification research and development effectively ends (Fleming 2010a:185). But at the same time funding is on the increase for the study of climate change.

It is unclear whether the same funding shift happened in the Soviet Union. But certainly comparable intellectual shifts are in evidence both in dissident and more ‘official’ circles. As early as 1968, nuclear physicist Sakharov was warning of the ecological stress being placed on the Earth by both economic systems and climate change: rising carbon dioxide levels ‘from the burning of coal [are] altering the heat-reflecting qualities of the atmosphere. Sooner, or later, this will reach a dangerous level” (cited in Corry 2014:315).

Or take a 1974 publication, *Climate Changes*, by leading Russian climatologist Mikhail Budyko, which includes a speculative proposal for solar geoengineering (particles in the stratosphere). This includes estimates of the amounts of sulphur dioxide needed (15 tons), an amount ‘not at all important in environmental pollution’, and the suggestion that the technique would be easy and cheap. He also states:

‘If we agree that it is theoretically possible to produce a noticeable change in the global climate by using a comparatively simple and economical method, it becomes incumbent on us to develop a plan for climate modification that will maintain existing climatic conditions,
in spite of the tendency toward a temperature increase due to man’s economic activity.’ (1977[1974]:244)

Whilst proposing intervention, and assuming perfect ‘knowability’, Budyko also goes on to add a note of caution:

"The perfection of theories of climate is of great importance for solving these problems, since current simplified theories are inadequate to determine all the possible changes in weather conditions in different regions of the globe that may result from modifications of the aerosol layer of the stratosphere." (1974, cited in Schneider 1996:293)

This indicates a move towards a climate change framing of the issue, and a partial retreat from the hubris of the previous decades. Budyko remains a proponent of solar geoengineering. He prefigures the second (current) wave of interest in geoengineering in that he shifts the argument for climate modification from one of desirability as an indicator of human mastery, to one of necessity. And, whilst retaining some of the older vision, climate modification is couched in terms not of ‘improving’ the climate, as the Mastery discourse would have done, but in terms of ‘maintaining’ the existing climate.

A comparable article on the topic, although taking the cautious tone of Budyko a step further, can be found in an article in Science by leading US climatologists Kellogg & Schneider entitled ‘Climate Stabilization: For Better or for Worse?’ (1974). They note that climate prediction will not be straightforward given that “… our climatic system is a highly nonlinear, interactive system that has defied a complete quantitative description” (p.1163). They argue that even if any future climate could be predicted, “control would be a hazardous venture” (p.1163). In a mark of the times their article also refers to contemporary debates around the Club of Rome’s ‘Limits to Growth’, and other “advocates of reduced economic growth” (p.1167). Given that “mankind will very likely have the technological capability to alter climate purposefully as well as inadvertently” (p.1168), they analyse a range of climate modification schemes, including particle injections to counteract warming, to “create a kind of ‘stratospheric smog’” (p.1170). Their prescient account, pre-figuring arguments which emerge in the second wave, leads them to be sceptical of climate modification proposals on three grounds: because of an inability to “adequately foresee the outcome”; because it would lead to conflict since “cause and effect are hard to unravel”; and because of uncertainty as to how the decision would be made regarding “whose climate should be preserved, whose improved, and whose sacrificed” (p.1170-1).

For the remainder of the 1970s and through until the end of the Cold War around 1990, very little work on geoengineering is published. There is a speculative article by Marchetti entitled ‘On geoengineering and the CO₂ problem’ (1977). It is a sign of the times that this is published
in 1977 in the first issue of a new journal, *Climatic Change*, and that it argues not for solar geoengineering but for the need to consider capturing and injecting CO₂ into the ocean depths, an early version of carbon capture and storage (CCS). Dyson and Marland (1979) use ‘old-school’ language in entitling their paper ‘Technical fixes for the climatic effects of CO₂’. But the paper itself focuses on reforestation. Broecker (1985) touches on ocean fertilisation to draw down CO₂. Budyko is almost alone in remaining focussed on solar geoengineering: in *The Earth’s Climate: Past and Future* (1982) he calculates the tonnage of sulphuric acid needed to reduce solar radiation by 1%.

**Attempts at post-Cold War revival**

The Cold War came to an end around 1989-90 with the implosion of the Soviet Union and many of its client states. This immediately meant that countries of the global ‘South’ could no longer play the two great powers off against one another, or rely on Soviet support. It also meant that capitalism was seen as economically triumphant. The US ideology of ‘liberty’ had trumped the Soviet one of ‘justice’.

In the new, market-friendly, world one might have expected a revival of interest in geoengineering. After all, solar geoengineering, long held to be the cheapest option, should have been attractive. And, as I will recount shortly, there were indeed some attempts along these lines – emerging, perhaps predictably, from Edward Teller and his colleagues at the Lawrence Livermore Laboratory.

The most notable effort to revive the idea emanated from parts of the US scientific community. A major 1992 National Academy of Sciences (NAS) study on *The Policy Implications of Greenhouse Warming: mitigation, adaptation and the science base* (NAS92) included a chapter on geoengineering. Largely written by Robert Frosch (cited at the head of this Chapter) and the Livermore group of scientists, this chapter assumed that geoengineering could mitigate greenhouse gas effects and do so affordably, and focussed on whether this could be done with acceptable or manageable adverse effects (p.434). With regard to solar geoengineering, which it called ‘stratospheric dust’, the report notes that the chemical reactions might destroy ozone: ‘a possible side effect that must be considered and understood before this possible mitigation option can be considered for use’ (p.451).

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32 I am not aware of parallel efforts at this time to revive the idea of geoengineering in the ‘East’, not surprisingly given that the Soviet Union was rapidly disintegrating both as a territorial entity and an ideological project, as well as institutionally.
This is the first study, to my knowledge, which places so much emphasis on solar geoengineering’s purported cheapness. Apart from this, the bulk of the chapter’s examination of solar aerosol geoengineering is devoted to the comparative costs of distributing the ‘dust’ by navy guns, rockets, or balloons. There is even consideration of emissions being done by dedicated ships roaming the oceans, or by purpose-built, high-sulphur coal burning power stations placed at seal. Figure 3-2, a 1992 cartoon from a popular publication, Geographical Magazine, shows how the idea was lampooned at the time. The NAS report’s chapter on geoengineering generated little interest and the report’s overall focus, as its sub-title suggests, was elsewhere. The report summary recommended research into geoengineering options but made explicit that ‘[t]his is not a recommendation that geoengineering options be undertaken at this time’ (1992:81).

Leading climate scientist Stephen Schneider, who was part of the panel that compiled the 1992 study has recalled that ‘... the very idea of including a chapter on geoengineering led to serious internal and external debates’, with critics (himself included) arguing it would be used as ‘an excuse to continue polluting’. Another panellist and the report’s lead author, Robert Frosch, apparently argued that if climate change was more extreme than expected “[w]e would simply have to practise geoengineering as the ‘least evil’. Schneider seems to have been persuaded by this argument as he continues:

“Although sceptical about the viability of specific engineering proposals and the questionable symbolism of suggesting that we could sidestep real reductions in emissions, I nonetheless voted reluctantly with the majority of the NAS panelists who agreed to allow a carefully worded chapter on the geoengineering options to remain in the report” (Schneider. 2001:418).

The arguments we will meet in the 2000s with geoengineering’s re-emergence are all prefigured here. It is also apparent that the idea was still effectively ‘taboo’. A thought bubble was being floated to see if it would fly. It did not.

Little other scientific work was being done in the area with Charlson (1992) a rare example. Russian climatologists, Mikhail Budyko and Yuri Izrael, also published new work on climate and solar geoengineering ([1987]/1992). Long-time enthusiast for solar geoengineering, Lawrence Livermore scientist Michael MacCracken, in his 1991 paper to a limited attendance workshop, acknowledges that geoengineering and its solar variant, which he likens to “a human volcano”, is “a particularly controversial option” (1991:2). A 1992 article, ‘Taking Geoengineering Seriously’, by Keith and Dowlatabadi was largely an argument, “ignoring important ethical issues”, for research money to be allocated to geoengineering: essential “unless nasty
surprises are assigned a zero probability” (1992:293). Their article prefigured much of today’s thinking about geoengineering by framing solar geoengineering as humanity’s ‘Plan B’.

Figure 3-2: Satirical cartoon of NAS 1992 report *

There is remarkably little published research beyond this. The early 1990s effort to revive interest is largely ignored and, in effect, geoengineering remains taboo and beyond the realm of respectable policy consideration. Significantly, the first assessment report of the IPCC was published in 1990 and made no mention of geoengineering. Neither did the United Nations Framework Convention on Climate Change (UNFCCC) adopted at the Earth Summit in 1992, nor the subsequent Kyoto protocol.

* ‘Shooting dust into the stratosphere to offset global warming, [a] proposal by the National Academy of Sciences in its report published in 1992’. Cartoon by John Ireland, in Geographical Magazine, May 1992. This cartoon by John Ireland is cited in Fleming 2006:238. I am indebted to Jim Fleming for providing me with a copy and details of the original source.
By the mid-1990s geoengineering briefly re-emerged in debates between scientists, as concern grew about the warming effects of increasing GHG concentrations and the apparent lack of action to tackle this. But these debates, whilst not secret, were not yet influential on climate policy debates more generally. In July 1996, Issue 3 of the influential journal *Climatic Change*, was devoted to the topic. It drew on papers presented to a 1994 symposium by scientists and non-scientists including some traditionally hostile towards geoengineering and committed to the then-dominant climate strategy of mitigation through abatement. The titles are revealing of the tentativeness with which the topic was approached.

The editorial, ‘Could we/should we engineer the Earth’s climate?’ stresses that the various articles ‘... provide analysis not advocacy ... [and] make it abundantly clear that relying on these approaches now would be irresponsible, given our current state of understanding of the climate system’ (Marland 1996:277). Stephen Schneider’s article ‘Geoengineering: could – or should – we do it?’ concludes that: '[A]lthough I believe it would be irresponsible to implement any largescale geoengineering scheme until scientific, legal and management uncertainties are substantially narrowed, I do agree that, given the potential for large inadvertent climatic changes now being built into the earth system, more systematic study of the potential for geoengineering is probably needed’ (1996:291). Schelling’s article talks about geoengineering being ‘an unmentionable subject’ and the need to pull it ‘out of the closet, but I’ll wager not all the way’ (1996: 303). A legal academic, Bodansky, in his article entitled ‘May we engineer the climate?’ notes that ‘[w]hether we can engineer the climate will depend not only on its technical feasibility, but also on its political acceptability’ (1996:320).

In the wake of the *Climatic Change* articles a number of pre-existing scientific enthusiasts published work favourable towards solar geoengineering. These included scientists from the military-scientific Lawrence Livermore Laboratory, including an ageing Edward Teller, his associates Lowell Wood, Michael MacCracken and others (Teller et al. 1997; Teller 1997; see also Flannery et al. 1997). Teller et al’s paper argued that solar geoengineering would be much cheaper than mitigation and was technically possible. Indeed, the paper frames the issue in terms comparable to Teller’s over-confidence of old: ‘Today, our scientific knowledge and our technological capability already are likely sufficient to provide solutions to these problems; both knowledge and capability in time-to-come will certainly be greater’ (1997:17).

But, as Schelling had predicted, this was not enough to get the taboo lifted from policy discussions of geoengineering, to get it ‘out of the closet’. Indeed, enthusiasts like these may have helped keep it in. The IPCC’s Second Assessment Report, Working Group 2, mentions solar geoengineering in passing within a brief section on counter-balancing climate change, in
large part authored by Michael MacCracken (1995b:812). In the synthesis summary of the whole second assessment report, the formulation is dismissive: geoengineering is “...likely to be ineffective, expensive to sustain and/or to have serious environmental and other effects that are in many cases poorly understood” (1995a:41). Context is important here. The IPCC’s Third Assessment Report in 2000 is also cursory and equally dismissive when it argued that “most papers on geo-engineering contain expressions of concern about unexpected environmental impacts, our lack of complete understanding of the systems involved, and concerns with the legal and ethical implications ... Unlike other strategies, geo-engineering addresses the symptoms rather than the causes of climate change” (IPCC 2000:334).

Political unacceptability was apparent when, in September 2001, President George W. Bush’s Climate Change Technology Committee included geoengineering in its initial formulations of possible approaches. A high-level meeting of about a dozen scientists was held with some, such as Lowell Wood, on speakerphone. According to David Keith, "[i]t was a frank discussion of geoengineering options and the need for research funding" (reported by Goodell 2006:n.p.). The idea was dropped by President Bush’s team, according to another participant, as it might add ‘... to the perception that the Administration’s emission reduction program was not serious’ (MacCracken 2006:239). In any event, the September 11th attacks on the US only days later pushed climate and many other issues off the US political agenda.

The taboo on geoengineering was only lifted in the mid-2000s, again signaled by a series of articles in Climatic Change in 2006. As we shall see in the next chapter, this allows the second, contemporary, wave of geoengineering-as-potential policy, to emerge.

Explaining the failed post-Cold War revival
In many respects it seems surprising that geoengineering did not re-emerge as a serious policy option in the aftermath of the Cold War. After all, the end of the Cold War is closely linked to the acceleration of ‘globalization’ as an expansion of the neo-liberal project from its US heartland. Manfred Steger has summarized the central tenets of neoliberalism as including:

‘... the primacy of economic growth, the importance of free trade to stimulate growth, the unrestricted free market, individual choice, the reduction of government regulation, and the advocacy of an evolutionary model of social development anchored in the Western experience and applicable to the entire world.’ (2009:10)

‘Globalisation’ became a framing metaphor not only for the neo-liberal economic project, but also across a range of disciplines and discourses, including climate and environmental discourses. Accompanying these developments was an increase in the perceived and actual power of global corporations. There was a growth too of what Milonakis and Fine (2009) call
‘economics imperialism’: an elevation of the status of economics, and of the perceived salience of economic metrics in making policy choices, and ‘the extension of economic analysis to subject matter beyond its traditional borders’ (2009:5). In practice a particular notion of economics, rooted in neo-classical economics, centred on ‘rationalism’ and often manifesting as cost-benefit analysis, assumed centrality in policymaking, even being adopted as a worldview and method by many in the social sciences.

One might therefore have expected geoengineering to be embraced following the end of the Cold War, and solar geoengineering in particular with its suggestion of being a cheap ‘solution’ to climate change. The 1992 NAS study did indeed put much emphasis on solar geoengineering’s purported cheapness. The report does not make explicit solar geoengineering’s compatibility with the neo-liberal project as a whole which was then in a triumphalist phase in the immediate aftermath of the Cold War. But although not explicitly stated, this was clearly part of the thinking, as an interview at the time with Robert Frosch reveals. Frosch, previously with NASA and also a vice-president at General Motors, led the compilation of the NAS report’s chapter on geoengineering. Interviewed by Newsday he said:

‘I don’t know why anybody should feel obligated to reduce carbon dioxide if there are better ways to do it. When you start making deep cuts, you’re talking about spending some real money and changing the entire economy. I don’t understand why we’re so casual about tinkering with the whole way people live on Earth, but not tinkering a little further with the way we influence the environment. ... I think of it as designer volcanic dust put up with Jules Verne methods’ (Fagin 1992:7).

The failure of the attempts through the 1990s to resurrect geoengineering can be ascribed to a number of factors, both small and large: the credibility of the people proposing the idea; the playing down of climate change in the corridors of US power, and the emergence of climate science refutation/denialism as an alternate response to global warming; the relative autonomy of the epistemic community of climate scientists and their growing anxiety about the ‘climate problem’; and the belief that environmental problems could be solved alongside the neo-liberal project now that the ‘end of history’ had arrived. I will briefly touch on these.

Firstly, most of the enthusiasts for solar geoengineering during the 1990s were individuals strongly associated with the old Mastery paradigm (eg. Teller and Wood), and from institutions of ‘big science’ such as the Lawrence Livermore Laboratory (eg. MacCracken). Those with weaker links to these institutions, and indeed most of the climate science community, were not enthusiastic (eg. Schneider). In short, geoengineering’s scientific messengers lacked social and environmental credibility, even as they were scientifically respected. There was a growing
divergence between their values and the increasing ‘green-awareness of many of the epistemic community of climate science. In part this may have been generational.

Secondly, in the early 1990s in the United States, whilst climate change was recognized as an issue, it was beginning to be a contested one. President George H.W. Bush had come into office in 1988 pledging to be the “environmental president” and to “do something about the greenhouse effect”. In office he was less active than expected and his administration was accused of playing a major role in watering down both the Rio Declaration and the UNFCCC which emerged from the first Earth Summit in 1992 (Carcasson 2006). Equally significantly was the emergence of a new strand of thinking within the Republican side of US politics. According to Philander, during the early 1990s President George H.W. Bush began to see ‘the economic costs of an aggressive stance on global warming as too high for comfort’ (2008:146). In a foretaste of future thinking, junior officials in his administration notoriously edited NASA climatologist James Hansen’s 1988 testimony to Congress to downplay his conclusion that global warming was accelerating. Indeed, the President’s Chief of Staff was one of the earliest leadership figures to question the veracity of the climate science (Philander 2008:146-7). The ‘merchants of doubt’ were becoming increasingly active (Oreskes & Conway 2010). Why consider geoengineering, or indeed any action, if the science was wrong?  

Whilst the US political commitment to action was softening, warnings about the problem of global warming were hardening amongst the community of climate scientists. These would prove to be formative years in shaping the political-environmental outlook which would become significant within the epistemic community of climate science – making it green-tinged and, occasionally, activist. In short, whilst those on the right of US politics were shifting away from action of any sort on climate, the climate scientists themselves were becoming increasingly shrill in their warnings of looming catastrophe and their calls for deep cuts in emissions. In particular many suggested that ‘Business as Usual’ was incompatible with taking the problem of climate seriously.

Thirdly, the dominant master narrative (and practical project) of the 1990s was ‘globalisation’, understood as the expansion of neo-liberalism globally. New multilateral initiatives

\[\text{33 As we now know, at this time a range of think-tanks were switching from the now disappeared ‘red peril’ to the ‘green peril’ of environmentalism, and a range of corporate interests were starting to promote doubt about global warming (Oreskes & Conway 2010).}\

\[\text{34 I follow Litfin’s more expanded use of Haas’s ‘epistemic communities’ notion, and her emphasis on paying particular attention to how “discursive practices promote specific narratives about social problems” (1995:252).}\]
commenced aimed at forging a new global consensus and creating institutions able to take this vision forward. The World Trade Organisation (WTO) emerged in 1995. On the environmental front, the major initiative was the 1992 Earth Summit. The Rio Declaration emerged from this summit. Building on the Brundtland report, and popularising the new term ‘sustainable development’ – one of the keywords of the period – it committed the international community “to equitably meet developmental and environmental needs of present and future generations”, as Brundtland had expressed it (WCED 1987). It also included ideas such as ‘precaution’, ‘polluter pays’ and ‘environmental costs’, with their implication of both the importance of environmental sustainability and market-style regulation. The Declaration’s compatibility with the neo-liberal project was emphasised in its commitment to Principle 12: an “open international economic system that would lead to economic growth and sustainable development in all countries”. Alongside this vision of sustainable development, the Earth Summit introduced a framework of action against global warming (the UNFCCC), essentially committing the industrialized countries to reduce their greenhouse gas emissions using market mechanisms.

This period saw the emergence of a number of globalised discourses. Poverty and the environment were reframed as *global* problems requiring *global* solutions. Global warming too, as I explore in the following sub-section, was also increasingly understood as a global challenge requiring global action. Bernstein and Ivanova have noted how the Earth Summit tried to capitalize on the ‘new optimism’ which, its organizers hoped, “... would be a catalyst for a post-cold war order characterized by an open, market-friendly international economic system and a peaceful multilateral political system” (2008: 162). But they also note that, in hindsight, the commitment to sustainability was ‘...less significant than its integrative proposition that action on the global environment rested on a foundation of liberal economic growth’ (p.164).

Sustainable Development was, therefore, overwhelmingly attached to the global rollout of the neo-liberal project, operationalized in the global South as the Washington ‘consensus’ (see Steger 2009:77 for an account of this). At the time, from an environmental perspective, this was either believed to be compatible with enhanced environmental protection and climate action, or regarded as a framework to which, after the collapse of communism, ‘there was no alternative’. Indeed, given that the Earth Summit placed mitigation at the centre of its climate thinking, and given that it promoted the virtues of a healthy environment perhaps for the first time in so authoritative a document, many saw in ‘sustainable development’ a new and
progressive narrative. Which it was, to a certain extent (Robinson 2004): sufficiently so to keep geoengineering unimaginable.

Finally, and relatedly, there was another reason keeping geoengineering unimaginable: a brief moment of naïve optimism. The Cold War had ended with the triumph of the West. Global conflict had come to an end with only one superpower left standing. The spirit of the time was that global problems, including a healthy environment, could be solved through global cooperation. North-South problems could now be addressed free from ideology and the competing demands of the post-war past. The argument was famously made that humanity had reached the ‘end of history’. Fukuyama (1989) was not arguing that in future there would be no conflict or change, but rather that no serious ideological alternative to liberal democracy and market capitalism now existed in both the West and, increasingly, across the world. Fukuyama’s thesis arguably reflected an elite vision of the times, especially in the United States, and it was widely embraced by the advocates of neo-liberal globalisation. If an endpoint had been reached then, by implication, all that was left was to see liberal market democracy eventually seeping into all the corners of the Earth. Perhaps there were now only conflicts to be managed, technical problems to be solved and market solutions to help answer them? As is well known, and as we shall explore in the next chapter, this illusion was not to last.

From weather to global climate
The evolution of ‘climate change’ after about 1970 as an object of science and policy is at least part of the explanation for the reluctance to lift the geoengineering taboo. It also helps explain the emergence of an increasingly radicalised ‘epistemic community’ of climate scientists, committed to greenhouse gas abatement (mitigation) as a central strategy. The discovery of global warming is well documented elsewhere (for example Behringer 2010; Weart 2008) and not recounted here. I restrict myself to a few observations which are of relevance to this thesis. These help explain the context within which geoengineering largely dropped off the policy agenda from the early 1970s, and its failure to re-emerge in the immediate aftermath of the end of the Cold War. They also, as we shall see in subsequent chapters, assist our understanding both of geoengineering’s current move into the mainstream of climate policy consideration, as well as the widespread scientific reluctance to embrace it. I will make seven observations.

Firstly, global warming was ‘discovered’ in the early 1970s, roughly coincident with the end of the first wave of interest in geoengineering and the emergence of modern environmentalism, at least in the West. Although the physical basis of the greenhouse effect was understood in
the 19th century and data on CO₂ concentrations was available from the 1950s, the dominant view until the early 1970s, and with some support from the temperature record, was that the climate was cooling (Behringer 2010:185). Prior to this, whilst there were some scientists (see for example NAS 1965) alert to the possibility of warming – as some of the quotations in Chapters 2 and 3 suggest – this was not the agreed, nor even the dominant view. As Budyko, among the leading climatologists of the time, put it in his 1971 book *Climate and Life*: ‘there is at the present time no generally accepted view on the causes of climatic change and fluctuation’ (p.292). The cutting-edge 1971, global but MIT-led, *Report of the Study of Man’s Impact on Climate* involved some of the world’s leading climatologists from both East and West. It asserted that “… we do not yet know enough to make positive assertions about man’s potential role in climate” (SMIC 1971:3). 35 The influential publication *Limits to Growth* (Meadows et al. 1972) mentions CO₂ but has no concept of global warming. Only by the mid-to-late 1970s was the view becoming established amongst the scientific community, that the CO₂ effect was significant, that it was causing atmospheric warming, and with it the insight that global warming posed a potential threat (Behringer 2010:190).

Secondly, and almost concurrently, the military-industrial-scientific complex, which was at the heart of the first period of the Cold War, was facing scrutiny and criticism. Numerous studies have shown how stable and co-dependent was the relationship was between the state, military strategists and the scientists and scientific institutions for much of the Cold War (see for example McNeill & Unger 2010:14; Fleming 2010; Oreskes & Krige 2014). Meteorology and the climate sciences more generally were no exception, as is evidenced not only in their funding but also in their being at the forefront of the application of emergent satellite and computer technologies. 36 By the early 1970s, at around the same time as global warming was being discovered, many scientists were accused of ‘… selling their knowledge for immoral causes and of sacrificing science’s freedom for personal advantage’ (McNeill & Unger 2010:17).

35 This intriguing study prefigures the idea of the Intergovernmental Panel on Climate Change (IPCC), not only in its participants, but also in its call for “…an international consensus among concerned scientists...” (SMIC 1971:3-4). The reports instincts were to seek non-anthropogenic causes for climate change, and, if anything, to link human industrial activities and attendant pollution with recorded cooling of 0.3 degrees in the Northern hemisphere between 1940 and 1970 (p.10).
36 As a personal note: whilst researching this chapter it is remarkable how many of the publications on climate and meteorology up until the early 1970s were available only on inter-library loans from relatively obscure military libraries in the US.
The charge cut deeply and some scientists, in the US and also in the Soviet Union, sought to re-establish some of the academic distance they had pre-War.\textsuperscript{37}

Thirdly, by the mid- to late-1970s the ‘epistemic community’ (Haas 1992: Litfin 1995) of the emerging theorization and science of global warming was being driven by its findings to assume a more critical social stance. Not only was the connection between warming and anthropogenic emissions emerging, explicitly linking the ‘social’ with the condition of the ‘natural’. It was also not a major argumentative leap to point out the implication that something was amiss with ‘our civilization’. Further, through the 1970s and into the 1980s, scientists were starting to reach uncomfortable, and increasingly alarming, conclusions about the possible local and regional effects of a continuing rise in emissions, and not only in the long term. Scientists and scientific knowledge had been conferred an elevated status in society. So it was hardly possible, at least at this time, to question the increasingly critical comments emerging from the climate scientists. As McNeill and Unger have put it, writing about this period: ‘[i]t was difficult for politicians and strategists to question those statements without risking their own credibility. Thus, in a dialectical sense, the Cold War, by conferring on scientists a special position within society, produced its own, severest critics’ (2010:17).

Fourthly, at this time the policy of \textit{détente} was occurring concurrently with an emerging environmentalism. Both opened a significant political space which made possible a normative convergence between the emerging environmental movement and the epistemic community of climate science. The former had been largely hostile to ‘big science’ and focused on problems in the ambient environment, but now found justification for their environmental stance in the research being produced. The latter were keen to assert some relative autonomy from the military-industrial complex and increasingly uncomfortable with the implications of their own findings.\textsuperscript{38} At the same time the early 1970s was the so-called \textit{détente} period of the Cold War. This saw a shift towards proxy Cold War conflicts in the global ‘South’ and, as

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\textsuperscript{37} The story is in fact slightly more complex and, from the 1960s, in the United States, a political bifurcation starts to emerge. The biology-centred disciplinary side was focussed on ecological problems and publishing openly. The geophysics-centred side remained, in large part, more directly responsive to the military’s operational needs, and its key findings were often classified (Doel 2003). It was largely the former that gravitated towards a more environmentally aware politics, and only some of the latter. As Masco argues: during the Cold War and beyond, the damaged biosphere was “[b]oth discovered as an object of state interest and repressed as a political project” (2010:17). This may also help explain why scientists from the military-linked Lawrence Livermore Laboratory could never be credible promoters of solar geoengineering.

\textsuperscript{38} Later this would manifest in prominent establishment figures, such as NASA’s James Hansen and Gus Speth, becoming significantly radicalised, even activist in relation to climate policy.
already indicated, a concern in the West about environmental problems provoking revolution. It also meant politicians in both East and West had to search for issues to bring into dialogue if détente was to be given concrete form. Environmentalism was on the rise in the West and the environment was one of the few areas in the ‘East’ where some oppositional activity was tolerated (Corry 2014). Not surprisingly, as Hünemörder has put it: ‘[i]nvoking the slogan ‘Only One Earth’ enabled the two superpowers to bridge, at least partially, the deep ideological gap dividing them’ (Hünemörder 2010:274; see also Uekötter 2010:344). The net effect of the shift to a more independent stance already described, and the space opened by environmentalism and détente, was to make an attachment to science more central to the environmental movement, and to ‘green’ (at least to some extent) the normative sea within which the climate scientists swam. It was no longer a context conducive to Teller-style talk of asserting ‘control over nature’.

Fifthly, starting in the 1970s and running through until the late 1980s a number of epistemological shifts occurred within climate science. There was growing recognition of the complexity of the climate system and increasing reference to feedback loops, hysteresis, non-linearity, chaotic interactions, probabilistic assessments and so on. Whilst greatly expanding their knowledge and modeling, climate scientists were also aware of major gaps in their understanding. This was not humility, but it was in stark contrast to the early geoengineers’ confidence in how much they knew. Understanding the climate as a complex, dynamic system rather than an easily modifiable machine made arguments for geoengineering less persuasive and affectively homeless. Geoengineering did not sit comfortably with the new ‘structure of feeling’ which emerged during the 1970s.

Sixthly, since the 1980s mitigation through cutting greenhouse gas emissions has overwhelmingly been regarded as the key required policy response to the global climate problem. Adaptation has typically been regarded as an adjunct policy, necessary since actual emissions reductions have been inadequate. Whilst this is, arguably, now changing, the observation holds for most of the period covered in this chapter. Indeed, for much of the period adaptation was regarded with hostility by many climate scientists, environmentalists and climate policymakers. Al Gore famously argued in 1992 that adaptation represented a ‘kind of laziness, an arrogant faith in our ability to react in time to save our skins’, a position he later retracted (cited in Pielke et al. 2007:597).

Finally, there is an important analytical and conceptual point to be made. From the 1970s to the early 1990s there was a shift in framing the object of concern from ‘weather’ to global climate change. As is evidenced in many of the quotes in this section, and as Miller has
demonstrated, during much of the Mastery phase and even into the 1970s, “[c]limate remained merely another way of describing the weather, a statistical artifact constructed through mathematical averaging” (Miller 2004:52). Hence, the first wave geoengineering fantasies and proposals covered both weather control and climate control, and the boundaries between these objectives were never clear. Indeed, until the 1980s, climate changes and climate interventions were generally imagined as local or regional, not global.

Moving from ‘weather’ to ‘global climate’, entailed treating the atmosphere as a single entity and, increasingly, as linked to all aspects of what we now term ‘Earth Systems’. This framing shift had a number of implications for the status of science, for the climate policy approaches adopted, and for public engagement with these. I will mention two here, but not elaborate extensively on them. Their significance will become apparent and be fleshed out as this thesis progresses: suffice to note that global problems summon up global solutions, and SGE to cool the planet fits neatly into such narratives.

The term ‘climate’, as Miller puts it, went ‘from signifying an aggregation of local weather patterns to signifying an ontologically unitary whole capable of being understood and managed on scales no smaller than the globe itself’ (Miller 2004:54). Climate was to be understood as a global risk needing global science and global political co-operation.

By the end of the Cold War, the imaginary this fed into and helped generate, was of the need for a global politics able to tackle a global problem by global action: reducing emissions in order to limit disruption of the atmosphere. And indeed this approach came to the fore in the early 1990s, with the Earth Summit and the UNFCCC. This was an era of globalizing, universalist discourses, such as global climate, international human rights, sustainable development, and global free trade. But the imagined solution to the global climate problem sat uneasily with the master narrative of the time: neo-liberal globalization, or market globalism. This would become increasingly apparent as the millennium approached.

A second implication of the globalisation of climate has been developed extensively by Sheila Jasanoff. She argues that in establishing climate change as a global phenomenon, knowledge became detached from meaning.

“Durable representations of the environment, … do not arise from scientific activity alone, through scientists’ representations of the world as it is, but are sustained by shared normative and cultural understandings of the world as it ought to be… The resulting representations of the climate have become decoupled from most modern systems of experience and understanding.” (2010:248-9)

Jasanoff explains that
Climate facts arise from impersonal observation whereas meanings emerge from embedded experience. Climate science thus cuts against the grain of common sense and undermines existing social institutions and ethical commitments at four levels: communal, political, spatial and temporal. ... [Tensions] arise when the impersonal, apolitical and universal imaginary of climate change projected by science comes into conflict with the subjective, situated and normative imaginations of human actors engaging with nature. (2010:233)

The move from weather to global climate made it difficult to distinguish climate from other universalising global discourses, even where these ran counter to significant mitigation action. And it made it harder to attach the climate problem and proposed solutions, to concrete and socially grounded institutions and beliefs. Geoengineering multiplied these difficulties and was easier left unimagined or unimaginable. Stilgoe has made the related point that, along with the scientisation of climate change has come the scientisation of the suggested solutions (2015:71).

* * * * *

Geoengineering’s Hiatus, therefore, covers two distinct phases in the pre-history of geoengineering. From the early 1970s until the late 1980s, geoengineering does not make sense as a solution to the climate problem. It fits neither with the emerging, only starting to be alarmed, climate science, nor with still low profile of climate policy in the long list of public policy concerns, nor with the spirit of the times. There is no need for it and so it is unimagined. In the aftermath of the Cold War, and with growing concern about climate change, it peeks out of the closet. But given the background of its sponsors, the primacy of as-yet-untested mitigation strategies, the shifting outlook of the epistemic community, and the difficulties of getting global climate policy in place despite some initial optimism about a new global order, there is no appetite by either scientists or politicians for lifting the taboo on a controversial idea. It is unimaginable.

This situation persists until around 2005 when, as we shall see, the taboo is effectively lifted by a number of leading climate scientists, and geoengineering starts to become respectable to talk about as a potential climate policy... even when it is not yet embraced.

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39 Whilst Stilgoe locates this suggestion in a discussion of post-2000 developments, I would emphasise the time-lag between the two. A range of factors, including the involvement of environmentalists in the scientisation of climate, helped constrain an immediate move towards the scientisation of solutions.
Section Conclusion

When looking at the ‘Yesterday’ of geoengineering I have identified three broad phases, and labelled them from the perspective of the dominant political and scientific elite. These are the ‘Mastery’ phase from the end of World War Two until about 1970 when climate modification is embraced enthusiastically both as an idea, and to some extent in practice. This is followed by an ‘Unimagined’ phase until the end of the Cold War when climate modification (increasingly labelled geoengineering) is largely ignored as an idea, and is not imagined as a ‘live’ option. Finally, from around 1990, there is a limited, and unsuccessful, attempt in the United States to revive interest in geoengineering. The silence of the previous phase becomes explicit and geoengineering is regarded as unthinkable, in effect ‘Taboo’.

The reigning imaginaries change over these three phases. Table 3.1 summarises, schematically and in simplified form, the holding imaginary of each phase, as well as the mood of the time. It also summarises the particular dominant understandings of nature/environment, and of technology in each phase. Finally it captures the dominant scientific (and political) understanding of climate and the climate problem in each of the phases, and the implications for geoengineering. These are mainly the reigning imaginaries in the United States, which is where (other than in the Mastery phase) almost all thinking and research relevant to geoengineering was occurring.

In the Mastery phase, geoengineering was a ‘solution’ without an obvious problem. It was simply one manifestation of the desire to tame nature, and spurred the invention and exaggeration of ‘problems’ such as too much ice in the Arctic or the need to combat deserts in Africa. It was embraced because it could be done, not because it was needed. In the Unimagined phase, with environmental limits acknowledged but the magnitude of potential warming not widely understood, it could be said that no problem was imagined which could throw up geoengineering as a solution. In the Taboo phase, with the seriousness of the climate condition becoming generally apparent, geoengineering finally had a problem to which it might be the answer. But, especially with the commitment to emissions reductions, there was little taste for it in environmental and climate science and policy circles.

In the following section, ‘Today’, I turn to an examination of the current, post-2005, second wave of geoengineering. It will become apparent that there are both continuities and discontinuities with these earlier phases.
Table 3.1: Schematic summary of reigning imaginaries

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<td><strong>Progress</strong></td>
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<td>Neo-liberal economics</td>
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<td><strong>Development</strong></td>
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<td>Development 1.0</td>
<td>Development 2.0</td>
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<td><strong>Titanic struggle against other superpower and its vision (liberty vs. justice)</strong></td>
<td>MODERNISATION THROUGH STRENGTH</td>
<td>Environmental limits</td>
<td>Risk</td>
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<td><strong>Liberty vs. Justice conflict played out in 3rd World</strong></td>
<td>MODERNISATION THROUGH LEADERSHIP</td>
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<td>‘There is no alternative’</td>
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<td><strong>Modernisation through strength</strong></td>
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<td>MODERNISATION THROUGH GLOBALISATION</td>
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<tr>
<td><strong>Human mastery over / subjugation of nature both possible and desirable</strong></td>
<td></td>
<td>Heightened awareness of environmental problems / impacts / damage</td>
<td>(Politised) awareness of environmental problems</td>
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<td><strong>Contestation: human mastery over vs. human responsibility for</strong></td>
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<td>Environment + Development = Sustainable Development possible</td>
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<td><strong>Faith in authority of science and scientists</strong></td>
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<td>Faith in authority of science and scientists</td>
<td>Challenges to authority and certainty of science</td>
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<tr>
<td><strong>‘Big’ S&amp;T; including hubristic projects</strong></td>
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<td>Reduced faith in ‘big’ science</td>
<td>Increased ‘speed’ of technological change</td>
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<td><strong>Close to military-industrial complex</strong></td>
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<td><strong>No weather-climate distinction</strong></td>
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<td>Emergence of warming as a (possibly serious) problem</td>
<td>Globalisation of climate</td>
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<td><strong>Something to be modified</strong></td>
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<td>Anthropogenic link</td>
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<td><strong>No generally understood warming trajectory</strong></td>
<td></td>
<td>GROWING UNDERSTANDING</td>
<td>Cost of action</td>
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<td><strong>CLIMATE?</strong></td>
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<td>Emergent climate ‘denialism’</td>
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<td><strong>Positive, confident, unbridled optimism</strong></td>
<td></td>
<td>Tempered optimism</td>
<td>Rising pessimism despite ‘end of history’, Uncertainty</td>
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<td><strong>A ‘solution’ without a problem</strong></td>
<td></td>
<td>No imagined problem needing geoengineering</td>
<td>Emerging climate problem, no credible SGE advocate</td>
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Section II – TODAY
This section contains three chapters. In the first of these (Chapter 4) I pick up the story from the previous section and trace the emergence, from around 2005, of a second wave of interest in geoengineering. In contrast to the failed attempts at resurrecting the idea in the early 1990s, this time the idea gains a certain amount of traction and becomes ‘respectable’ to talk about as a policy option. Focussing on the ‘official’ institutional literature, I trace the lifting of the ‘taboo’ and geoengineering’s emergence into the climate policy mainstream. I track the associated anxiety about an approaching climate crisis and the rationales and thinking which accompanied its revival. In the process I analyse the various ways in which it is framed, understood and imagined today. Finally, I show how geoengineering has struggled to normalise itself as a concept, and as a respectable third leg of climate policy.

In Chapter 5 I take a deeper dive into solar geoengineering (SGE) today. My primary concern is to understand what travels with SGE as it re-emerges. I explore this along three inter-related axes – knowledge, power and values – and aim to uncover the inconsistencies, paradoxes and assumptions which accompany SGE. I explore some of the epistemological assumptions in the institutional literature that both have a normalising effect but which also make meaningful assessment of SGE more difficult. I examine the relationship of SGE to power in the world especially the invocation of emergency, the relationship to the capitalist socio-economic order, and to the existing geo-political order. I look at how ethical questions are both acknowledged and also narrowed and marginalised.

Chapter 6 examines competing narratives of SGE and the imaginaries these contain and reveal. I select four different exemplars to illustrate the assumptions which each makes about climate change, nature, the dominant order, technology and so on. I explore the visions which they project onto SGE and their entanglement in pessimistic visions of climate. I show the ways in which elements of each imaginary are present in the most recent, authoritative institutional report, from the NRC, and argue that there is not yet a single dominant sociotechnical imaginary, and that a hegemonic vision has yet to be born. In the process I show how SGE is best understood as a sociotechnical project rather than as a technoscientific object, and how the absence of a hegemonic narrative is constraining its social acceptance and its emergence as a normalised and deployed technology.
Chapter 4: The re-emergence of geoengineering

‘I’ll tell you one thing I’m not going to do is I’m not going to let the United States carry the burden for cleaning up the world’s air like the Kyoto treaty would have done.’


‘[T]his is a crisis with an unusual sense of urgency attached to it, and we should see it as an emergency ... And it carries with it, unless we do something, catastrophic consequences for all civilization.’

Al Gore (2004)

‘This taboo became very apparent in the discussions around an editorial essay about SRM using stratospheric sulfate aerosols published by Paul Crutzen in 2006.’

Mark Lawrence & Paul Crutzen (2013:2)

In this Chapter I begin by relating how neo-liberal market globalism rapidly became hegemonic following the end of the Cold War, and what this meant for the natural environment, the early promise of sustainable development, and the general mood of the times. I then look at how a sense of impending climate emergency became widespread during the 1990s and beyond, not least among scientists. I trace, in some detail, the re-emergence of geoengineering and the lifting of the taboo surrounding it and its rapid movement from the fringes to mainstream climate policy consideration. It’s second coming can be linked to the explicit lifting of the ‘taboo’ by leading scientists, which was in turn motivated by rising concern about climate change and a deep pessimism about the adequacy and effectiveness of existing climate policy approaches. Solar geoengineering (SGE) in particular is largely imagined as an unfortunate but perhaps necessary response to a looming climate crisis. I go on to unpack the particular ways in which it was (and is) rationalised, framed and represented, and how arguments for geoengineering are mobilised. I show that whilst the idea has entered mainstream consideration it remains deeply contested, and still lacking in legitimacy. It has not (yet) been normalised as acceptable.

The resumption of history
With the collapse of the Soviet Union in the early 1990s, the United States was now the single dominant power economically and militarily. Its economic vision for the rest of the World, the so-called ‘Washington consensus’, focussed on encouraging, or insisting in the case of ‘developing’ countries, upon privatisation, de-regulation and liberalisation: to cut public
spending, curb fiscal deficits, liberalise and de-regulate the financial sector, curb capital controls, protect property rights, liberalise trade and cut tariffs, encourage foreign investment, privatise state-owned enterprises, cut taxes and repay established debt (Steger 2009:77). Its political vision was for the spread of democracy, although this was conceived largely in a procedural sense.

But as the decade of the 1990s progressed the shine was coming off earlier suggestions of the ‘end of history’. The promotion of democracy, often by imposing governance-related conditionalities, bred resentment in the global South and highlighted their dependent status. Besides, it was pursued selectively depending on established connections to existing ruling elites. Moves towards privatisation and fiscal de-regulation sometimes led to economic turbulence: such as the collapse of the Eastern bloc economies and the looting of public assets by a new elite; or the economic meltdowns and debt crises across South-East Asia in 1997; or the devastation and conflict generated in Africa in the wake of ‘structural adjustment programmes’. By the turn of the millennium it was far from obvious that de-regulated and open markets would culminate in either development or democracy.40

Prioritising the pursuit of GDP growth became an article of faith in most countries and in all multilateral economic institutions. Growth was accompanied by a substantial rise in inequality within most of the world’s economies: even where the poor were not getting poorer, the very rich were becoming substantially richer (Piketty 2013). Large swathes of the emerging Southern elite aspired to imitate or exceed US-style consumption patterns, and visibly so. This era also sees the rapid expansion of the internet and major shifts in the patterns of production and trade. The increased mobility of capital is accompanied by the widespread relocation of production, in search of lowest cost locations and across multiple countries. Supply chains become more complex, more extended and more varied: to such an extent that contemporary consumer products are now largely compositions, assemblages, created from designs, components and natural resources originating in a myriad, often interchangeable, locations.

From an environmental perspective it is hard to overstate the magnitude of these developments and the extent of ecological degradation which has followed (see for example UNEP 2012). Dauvergne refers to the ecological ‘shadows of consumption’ (2008). Christoff & Eckersley argue that ‘… the contemporary dominant form of economic globalization (capitalism) serves as the main intensifier of environmental degradation’ (2013:13, emphasis in

40 Indeed, the most notable instance of sustained growth, China, was disconnected from democracy and achieved through a particular brand of state capitalism, or ‘market-Leninism’.
original; see also Speth 2008:9). Importantly, for this thesis, affect and effect have become entwined. ‘Growing economic *interconnectedness* ... has produced a growing ecological *disconnectedness* and *dismemberedness* between people and places’ (Christoff & Eckersley 2013:12, emphases in original).

At the institutional and political level states were becoming less powerful, or at least appeared to have a reduced palette of options and policies available to them. Only the most powerful states were, to some extent, exempt from this trend. Fear of causing damage to ‘the economy’ or to the country’s standing in the competitive global market was a restraint on multilateral initiatives to restrict ecological damage. Further, there was growing political influence by the ultra-wealthy and the large corporate sector, and this was sometimes even formalised within multilateral institutions: the Davos effect. It had a counterpart in the recognition of a range of less-resourced civil society organisations. There were many multilateral environmental initiatives and agreements during this period, often innovative ones, but little decline in the pace and intensity of ecological destruction.

The turn towards ‘Market Globalism’ generated resistance: massive protests against the WTO and the G8 around the turn of the millennium, uprisings in Chiapas and elsewhere. The alternatives suggested have been labelled by Steger as ‘Justice Globalism’ (2009). Another globalism, ‘Jihadist Globalism’ (Steger 2009), made its presence on the world stage felt in shocking fashion, with the September 11 2001 attacks on key symbols of US power. Responding to this entailed a sharp increase in the power and budgets of the security establishment, as well as commitment to substantial, and ongoing, military and security activity across the globe by the US and its closest allies. Securitisation spelt the end of any residual optimism from the end of the Cold War. According to Steger, drawing on Jan Nederveen Pieterse, the militarisation of market globalism twinned the practices of empire and those of neoliberalism. It disclosed American empire behind the neo-liberal project, and that ‘market globalism’ entailed ‘imperial globalism’: ‘the allegedly “invisible hand” of the market (claiming to operate without interference from state power) must openly call on the iron fist of the state to save itself’ (Steger 2009:164). 41 The global financial crisis of 2009 would also show, in less military fashion, the need for the state to save the financial markets.

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41 Polanyi’s seminal work, *The Great Transformation* (1940), is remarkably prescient in analysing the underlying dynamics at work. Subordinating society to the logic of the market meant that ‘instead of economy being embedded in social relations, social relations are embedded in the economic system’ (cited Block 2001:xxiv). This requires ‘that human beings and the natural environment be turned into pure commodities, which ensures the destruction of both society and the natural environment’ (p.xxv).
I will turn to the particulars of climate change and climate politics shortly. For now, the broad-brush account of global developments during the 1990s and across the turn of the millennium, presented above, suggests two things about the holding imaginary of the time which are of relevance to geoengineering: the limits of the ‘sustainable development’ paradigm as a way to achieve both growth and ecological protection, and a growing mood of pessimism.

The reigning concept of ‘sustainable development’ was shown to be weak, at least insofar as it had promised a framework to tackle ecological degradation and climate change. What transpired was that environmental considerations were to be tackled as part of the larger neoliberal project, and where conflicts emerged the drive to sustain and increase economic growth would trump all. According to Bernstein and Ivanova, by the mid-2000s

‘... the promise of sustainable development remain[ed] largely unfulfilled and environmental governance ha[d] evolved largely in conformity with the changing demands of a hyper-liberal global political economy, rather than vice versa’ (2008:162; see also Bernstein 2001).

Further, the securitisation of the globalisation project, especially after September 11, meant that tackling environmental issues dropped further down the policy agenda, behind economic growth and waging war on Jihadist globalism.\(^42\) The initial optimism in the early 1990s, that history had ended and that new forms of global regulation might help address ecological damage, was soon supplanted by a more pessimistic mood.

Indeed, whilst there was some initial triumphalism in the West in the wake of the Cold War, it was an insecure triumph and surprisingly short-lived. By the turn of the millennium the global order seemed to be typified by dissolution rather than convergence, disorder rather than order, environmental inaction rather than action, and the management of conflict without the framework of a compelling vision. ‘Market globalism’ was manifestly hegemonic, and even the undoubted global ‘losers’ seemed largely unable to opt-out of its prescripts. But it seemed to be both uninspiring and unable to address the collateral damage, social and environmental, which accompanied it.

There were good reasons, as we have seen, to be pessimistic about the state of the world, especially when reflecting on its ecological health. The hegemonic project claimed that,

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For Polanyi, disembeddedness could not be successful in part because as the effects of commoditisation became apparent it would promote social resistance and a return to a more embedded situation. The danger is, Polanyi believed, that as dissatisfaction increases, ‘... political leaders will seek to divert discontent by scapegoating internal or external enemies’ (Block 2001:xxxiv-xxxv).

\(^42\) Further, when environmental issues were considered post-2001, this was often in a securitised mode, such as the framing of climate change as a security concern (Dalby 2009 and 2013).
despite its faults, it worked, and certainly there was GDP growth in many parts of the global South, and an increase in the availability and cheapness of a range of commodities. But despite being hegemonic, it seemed not to inspire. Where it was electorally endorsed this seemed to be based on reluctant acceptance or a belief that there were no alternatives or only worse ones, rather than love of the idea itself. Intriguingly, it was Fukuyama himself who noted, presciently, that:

‘The end of history will be a very sad time. The struggle for recognition, the willingness to risk one’s life for a purely abstract goal, the worldwide ideological struggle that called forth daring, courage, imagination, and idealism, will be replaced by economic calculation, the endless solving of technical problems, environmental concerns, and the satisfaction of sophisticated consumer demands’ (1989).

In short, we find from around the turn of the millennium, a pessimistic, increasingly securitised, market globalism under US hegemony, one manifestly incapable of addressing environmental degradation. This was the broad social, economic, ideational and geo-political context within which geoengineering was to re-emerge.

The changing climate of climate change
What was the climate context within which geoengineering re-emerged? How was climate change imagined and understood in the ‘developed world’, in the first years of the 2000s.\textsuperscript{43} For reasons of space, and because the story is well known, my account will simply sketch the contours of the time. I will touch on the Kyoto Protocol, the cornerstone of multilateral agreement to address climate change; the linking of the ‘wildness’ of specific weather events to climate change; and the state of the ‘consensus’ climate science.

From the start of the millennium, the signs were clear that the United States, the world’s largest greenhouse gas emitter, had neither the appetite nor the desire to cut emissions. This was not encouraging for anyone wanting to tackle climate change through mitigation. After all, the Kyoto protocol had set the modest goal of reducing greenhouse gas emissions, by the year 2012, to 5% below 1990 levels.

In June 2001 President George W Bush announced that the United States would not sign up to the Kyoto Protocol to which it had previously agreed. Reasons given for rejecting this ‘flawed treaty’ included that it imposed no obligations on developing countries like China and India, that there was insufficient knowledge about global warming, that the Kyoto targets were ‘arbitrary and not based upon science’, and that ‘complying with those mandates would have a

\textsuperscript{43} Here I limit myself to the ‘developed world’ since it is there, mainly in the United States and to a lesser extent the UK, that the idea of geoengineering re-emerges.
negative economic impact’ (White House 2001). Instead a target for improving emission intensity was announced, one that would allow emissions to increase, but at a slower pace. Pulling out of Kyoto did not come as a surprise. In his second presidential debate with Al Gore in 2000, Bush had made his approach clear:

‘I’ll tell you one thing I’m not going to do is I’m not going to let the United States carry the burden for cleaning up the world’s air like the Kyoto treaty would have done. China and India were exempted from that treaty and I think we need to be more even handed’. (cited in Singer 2002:27)\(^4^4\)

The 2002 CoP meeting in New Delhi, in a sop to the US, saw references to the Kyoto Protocol dropped from the draft statement. Russian ratification of the treaty was essential in order to bring it into effect, but it was hesitating. The 2003 CoP in Milan saw the ongoing instability in post-communist Russia on display. The deputy Economy Minister said Russia was moving towards ratification, but was flatly contradicted by President Putin’s economic advisor who said “[i]t is impossible to undertake responsibilities that place serious limits on the country’s growth” (Kirby 2003).

A review of the year 2003, published in *Nature*, noted that ‘[e]nvironmentalists may remember 2003 as the year in which the Kyoto Protocol died’ and that ‘the international community’s first attempt at tackling climate change is in terminal decline’. Only Russia, it argued hopefully, ‘was capable of breathing life into the protocol’. But, the review conceded, ‘this looked very unlikely to happen’. The review went on to cite the director of MIT’s Joint Program on the Science and Policy of Global Change: ‘The common view here is that Kyoto doesn’t live any more’. It also cited the influential climate policy scientist, Hans Joachim Schellnhuber: ‘A homogeneous solution to climate protection is a broken dream’ (All above quotations from Schiermeier 2003:756).

Some signs of the times: an unusually intense European heatwave in the summer of 2003 resulted in an estimated 15,000 deaths in August in France alone (see Robine et al. 2008 and UNEP 2004). Shortly thereafter major wildfires swept across Southern California. In August 2005 Hurricane Katrina struck New Orleans to devastating effect. Examples of extreme weather such as these suggested the severity of global warming already being felt\(^4^5\). They also formed part of an emerging narrative at this time. This presented climate change as easily the

\(^4^4\) His father President George Bush Snr. had spoken along similar lines at the Rio Earth Summit in 1992 when he said “the American lifestyle is not up for negotiation” (cited in Singer 2002:2).

\(^4^5\) I am aware that at this time the standard scientific response was that no particular weather event could be attributed to climate change. For my purposes it is the felt effect that is relevant to understanding the shape of the imaginary of the times.
biggest environmental problem of all, and pointed to the existential threat this posed to humans. The language of the need to go onto a ‘war’ footing, and for Churchillian-style leadership, starts to emerge in some accounts of this time (see Dibley & Neilson 2010 for an account of this). In general this framing stressed crisis, urgency and emergency, and called for action in the face of impending catastrophe. An influential example can be found in a talk at Yale University in April 2004 by former US Vice-President Al Gore, entitled ‘The Climate Emergency’:

‘The title I chose for this speech is not a misprint... this is a crisis with an unusual sense of urgency attached to it, and we should see it as an emergency (2004:154). ... [T]his is happening right now. And it carries with it, unless we do something, catastrophic consequences for all civilization’ (Gore 2004:157).

Gore’s influential 2006 movie, An Inconvenient Truth, was still to follow and would continue this theme. But it faced a competing narrative which rejected any suggestion of a crisis, labelling such talk alarmist. Its protagonists were accused of hype and, occasionally, conspiracy. The competing narrative, dominant within the Bush presidency, stressed the naturalness of climate variations, the uncertainty of the science, and that climate impacts were not imminent but in the future. Apart from those who denied that climate change was an issue at all, they either accepted modest climate measures or actively called for inaction.

We now know, as Brysse et al. have shown, that the “official” findings of climate science during this period probably erred on the side of caution rather than alarmism when it came to making predictions. ‘Scientists, particularly acting in the context of large assessments, may have underestimated the magnitude and rate of expected impacts of anthropogenic climate change’ (Brysse et al. 2013:335): an example being estimates of sea-level rise. If anything, the scientists were understating the severity of the data... and they often knew it.

At the turn of the millennium a cautious scientific ‘consensus’ about climate change was becoming apparent (Oreskes 2004) and, most significantly, was being communicated to policymakers, leading politicians and even the general public. The IPCC’s Third Assessment Report published in 2001 included, for the first time, a separate synthesis and summary for policymakers and paid greater attention than previously to presentation. The emerging ‘consensus’ crystallised around a number of propositions. First, that global warming was

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46 It is symptomatic of this period of market globalism that a leading billionaire airline entrepreneur and celebrity, Richard Branson, is selected to give a keynote address on climate change to the UN General Assembly. In it he calls for an ‘Environmental War Room’ to be established and for mankind to ‘regulate the Earth’s temperature’ (Branson 2008:n.p.).
occurring. As the IPCC’s Third Assessment Report put it, the 1990s was the warmest decade, and 1998 the warmest year, since instrumental records began in 1861 (2001:4). Second, that the cause was primarily anthropogenic, with ‘new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities’ (2001:5-7).

Contrast this with the 1995 Second Assessment Report with its more modest claim that ‘the balance of evidence suggests that there is a discernible human influence on global climate’ (1995:22). Third, that the effects of increasing climate change would be mainly adverse, that the impacts would ‘fall disproportionately upon developing countries and the poor persons within all countries’, including that it would ‘exacerbate water shortages in many water-scarce areas of the world’ (2001:9-12). Contrast this with the Second Assessment Report which, although it contains some similar conclusions in the small print, headlines the relevant section ‘Impacts are difficult to quantify and existing studies are limited’ (1995a:29). The take-home message being conveyed in the Third Assessment Report was that ‘it’s happening, it’s us and it’s possibly serious’. A fourth conclusion was that significant emissions cuts were needed, although the modelling of various scenarios produced very different estimations of what was required, and with large error ranges.

In short, to understand the context within which geoengineering was to re-emerge we need to understand that global and co-ordinated responses to climate change were typified more by inaction than action and that mitigation was, at best, underwhelming in scale and scope. Alongside this, the ‘consensus’ science was expressing growing concern at the likely effects of rising greenhouse gas concentrations, and greater certainty about the driver of climate being mainly anthropogenic. Finally, the ‘climate problem’ was being articulated by some as the world’s single greatest environmental challenge, and framed as both a global crisis and a civilizational emergency.47

Feeding into the emergency/crisis discourse, during this period a number of terms from the climate sciences were becoming more commonplace in the adjacent climate policy world. Two bundles of concepts are especially important for consideration of solar geoengineering. First, ideas of ‘non-linearity’, ‘hysteresis’ and the possibility of abrupt and hard-to-predict changes in the climate system. Most dramatically presented as ‘tipping points’, these were understood as critical thresholds in non-linear systems beyond which changes might be unleashed which could not be reigned back in. Elements of the Earth system (such as the West Antarctic Ice

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47 This, in effect, converted a range of existing concerns – such as extinction, biodiversity, toxicity and waste – into second-order environmental issues. See for example Crist (2007), who examines the implications of this.
Sheet or the release of methane from melting permafrost) were understood to be at particular risk of ‘tipping’. Second, and relatedly, ‘inertia’ and the concern that, once set into motion, many climate changes (such as sea level rise or ocean acidification) would lumber along, unfolding over centuries, even millennia, and be effectively ‘irreversible’ even with emission cuts. In the field of public policy, growing awareness of the complex and ‘coupled’ system dynamics associated with climate change, led to the revival and reworking of concepts such as ‘messy’ problems (Ackoff 1974, and Horn & Weber 2007) ‘wicked problems’ (Rittel & Webber 1973, and see APSC 2007), and even ‘super-wicked problems’ (Levin et al. 2007 and 2012).

James Hansen, perhaps the most prescient and highly-regarded climate scientist of his generation, and also deeply engaged with climate policy debates, summarised the situation as he saw it in a speech to the peak event of his disciplinary community, the conference of the American Geophysical Community (AGU) in December 2005:

‘The Earth’s climate is nearing, but has not passed, a tipping point beyond which it will be impossible to avoid climate change with far-ranging undesirable consequences. These include not only the loss of the Arctic as we know it, with all that implies for wildlife and indigenous peoples, but losses on a much vaster scale due to rising seas... This grim scenario can be halted if the growth of greenhouse gas emissions is slowed in the first quarter of this century.’ (cited in Bowen 2008:4)

In short, the climate context, scientifically and discursively, was one which stressed urgency, seriousness, the need for determined leadership, and a sense that the time to act was running out. Not surprisingly geoengineering re-emerges closely attached to the climate emergency/crisis narrative.

Foundations for geoengineering’s re-emergence
In late 2001 the US National Research Council convened a committee to examine and report on weather modification. There had been a gap of almost three decades since the previous reports in 1964, 1966 and 1973. Its report, published two years later, carries the marks of the ‘taboo’ period when it notes that weather modification generates ‘serious feelings of ambivalence’ in the scientific community and the support agencies (NRC 2003: iv); and when it partly disregards its brief which ‘explicitly excluded consideration of the complex social and legal issues’ (p.viii); or when it stresses that the results of improved scientific knowledge of atmospheric processes are ‘... as likely to lead to viable weather modification methodologies as they are to indicate that intentional modification of a weather system is neither currently possible nor desirable’ (p. vii). The committee’s brief included examining research directions relevant to ‘reduction in severe weather hazards’ and specifically covered both ‘localized weather modification’ and ‘large-scale weather and climate patterns’. The significance of the
2003 report lies not in what it says but in its silences. It contained no discussion, no mention even, of geoengineering. The topic was still, effectively, ‘taboo’.

Around this time, geoengineering is considered in a scenario prepared for the Pentagon in October 2003 by leading scenario specialists Peter Schwartz and Doug Randall. Whilst the document is not an official Pentagon one, it is of interest as suggestive of the types of planning scenarios under consideration at that time. Schwartz and Randall’s stated aim is to ‘imagine the unthinkable’, and present a ‘plausible scenario’ of abrupt climate change following a sharp slowdown in the North Atlantic thermohaline conveyor. This would be associated with sharp changes to weather patterns across much of the world (both warming and cooling), as well as food shortages, water crises and warfare. They conclude with seven recommendations, one of which is to ‘explore geo-engineering options that control the climate’, although they caution that such an action ‘would have the potential to exacerbate conflict among nations’ (2003:22). Geoengineering is mentioned, but in an explicitly “outside-the-box” and non-official document.

A few months later, in January 2004, the Tyndall Centre for Climate Change Research and the [University of] Cambridge-MIT Institute convened a special joint Symposium on ‘Macro-Engineering Options for Climate Change Management and Mitigation’. The symposium report starts by outlining the background: ‘many people’ recognise it will be ‘extremely difficult’ to reduce emissions, especially if combined with per capita convergence requirements requiring greater cuts by developed countries. ‘The urgency of implementing climate change management [means] more innovative approaches to ... mitigation’ will likely be needed (Tyndall Centre 2004:1). Nuclear fission and fusion will not make up the shortfall in the medium-term and so ‘macro-engineering options for climate change management’ (ie. geoengineering) need to be discussed and evaluated before they can be ‘seriously considered for implementation’ (p.1).

The symposium covered a range of proposed technologies including carbon capture and storage (CCS), ocean fertilisation, cloud stimulation and, most relevant for our purposes, stratospheric aerosols. It is worth quoting at some length the report section entitled ‘Philosophy’ as this helps in understanding the imaginary and assumptions then prevalent. It also makes clear that what was being discussed was still ‘taboo’, and that there was a need to rationalise breaking that taboo.

‘Although most of the macro-engineering approaches identified so far are not currently in the mainstream thinking in relation to climate policy, the mere fact that they have been conceived and proposed places an obligation on engineers, economists, and environmental and social scientists, working together, to explore their feasibility and evaluate their consequences and their wider implications. At the very least, such options may need to be
considered as *emergency policy options* in the event of greater adverse climate change impacts than expected, or less effective carbon reduction measures than anticipated. The process of exploration, evaluation, development and (eventually) pre-operational implementation of such approaches should be regarded as at least an *insurance* against these eventualities.

Many of these possible options are *highly speculative* at present, and some may even appear to be quite *crazy*. However, that is precisely why they should be evaluated (and if necessary dismissed) as soon as possible. Otherwise, politicians may seek to use them as "Magic Bullets" either to postpone action, or as prospective solutions for actual implementation, once it becomes clear that the *mitigation of climate change is going to be a major and very difficult task indeed*...

The symposium therefore aimed to

- Consider all approaches identified, objectively, and *without preconceptions*
- Engage in an open, unbiased, and *visionary* but still concrete discussion
- Disregard potential pressures in relation to political correctness.
- Employ a very wide range of criteria for a preliminary evaluation`

*(Tyndall Centre 2004:2, all emphases my own)*

One can see that geoengineering here is tied to ‘emergency’, ‘urgency’, and seen as an ‘insurance’ policy in a context where climate mitigation seems impossible. There is awareness that these ideas may be seen as ‘crazy’, and a self-perception by the attendees that they are fearless, even ‘visionary’, straight-talking and unbowed by ‘political correctness’. The last of these is presumably dismissing a hard-won *de-facto* ‘taboo’ on geoengineering, dating from the mid-1970s, as ‘mere’ political correctness.

Only 34 invited attendees from North America, the UK and elsewhere in Europe participated. The Stratospheric Aerosol discussion was led by Lowell Wood, a long-standing proponent for ‘albedo modification’ and explicit political conservative. Indeed the brief symposium report, when discussing ‘Next Steps’ makes the point that ‘the debate could now usefully be re-envigorated (sic) in North America, where a way is needed to build further on the 1992 NAS report’ (Chapter 28), of which Wood had been a co-author. The report envisages the need for more basic research, large scale pilot experiments, and large scale tests (Tyndall Centre 2004:5). It cautions against using research as a reason to delay implementation of known existing solutions. The symposium report notes that all participants agreed to promote the

48 We have already encountered Lowell Wood in the previous Chapter as a close colleague of Edward Teller, as a co-author of the largely ignored geoengineering chapter in the 1992 NAS study on climate change, and as one of the advisors in the unsuccessful attempt by George W Bush’s climate advisors to put geoengineering back on the policy agenda.
idea that “macroengineering options” ‘... needed to be brought into the main-stream of the
debate on possible responses to climate change’ (p.6).

Wood’s paper to the Cambridge-MIT Institute symposium is not available.49 But his thinking at
the time can be found in a 2002 paper for the National Academy of Engineering that he co-
authored with Teller and Hyde, his colleagues at Lawrence Livermore. This paper largely
reprises the calculations done for the 1992 NAS study and argues that stratospheric aerosols
are a cheap and effective solution: entailing ‘... expenditures of no more than $1 B[n]/year,
commencing not much sooner than a half-century hence, even in worst-case scenarios’ (Teller,
Hyde & Wood 2002:8). It makes its normative case more transparently than in the 1992 NAS
study, and one can hear the voice of the George W Bush advisor coming through. He makes
the unusual argument that solar geoengineering’s cheapness means that ‘technical
management of radiative forcing of the Earth’s fluid envelopes, not administrative
management of gaseous inputs to the atmosphere, is the path mandated by the pertinent
provisions of the UN Framework Convention on Climate Change’ (p.8).50 The technique is seen
as doubly cheap as not only is its cost low, but by allowing CO2 concentrations to rise plant
fertilisation is enhanced thereby enabling humankind to get around “the basic food production
challenge of the 21st century” (p.8). In essence solar geoengineering is presented as a better
alternative, if climate change is a problem, to mitigation via emissions reductions, and with
added ‘development’ benefits. This is not about ‘urgency’ or ‘emergency’.

This echoes the thinking of Wood’s mentor Edward Teller. In a 1997 article in the Wall Street
Journal Teller had called for ‘a sunscreen for planet Earth’, for a problem he clearly thought
had been hyped:

‘[F]or some reason, [the geoengineering] option isn’t as fashionable as all-out war on fossil
fuels and the people who use them. Yet if the politics of global warming require that
‘something must be done’ while we still don’t know whether anything really needs to be
done – let alone what exactly – let us play to our uniquely American strengths in innovation

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49 I have emailed various institutions trying to obtain this paper, but without response.
50 Wood’s argument, in his and his co-author’s words, is: ‘... if you’re inclined to subscribe to the Rio
Framework Convention’s directive that mitigation of global warming should be effected in the “lowest
possible cost” manner – whether or not you believe that the Earth is indeed warming significantly
above-and beyond natural rates, and whether or not you believe that human activities are largely
responsible for such warming, and whether or not you believe that problems likely to have significant
impacts only a century hence should be addressed with current technological ways-&-means rather than
be deferred for obviating with more advanced means – then you will necessarily prefer active technical
management of radiation forcing of the Earth to administrative management of greenhouse gas inputs
to the Earth’s atmosphere, for the practical reasons sketched in the foregoing” (Teller, Hyde & Wood
2002:6 emphases in original).
and technology to offset any global warming by the least costly means possible. ... Injecting sunlight-scattering particles into the stratosphere appears to be a promising approach. Why not do that?’ (Teller 1997)

Echoes of the ‘Mastery’ imaginary, discussed in the ‘Yesterday’ section of this thesis, are clearly evident. And the developmentalist claims being made prefigure those contained within the ‘Salvation’ imaginary I will discuss in Chapter 6.

The trope – geoengineering as an alternative plan for tackling climate change – can still be found today, even if not as crudely expressed as in Teller’s version. And it remains attractive to both the politically conservative, since it explicitly rules out tackling the dominant energy and economic order, and also to the climate “sceptical”, since it provides a backstop “in case the science turns out to have been right” (for examples see Lomborg interviewed by Dickinson 2010; Gingrich 2008; Levitt & Dubner 2009). But it was a perspective which had failed to gain traction in the 1990s and was unlikely to do so in the 2000s if argued in this way, even as the magnitude of the climate condition became more, rather than less, concerning.

If geoengineering was to become a part of mainstream climate policy consideration it would need to be detached from climate inactivist thinking and attached to the mainstream scientific narrative that stressed the magnitude of the anthropogenic climate issue, not its uncertainty. And it needed a proponent with greater credibility and less ideological baggage than Teller or the Lawrence Livermore circle. This happened in 2006.

**Lifting the taboo**

The entry of geoengineering into mainstream policy consideration can probably be dated to a 2006 editorial by Paul Crutzen in the journal *Climatic Change* entitled ‘Albedo Enhancement by Stratospheric Sulfur Injections: a contribution to resolve a policy dilemma?’ (Crutzen 2006). Crutzen, now retired, was a prominent Dutch atmospheric chemist and climate scientist, Nobel prize winner for chemistry for his work linked to the creation of the ozone hole, and influential thereby in shaping one of the few international environmental treaties (the Montreal protocol) often regarded as a success, as well as populariser of the idea of ‘nuclear winter’ and the idea of the ‘Anthropocene’.

In the article Crutzen outlines the science indicating the seriousness of the warming projections contained in the models. He draws on two key arguments. Firstly, the possible need ‘to combat potentially drastic climate heating’ (2006:216). He is deeply concerned that initiatives to reduce smog and pollution, for health and ecological reasons, may paradoxically result in a potentially catastrophic spike in temperatures. Secondly, that the political response to the problem has been inadequate and CO₂ emissions have continued to rise, when ‘by far
the preferred way’ was that they fall by 60-80% (p.211-2). This is the “failure of mitigation” (or failure of environmental politics) argument.

‘[A]lthough by far not the best solution, the usefulness of artificially enhancing earth’s albedo and thereby cooling climate by adding sunlight reflecting aerosol in the stratosphere ... might again be explored and debated’ (p.212). Crutzen stresses that: ‘Importantly, its possibility should not be used to justify inadequate climate policies, but merely to create a possibility to combat potentially drastic climate heating’ (p.216). The crux of his argument was:

‘Given the grossly disappointing international political response to the required greenhouse gas emissions, and further considering some drastic results of recent studies [that the prognosis is worse than previously believed], ... research on the feasibility and environmental consequences of climate engineering ... which might need to be deployed in future, should not be tabooped’ (p.214).

Prior to publication, according to Ralph Cicerone, a climate scientist and the journal editor, a number of his scientific colleagues appealed to him not to publish (Cicerone 2006:221). Unusually for an academic journal, Crutzen’s contribution ended up being published alongside a number of responses, some critical of his position (for example Kiehl 2006). Once pushed out of the closet and into the public domain, geoengineering could not be re-closeted. Not that the idea had been secret. As we have seen, there was an existing, albeit limited, scientific literature on, or relevant to, geoengineering. But this mainly emanated from scientists associated with earlier and discredited visions of mastery. And there were pockets of support for the idea elsewhere, such as from economists Nordhaus (1994) and Schelling (1996) in the wake of the 1992 NAS report. But Crutzen’s stature, the deliberateness of the gesture and the forum chosen, ensured the idea of geoengineering entered into the domain of respectable climate policy discussion. The taboo was lifted.

Shortly after the Crutzen article, in November 2006, the NASA Ames Research Center, together with the Carnegie Institution sponsored an expert workshop on the use of what they called ‘solar radiation management’. The focus was on what technologies might be used, their effectiveness and unintended consequences. It had to acknowledge the contentious nature of the idea. The workshop report, ‘Managing Solar Radiation’ stated that participant views on ‘... the circumstances under which solar radiation management should be deployed ...’, ranged from ‘(i) never, (ii) only in the event of an imminent climate catastrophe, (iii) as part of a
transition to a low-carbon-emission economy, and (iv) in lieu of strong reductions in greenhouse gas emissions’ (Lane et al 2007:vi).  

In the report’s climate policy section, option (iv) is largely rolled into option (iii). Revealingly, option (i) makes no further appearance in the report. The positions from only a year earlier have been reversed – thoughts of ‘taboo’ have been assigned to the margins by the authors. Accordingly, the report’s climate policy section sets out two ‘rival strategic visions’:

‘One of these, which might be called the parachute strategy, would foresee deployment only in the event of a climate change emergency. The second, preemptive deployment strategy, would implement solar radiation management technologies as soon as research firmly established their safety and efficacy’ (Lane et al 2007:11).

The emergency vision was understood to be ‘politically straightforward’ ... after all this would be an emergency, seems to have been the assumption! The technology would be developed and then put on the shelf. The emergency view, as we shall see in the next Chapter, is far from being “straightforward”, either politically or scientifically.

The pre-emptive vision was understood as ‘a temporary measure to buy time for emission reductions’ and develop new technologies.  

It could ‘... be consistent with an economically efficient climate policy... postponing the deepest emission cuts until cheaper abatement technology is available’ (p.11, my emphasis).

* * * * *

2006 can be seen as a turning point. It was the moment when geoengineering became an acceptable idea at least for inclusion in discussions on climate policy. Whilst the Tyndall symposium of 2004 imagined its proceedings as transgressive, politically incorrect and ‘crazy’, the NASA Ames symposium of 2006 thinks of itself as mainstream and responsible: it focuses not on whether to geoengineer but on the circumstances under which to do so, and the knowledge needed.

51 A few years prior, the last three views would barely have received a hearing! The third view was also unusual and suggested the pre-emptive use of solar geoengineering as part of a suite of policy interventions into climate. It is associated with Tom Wigley (2006), who also attended this workshop. The related proposal of experimenting in the atmosphere, starting small and then “cautiously” scaling up any intervention, was also voiced (Lane et al 2007:6). It was a proposal which would later be championed by David Keith, another of the participants in the workshop.

52 Not mentioned is how the conception of the ‘temporary’ nature of any intervention might be reconciled with SGE being a long-term commitment and difficult to terminate. The ‘termination effect’ as it is known, is clearly outlined in the later ‘official’ literature (for example NRC 2015:36) but was perhaps not fully acknowledged at the time.
Geoengineering’s emerging respectability was a turn away from “taboo”. But it was not generally a switch towards its unconditional embrace. Geoengineering was widely seen, to use Kintisch’s phrase, as ‘a bad idea whose time has come’ (2010:13). And its move into the mainstream as a policy option provoked, as we shall see later in this Chapter, extensive pushback against the idea itself and also prompted calls for the regulation of research in the area and for restrictions on any suggestion of experimentation with the atmosphere (or the oceans).

Geoengineering’s becoming mainstream, at least in climate policy discussions, is further evidenced by the veritable flood of academic research, commentary, and popular accounts about geoengineering from 2006 (Belter & Seidel 2013; Oldham et al. 2014). As outlined in the introductory chapter, the surge in publications covered a wide range of scientific and engineering disciplines, and ranged from the theoretical to the applied to the speculative. There were also numerous contributions from economics and law, as well as the humanities and social sciences. Publications multiplied from disciplines such as international relations, philosophy, climate policy, environmental humanities, sociology, politics, communications, science & technology studies ... to mention only a few.

**Officially respectable, but not quite acceptable**

Since the lifting of the taboo, geoengineering has become increasingly visible in ‘official’ and authoritative climate policy documents and funded initiatives. The IPCC is indicative of this. Compared to the first four Assessment Reports – in 1990, 1995, 2001 and 2007 – the Fifth Assessment Report of 2013 significantly increased the amount of coverage and comment devoted to geoengineering: the topic is covered in all three working groups and in the synthesis report and the summary for policymakers. It was preceded by a special global expert meeting devoted to the subject (IPCC 2012). The shift in tone in the Fifth Assessment Report is subtle but noticeable. The synthesis report remains cautious about geoengineering and avoids a comprehensive assessment on the grounds of “limited evidence” (2014a:89). The document most read by those in power, the *Summary for Policymakers*, notes that ‘modelling indicates that SRM methods, if realizable, have the potential to substantially offset a global temperature

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53 David Victor, in a talk at Harvard University, has noted that when David Keith and Ken Caldeira invited all the experts, himself included, to a meeting on geoengineering at Norton Woods in November 2007, the experts could all fit into a room. In this sense, he notes that it is perhaps accurate to talk about a “geoclique” (as many opponents of geoengineering do), since today any comparable gathering would run into the hundreds, even thousands (Victor 2016).

54 In the Introductory Chapter I have outlined my rationale for paying special attention to the ‘official’ institutional literature.
rise’ (2013b:29), whilst also pointing to a range of risks, including the high likelihood of significant termination effects.55

In Europe, papers were commissioned for the United Kingdom’s parliament (2009; 2010). But most influential was a 2009 report by the Royal Society (2009) entitled Geoengineering the Climate: science, governance and uncertainty. Without endorsing its deployment, this suggested that solar geoengineering could be both highly effective and highly affordable. It ‘may provide a potentially useful short-term backup to mitigation in case rapid reductions in global temperature are needed’ (2009:59). In Germany reports have been prepared for the Federal Ministry of Education and Research (Rickels et al. 2011), and the Umweltbundesamt (2011), Germany’s Environmental Protection Authority. Alongside these, a number of major research initiatives have been funded by the official research bodies. These include, in the UK, the SPICE project, a science council funded Integrated Assessment of Geoengineering Proposals (IAGP) (www.iagp.ac.uk) and Climate Geoengineering Governance projects, a six-year inter-disciplinary priority programme in Germany, a French programme ‘Reflections on Environmental Geoengineering (REAGIR), and an EU-funded programme, the European Transdisciplinary Assessment of Geoengineering (EuTRACE).

In the United States there are reports associated with committees of Congress (for example 2009; 2010) and Senate (2007), and detailed reports produced by the Government Accountability Office (GAO 2010; 2011). Other relevant official and “close to power” studies include the NASA-Ames study already mentioned (Lane et al. 2007), a report commissioned by the RAND Corporation on governing geoengineering research (Lempert & Prosnitz 2011), and reports by or for the Council on Foreign Relations (Ricke et al 2008), and the Bipartisan Policy Center (2011). But easily the most comprehensive work has been done by the National Research Council, in a project largely sponsored by the intelligence establishment. This resulted in a major study, the most comprehensive and thorough to date, entitled Climate Intervention: Reflecting Sunlight to Cool the Earth (NRC 2015a).56 This report could not be said

55 Compare this to the more obviously dismissive references to geoengineering in earlier IPCC reports. The Second Assessment Report, in its ‘Summary for policymakers’, concluded that geoengineering was “…likely to be ineffective, expensive to sustain and/or to have serious environmental and other effects that are in many cases poorly understood” (1995c:18). The Fourth Assessment Report, published shortly after the lifting of the taboo, makes no mention of geoengineering in its Synthesis Report (2007d). It touches on ocean fertilization and solar radiation management in its Working Group 3 report. This noted that “[t]hese options tend to be speculative and many of their environmental side-effects have yet to be assessed; detailed cost estimates have not been published; and they are without a clear institutional framework for implementation” (2007d:624).

56 A parallel study published at the same time focussed on carbon dioxide removal (CDR) techniques.
to endorse solar geoengineering, indeed it could be read as implicitly critical of the idea... at least for now. But it did not take it off the table as an option.

No major published ‘official’ or institutional studies are known to come from China, Russia or other globally powerful countries. Given the geo-political sensitivity of many of the issues which emerge in discussions of geoengineering, it is possible that there are unpublished ‘official’ studies. In any event, work on solar geoengineering is taking place in both Russia and China.

In 2011, leading scientists from the SRMGI held high-level talks on the subject with Chinese scientists and officials (Edney & Symons 2014:4). Cao et al. (2015) have outlined the co-ordinated research on geoengineering (including solar geoengineering) being undertaken as part of that country’s National Key Basic Research Program. They note that of particular concern are the possible effects of SGE on the key elements of the climate system, including precipitation and the monsoon.

There are original academic studies of geoengineering emerging from Russia (in Russian) including some authored by Yuri Izrael, a long-time enthusiast for solar geoengineering. A 2008 Russian report quotes him as saying ‘We must have different “weapons” for fighting climate change and stabilizing the climate’ and showing him to be a strong supporter of SGE as the ‘optimal and inexpensive’ solution. The report concludes that a group of climatologists, headed by Izrael, ‘are preparing to conduct an experiment to assess the impact of sulphuric-acid aerosols on temperature fluctuations in some Russian areas’ (Sinitsyna 2008). Further, judging from the comments made by Russian ‘official’ bodies, such as the Institute for Global Climate and Ecology, regarding the drafts of the relevant chapters of IPCC’s Fifth Assessment Report, enthusiasm for solar geoengineering runs high (IPCC 2013d; 2013e).57

57 Yuri Izrael’s position appears to be an example of the entwining of science and politics. He was a disciple of Budyko and co-authored Global Climatic Catastrophes with him (1986/1988). In the aftermath of the end of communism he was a one of the leaders of the Russian Academy and apparently close to Vladimir Putin. He was a vice-chair of the IPCC but in the early 2000s seems to have focussed on discrediting any suggestion that climate change had anthropogenic causes and discouraging the Russian government from ratifying Kyoto (Bolin 2007:187-189). By 2009 he was conducting outdoor experiments on solar geoengineering (Izrael et al. 2009), spraying sulphate aerosols from helicopters and military trucks. See also Izrael et al. (2013).
In some countries, references to geoengineering are starting to appear in ‘official’ publications or policy documents aimed at the general public. But these countries are currently observers rather than major ‘players’ in the solar geoengineering space.

In summary, there is not an embrace of geoengineering in ‘official’ circles, but the idea is being taken increasingly seriously. It has moved from taboo to seriously considered policy option. As aspiring solar geoengineer David Keith put it in his response to the NRC report: ‘it serves as a marker of the extent to which solar geoengineering is becoming a more normal part of the science and policy of climate change’ (Keith 2015). A sign of the seriousness with which the idea is being taken can be found in its inclusion in new ‘realist’ climate policy thinking post-Copenhagen by individual academics known to influence policy shaping (for example Victor 2011; Wagner & Weitzman 2015). Indeed it is here, as we shall see, in the ‘policy influential’ literature, less constrained by being the agreed product of committees of scientists and others, that a more consistent set of arguments about what geoengineering might be imagined to be, can appear. And yet the idea of SGE faces significant resistance. As one climate scientist on the NAS (2015) panel, Raymond Pierrehumbert, put it:

‘The nearly two years’ worth of reading and animated discussions that went into this study have convinced me more than ever that the idea of “fixing” the climate by hacking the Earth’s reflection of sunlight is wildly, utterly, howlingly barking mad’ (Pierrehumbert 2015:n.p.).

**Rationales, frames and representations**

We can now delve a little more deeply into how geoengineering is being imagined as it enters mainstream climate policy consideration. What I aim to do in this section is to unpack the emerging discourses of geoengineering. How is geoengineering, and solar geoengineering in particular, understood in the ‘institutional’ literature? What are the expressed rationales for considering it? What narratives are used, what metaphors are mobilised? What visual representations predominate? How is it understood and framed? What unspoken assumptions underpin it? My assumption here, as outlined in the Introductory Chapter, is that discourse has productive power in shaping how, and even if, the technology emerges. How

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58 An Australian example of this is a document ‘The Science of Climate Change’ published in February 2015 by the Australian Academy of Sciences, an updated version of a now established publication aimed at providing an accessible state-of-the-art account. On the final page, dealing with options to address climate change, it states that managing climate risks “… will necessarily be based on some combination of four broad strategies”. In addition to mitigation and adaptation, it also includes sequestration and solar geoengineering (AAS 2015:30).
geoengineering is analysed, discussed and constructed; the terms and metaphors used; the assumptions and judgements relied upon... all this matters.

I make three general observations at the outset. Firstly, the shadow of the ‘taboo’ era remains and statements and propositions made are usually wrapped in cautious and conditional language. Most obviously, the ‘institutional’ studies have been reluctant to explicitly endorse, or be seen to endorse, solar geoengineering. To find more explicit proponents for SGE one has to look at the associated ‘policy influential’ literature by individual scientists and policy specialists who are active and regular participants in the specialist panels compiling the ‘institutional’ reports. These key knowledge brokers often fail to convince fellow panellists. Even in their work one observes that the dominant undercurrent is less enthusiastic embrace of geoengineering and more promotion of SGE’s acceptance as inevitable necessity and ‘realistic’. In another context, this has been called ‘conditional acceptance’: it is reluctant, context-dependent, and subject to conditions (Bickerstaff et al, 2008).

Secondly, there are, understandably, fears about moving the climate policy focus away from emissions reduction, or even suggesting that mitigation is unlikely to work, although that is indeed what has prompted geoengineering’s revival as an idea. The anxiety in this regard is palpable and the fear that geoengineering will divert attention from cutting emissions is commonly labelled as a ‘moral hazard’. I examine this in more detail in the next Chapter. For now it is sufficient to note most of the ‘institutional’ reports conclude with a primary recommendation prefacing their conclusions, of which the Royal Society report’s ‘Recommendation 1’ is typical:

“Parties to the UNFCCC should make increased efforts towards mitigating and adapting to climate change and, in particular to agreeing to global emissions reductions of at least 50% of 1990 levels by 2050 and more thereafter” (2009:57. See also NRC 2015a:3).

Thirdly, a notion of ‘climate emergency’ permeates all the ‘institutional’ reports and is used to convey a general sense of urgency (or emergency) regarding climate change. It is used in the sense in which the statements of Al Gore and Jim Hansen, cited above, utilise the term. I analyse ‘emergency’ in more detail in the next Chapter. For now it is sufficient to note that in some of the reports ‘emergency’ is additionally used to convey the idea of a specific emergency or ‘trigger’ or ‘tipping’ event. This distinction should be borne in mind when reading what follows.

Rationales
Since geoengineering’s re-emergence in 2006 one finds three basic rationales given for SGE. These are: climate emergency, climate risk reduction, and alternate climate Plan A (alternate
to emissions reduction that is). It should be noted that in ‘official’ studies the rationales are rarely fleshed out, are often used in combination, and occasionally unstated or only implicit. Table 4-1 provides a summary outline of the three rationales.

The ‘climate emergency’ rationale sees solar geoengineering, as a tool to be used in the case of a specific climate emergency, to hold off or reverse ‘tipping’ into rapid warming and/or imminent climate catastrophe. The Royal Society report predominantly takes this approach: SGE “may provide a potentially useful short-term backup to mitigation in case rapid reductions in global temperature are needed” (2009:59). The logic here is that the technology should be researched and developed and then kept in the toolbox for use if it is, regrettably, needed. The 2009 Novim report, entitled ‘Climate Engineering Responses to Climate Emergencies’, and produced by an eminent panel of policy experts and scientists, even includes “emergency” in the report title (Blackstock et al.). As we shall see in the following chapter, this rationale struggles to withstand critical interrogation – what constitutes an emergency? Who proclaims it? Has it already started? Can a climate emergency be predicted? … and so on. Nevertheless, climate emergency remains a common rationale, especially in presentation of the subject by and to non-specialists, and in the popular imagination. It is also the rationale used by the Arctic Methane Emergency Group (AMEG), a grouping comprised mainly of concerned polar scientists. They argue that ‘the tipping point for the Arctic sea ice has already passed’ and that this is ‘a catastrophic threat for civilisation’ (2014:n.p.). AMEG accuses the IPCC, in its Fifth Assessment Report, of vastly underestimating the rising concentrations of methane, and argues that ‘[i]mmEDIATE action must be taken to refreeze the Arctic to halt runaway melting’. In short they favour solar geoengineering now. AMEG’s 2012 strategic plan is encapsulated in Figure 4-1. 59 In his pivotal paper lifting the geoengineering taboo Crutzen also relied on the emergency rationale: ‘to combat potentially drastic climate heating’ (2006:216). But it is less commonly used in the more recent ‘institutional’ literature.

A second rationale focuses on geoengineering as a form of climate risk reduction, to shave the peaks off the warming effect, thereby both supplementing and allowing time for mitigation through emissions reduction and adaptation. The approach of the NRC study tends towards the risk argument. It does not adopt a detailed rationale but recognises that mitigation has been limited to date and that ‘… it may be prudent to examine additional options for limiting

59 AMEG’s website reveals the mood of despair amongst leading Arctic scientists, and presents an almost entirely science-based understanding of what the climate problem is, what a climate campaign might look like, and what climate policy should or might be. Undoubtedly heartfelt, the AMEG approach is socially and politically naïve, in the way it imagines a science-led climate policy.
the risks from climate change... [as part of] a broader portfolio of responses' (2015a:2, my emphasis). The GAO report (2011) argues along similar lines. So too does the IPCC. In 2010 it expressed the need for an expert group to investigate ‘... possible geoengineering options to complement climate change mitigation efforts’ (see IPCC 2012:10, my emphasis). The logic of the risk reduction rationale is to research and develop the technology and, if sufficiently safe, use it now to reduce warming, and do so as part of a cocktail of actions including emissions reduction. This was the approach suggested by leading climate scientist Tom Wigley in his 2006 intervention in the NASA-Ames symposium discussed above. In another publication that same year, entitled ‘A Combined Mitigation/Geoengineering Approach to Climate Stabilization’, Wigley argued that ‘[m]itigation is therefore necessary, but geoengineering could provide additional time to address the economic and technological challenges faced by a mitigation-only approach’ (Wigley 2006:452). Similar arguments are at the heart of David Keith’s *A case for climate engineering* (2013).

**Figure 4-1: AMEG strategic plan**

The third rationale sees geoengineering as an alternative climate plan, attractive because it is cheaper, less economically disruptive and therefore more politically acceptable than the current Plan A (mitigation). In this view solar geoengineering could largely substitute for abatement in the short to medium term since its benefits exceed its costs. The logic is that the

technology should be developed and deployed and if emissions reductions are still needed
then this can be addressed later when new technology will have made this cheaper. The
alternate Plan A rationale is rarely found explicitly in the major ‘institutional’ reports, although
when these emphasise SGE’s cheapness they implicitly adopt this line of thinking. A rare
example in the ‘institutional’ literature can be found in the perspectives of Lowell Wood voiced
at the Tyndall-Cambridge-MIT symposium, presented and discussed above. More commonly
this rationale is voiced by free-market think-tanks and advocacy groups such as in the report of
the American Enterprise Institute (Bickel & Lane 2013) and the related Copenhagen Consensus
Center report on geoengineering which claims to have made “… a strong case that the
potential net benefits of SRM are large” (Bickel & Lane 2009:52); or when conservative US
politician Newt Gingrich, notorious for flip-flopping on climate change, says that
‘geoengineering holds forth the promise of addressing global warming concerns for just a few
billion dollars a year’ (2008).60 The ‘alternative climate plan’ rationale differs from the
previous two rationales identified in that many of its proponents tend to regard claims that
climate change is a serious problem as overstated.

These rationales are often used in combination. For example, the Royal Society report
supplements its central (emergency) argument when, primarily in relation to CDR techniques
rather than SGE, it notes the merits of “… a portfolio approach to climate change, [where]
properly researched geoengineering methods …. could eventually be useful to augment
conventional mitigation activities, even in the absence of an imminent emergency” (Royal
Society 2009:56). Even Bickel & Lane’s more recent work for the American Enterprise Institute,
with its focus on the ‘... political bankruptcy of GHG control policies [and] SRM’s economic
promise’ (2013:20), repositions its support for solar geoengineering as potentially ‘... a highly
useful backup and supplement to current policy options’ (p.iv). The Bipartisan Policy Center
believes that managing risk is the central principle of effective climate policy. It argues that
‘climate remediation’, its preferred term for geoengineering, is appropriate only as a
complementary measure or in the event of an emergency (2011:3). And the IPCC’s Fifth
Assessment Report, Working Group 3, frames geoengineering mainly as a risk issue but
nevertheless manages to retain emergency argumentation when it argues that ‘... [risk]
strategies require preparing for possible extreme climate risks that may implicate the use of
geoengineering technologies as a last resort in response to climate emergencies’ (2014c:114).

60 http://www.factcheck.org/2011/12/gingrich-on-climate-change/
The addition of ‘(limited evidence, low agreement)’ to this statement illustrates the still contested nature of the geoengineering project.

<table>
<thead>
<tr>
<th>Reasoning</th>
<th>Climate emergency</th>
<th>Risk Reduction</th>
<th>Alternative climate plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>May need it to hold off imminent catastrophe or reverse ‘tipping’ into rapid warming.</td>
<td></td>
<td>Take the edge off warming and buy time (to cut emissions, develop new technologies &amp; overcome policy inertia).</td>
<td>Cheaper and more socially, economically and politically acceptable than abatement.</td>
</tr>
</tbody>
</table>

| Implications for abatement                                               | Abatement essential but may not happen in time. | Abatement essential but will be easier later. GE may supplement modest abatement targets. | GE could be a substitute for much abatement. |

| When deployed?                                                          | When necessary and for as long as emergency lasts. | As soon as ready and for as long as needed. | As soon as ready and then indefinitely. |

| In practice                                                              | Support research now to ensure future readiness. | Research then deploy incrementally. | Research then deploy. |

| Typical metaphors                                                        | Insurance policy, parachute | Chemotherapy, planetary medicine | Sunscreen, innovation |

| Attracts                                                                 | Climate catastrophist technophiles. | Climate policy ‘realists’. | Market fundamentalists and climate inactivists. |

| Table 4-1: Typology of arguments in favour of solar geoengineering       |

**Frames and metaphors**
Different rationales are, of course, likely to mobilise different stories, metaphors and frames. Before examining these it is important to remember that geoengineering is, of course, part of a larger discourse about climate change. Three points from that larger discourse are relevant here: “dangerous climate change”, climate understood as primarily a physical entity, and the effort to make climate action and GDP growth compatible, and I will briefly touch on each in turn.

Firstly, one of the key narratives which emerges in international climate policy from the early 2000s is of ‘dangerous climate change’, as something to be avoided, indeed to be fought.
Metaphorically and visually the planet is widely presented as a critically ill patient, with scientists as physicians monitoring and caring for it.

Figure 4-2 captures some examples which capture the metaphorical zeitgeist: cartoon illustrations from *Nature* depicting global warming and the Kyoto protocol. In the first image, from Issue 455 (2008), three scientists are, as Jim Fleming puts it, ‘diagnosing Earth’s CO₂-induced fever... But diagnosis is not cure’ (2014). The scientists are Bert Bolin (meteorologist and chair of the IPCC until 1997), John Houghton (oceanographer, central in the establishment of the IPCC, and at the time deputy director of the Tyndall Centre and leading the Royal

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61 I acknowledge Jim Fleming for drawing this illustration to my attention.
Society investigation into geoengineering) and Luiz Gylvan Meira Filho (climatologist and former co-chair of the science working group of the IPCC). In the second image from Nature (Issue 479, 17 November 2011:291-292), world leaders gather around the bedside of a terminally ill patient, the Kyoto Protocol.

In the scientific literature, important visual representations which reinforce the sense of imminent danger are the ‘burning embers’ image, common since it first appeared in the IPCC’s 3rd Assessment Report in 2001; and the ‘tipping point’ cartography which emerge from around 2004 (Kemp 2005). Shaw and Nerlich show that, whilst there are earlier antecedents, in the 2003-7 period themes and metaphors of ‘dangerous limits’, ‘ticking clocks’, ‘thresholds’ and ‘combating’, ‘attacking’ and ‘fighting’ climate change come to the fore (2015:37). These reinforce geoengineering’s emergency rationale both in general and in particular.

Secondly, and relatedly, ‘...these powerful images ... are predominantly biophysical, with human systems and geographies relatively unexplored or obscured’ (Liverman 2009:287-8). The implication is that “climate ‘emergency”, whilst it may be anthropogenically driven, remains primarily an object of science rather than a socially, temporally and spatially located entity. This is a long-standing approach, and pre-dates the re-emergence of geoengineering into the mainstream. As Hulme has argued, since the late 1980s the dominant framing of climate change has been as a largely physical phenomenon (Hulme 2008; see also Hulme 2009). This sits easily with both geoengineering’s emergency and risk reduction rationales. And, as we shall see below, this is manifest in the ways in which geoengineering is visually represented.

Thirdly, Shaw and Nerlich also identify a shift in the ‘official’ climate narrative between 2005 and 2007 which ‘... reframed the climate mitigation discourse in line with the demands of GDP growth’ (2015:35). The idea, of course, was to find ways of making the emissions reduction idea compatible with neo-liberal market discourse with its emphasis on economic growth. In particular this would lead to the rise of ideas of ‘green growth’ (IISD 2005) and the desirability (and presumed possibility) of ‘de-linking’ growth and emissions. These ideas build, of course, on earlier narratives including the environment-growth fusion implicit in the ‘sustainable development’ concept, as well as the Kyoto protocol’s emphasis on carbon markets. The idea that ‘stemming the rise in emissions need not cost the Earth’, was a central trope of the 2007 IPCC Fourth Assessment Reports. These ideational turns sit most comfortably with both geoengineering’s ‘risk reduction’ and its ‘alternative climate plan’ rationales.

It is in this context of how climate is understood, that geoengineering re-emerges into climate policy consideration. How does the ‘institutional’ literature frame geoengineering and what metaphors are used? I use ‘framing’ relying on Entman’s classic formulation, that it...
‘essentially involves selection and salience’. To frame ‘... is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described’ (1993:xx). I understand ‘metaphor’ to be a rhetorical device which presents, and thereby enables one to understand or see one thing as another, or in terms of another. Metaphors ‘provide us with visions of the world and instruments to change it’ (Nerlich and Jaspal. 2012:133). They help frame how we see and imagine things and how we might act.

Frames and metaphors can, of course, have powerful effects, particularly in the case of a technology which is not yet operational, and where its emerging form is contested. Fortunately, there is now a substantial literature examining metaphors and framing in relation to geoengineering, and solar geoengineering in particular (for example Cairns & Stirling 2014; Corner & Pidgeon 2015; Macnaghten and Szerszynski 2013; Nerlich & Jaspal 2012; Shaw & Nerlich 2015; Markusson et al. 2013; Markusson 2013; Porter & Hulme 2013; Sikka 2012; Huttunen & Hilden 2014). I will draw a limited number of points from this extensive literature, and from the ‘institutional’ literature, which are salient for my overall argument.

All the ‘institutional’ literature stresses the dangerous climate situation and the risks this poses. In the foreword to The Royal Society report by its President, Lord Rees, we are warned that if reductions ‘achieve too little, too late’ then a ‘Plan B’ may be needed; although we need to be aware that no geoengineering option offers ‘a silver bullet’ (2009:v). The technology assessment conducted by the US GAO speaks of ‘an insurance policy’ against ‘worst case climate scenarios’ (2011:iii). Similarly, the Bipartisan Policy Center makes use of the language of risk and of ‘tipping points’ (2011:3-4). It’s insistence on calling geoengineering ‘climate remediation’ is itself suggestive of a vision which sees the climate as damaged but fixable, and able to be returned through geoengineering to something approximating its former state.

But, these examples apart, the ‘institutional’ literature, with few exceptions, does not utilise metaphors extensively. To get a deeper insight we need to draw on the metaphors used by leading scientists central to the development and drafting of these reports. Crutzen, in his 2006 article, argued the need for “an escape route” (2006:216). ‘If my plane is going down in flames’, says Ken Caldeira, ‘I sure hope I have a parachute handy’ (Caldeira cited in David 2007:32). Medical metaphors and emergency framings are especially commonplace. ‘If you have a heroin addict’, argued Stephen Schneider, ‘the correct treatment is hospitalisation, therapy and a long rehab. But if they absolutely refuse, methadone is better than heroin’ (quoted in Chandler 2007:43). It is ‘like chemotherapy’, David Keith is reported as saying. ‘No
one wants to have it . . . but we all want the ability to do chemotherapy and know its risks should we find ourselves with cancer’ (cited in Howell 2010). The President of the Royal Society, writing in support of a geoengineering feasibility study (the SPICE project), argued that ‘[g]eoengineering research can be considered analogous to pharmaceutical research’ (Nurse. 2011). James Lovelock refers to geoengineering as ‘planetary medicine’ (2008, 2009). A persistent metaphor is of solar geoengineering as a ‘sunscreen’ or ‘sunshade’ (Teller 1997; Chandler 2007). Caldeira again: ‘If we become addicted to a planetary sunshade, we could experience a painful withdrawal if our fix was suddenly cut off’ (cited in David 2007:32).

Less commonly, machine metaphors are found such as conceiving of geoengineering as an ‘emergency brake’ (Brovkin et al. 2009), or referring, in this instance negatively, to ‘retooling the planet’ (Bronson et al. 2009). The NRC report asks the reader to imagine the Earth as a machine, specifically a thermostat.

‘The climate system can be compared to a heating system with two knobs, either of which can be used to set the global mean temperature. The first knob is the concentration of greenhouse gases ... The other knob is the reflectance of the planet, which controls the amount of sunlight that the Earth absorbs.... [T]hese two knobs do more than affect global mean temperature. In differing ways, they also influence regional temperatures, the global hydrological cycle, land plants, and other components of the Earth system. So, turning up one knob and turning down the other might be able to restore Earth’s global mean temperature, but could nevertheless produce substantial changes to Earth’s environment’ (2015a:27-28).

Nerlich and Jaspal (2012), in their examination of the use of argument and metaphor related to geoengineering in the period up to 2010, try to understand the ways in which geoengineering has been ‘linguistically engineered’ (2012:132). They find frequent reliance on master metaphors of the Planet as Patient, as Body and as Machine.

‘... the patient is conceptualised as being ill because of over-indulgence in or over-consumption of, even addiction to, carbon. The implication of such a metaphor is a moral obligation to help this “patient” and end its suffering’ (2012:141).

They conclude that their study:

‘revealed one master argument (The earth is seriously/catastrophically/broken/ill and can only be fixed/healed by geoengineering) which was linked to three conceptual master metaphors: “THE PLANET IS A BODY,” “THE PLANET IS A MACHINE,” “THE PLANET IS A PATIENT.” The Persuasive force of this discourse emerges from a fusion of the master-argument with the master-metaphors. It exploits what Beck (1992, p. 24) called “the political potential of catastrophes”’ (2012:141).

Nerlich and Jaspal find that ‘the overall framing of geoengineering is positive’ (2012:141). I think that is slightly too strong a conclusion. Using the evidence they present I would argue
that the overall framing of geoengineering is that ‘it is unfortunately necessary’. They themselves note that there is often metaphorical ambiguity: a tendency to ‘... supplement the argument from catastrophe with metaphors and analogies of healing and medicine’ (2012:143).

Importantly, they note that there is a minority negative framing of geoengineering, an indication that SGE is highly contested. This sometimes draws on the same master metaphors – ‘a band-aid to buy time’, ‘not a silver bullet’, ‘not a single global thermostat’ – but also uses phrases like ‘playing god’, ‘geopiracy’ or ‘techno-fix’ (2012:141-2). Interviewed in 2007, Meinrat Andreae, an atmospheric scientist at the Max Planck Institute for Chemistry viewed geoengineering as way to feed our addiction to fossil fuels: “[i]t’s like a junkie figuring out new ways of stealing from his children” (cited in Morton 2007).

In June 2006, Gavin Schmidt, a climate modeler at NASA, wrote a skeptical blog post in anticipation of the publication of Crutzen’s taboo-breaking paper in Climatic Change. He had heard about the forthcoming paper, and knew that, ‘unusually’, it would be accompanied by “… a suite of commentary articles by other scientists”.62 The analogy he uses is worth citing at some length, as it captures much of the negative attitude towards geoengineering then (and still?) prevailing among many climate scientists:

‘Think of the climate as a small boat on a rather choppy ocean. Under normal circumstances the boat will rock to and fro, and there is a finite risk that the boat could be overturned by a rogue wave. But now one of the passengers has decided to stand up and is deliberately rocking the boat ever more violently. Someone suggests that this is likely to increase the chances of the boat capsizing. Another passenger then proposes that with his knowledge of chaotic dynamics he can counterbalance the first passenger and indeed, counter the natural rocking caused by the waves. But to do so he needs a huge array of sensors and enormous computational resources to be ready to react efficiently but still wouldn’t be able to guarantee absolute stability, and indeed, since the system is untested it might make things worse.

So is the answer to a known and increasing human influence on climate an ever more elaborate system to control the climate? Or should the person rocking the boat just sit down?’ (2006:n.p.)

Representing
Visual representations of geoengineering in the ‘institutional’ literature are remarkably uniform across the reports. Figure 4-3a/b gives a typical sample of images used to represent geo-engineering.

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62 This provides further evidence, if any is still needed, that Crutzen’s 2006 article was clearly a political and policy intervention, in the shape of a scientific intervention.
Figure 4-3a: Representations of geoengineering: BPC (above) & IPCC (below) reports.
Figure 4-3b: Representations of geoengineering: Royal Society & German Federal Ministry. *

* Royal Society report (above) as seen by New Scientist. German Federal Ministry of Education and Research report (below).
All of these images present an un-peopled world, and the engineering of the climate is portrayed as a technical, physical endeavour with a range of interventions possible. The Bipartisan Policy Center (2011) figure reproduces an image widely found in the preceding years and since. It was used previously, for example, to illustrate an article by Keith published in Nature (2001), and in a 2008 press release from the Lawrence Livermore National Laboratory. The IPCC figure was used to illustrate the Fifth Assessment Report’s discussion of geoengineering (2013a:632). Even the more sceptical German Federal Ministry of Education and Research report uses a comparable visualisation (Rickels 2011:7). So too does an article in *New Scientist* magazine, headed ‘Geoengineering weighed up’, illustrating its reporting of the release of the Royal Society report: although this also aims to depict findings regarding the costs, effectiveness and readiness of the technologies (Brahic 2009:10). In all the images geoengineering is primarily about particular categories of technological intervention, and these are conceived as technoscientific objects (see also Schrickel 2014).

Figure 4-4 is a sample of ‘institutional’ images more specifically focussed on SGE. Here the emphasis is typically physics-focussed. Solar radiation management is visualised as little more than options for intervention in the radiation balance of the Earth, changing the formula regarding how much radiation comes in and goes out. An engineering focus is evident when it comes to depicting sulphate delivery techniques. Figure 4-5 presents some typical envisionings, in the ‘policy-influential’ literature, of how aerosols might be injected into the stratosphere. Guns, towers, balloons and aircraft are included. Today, most aspirant solar geoengineers favour the last of these, and imagine a small fleet of airplanes being used to spray aerosol into the stratosphere. Guns, towers and, to a lesser extent, balloons, seem to have fallen out of favour.

All these representations reinforce the notion of climate change as primarily a physical object, with the corollary that SGE is primarily a scientific concern and an engineering praxis. Absent from these images is the suggestion of any negative (or even positive) effects on actual people. Indeed there are no people in these images at all, and no social systems are represented or imagined. Absent too is anything comparable to the ‘heroic’ scientist of the Mastery phase depicted in Chapter 2 (Figure 2-3). Indeed the viewer watches from afar or hovers, unseen but all-seeing, over the world.

Like Gods?
Figure 4-4: Visualisations of SGE in ‘institutional’ reports *

An inability to normalise
Since the mid-2000s geoengineering has moved into mainstream climate policy consideration. But it has not yet been officially embraced. In particular, SGE as a proposition has struggled to become normalised and to be stabilised as a part of the climate policy landscape. It remains contested and on the margins of respectability. Symptomatic of this, as I have discussed in the Introduction, is the inability even to settle on an agreed name for SGE.

Finnemore & Sikkink (1998) have described and theorised the emergence of norms, and their ratification in international treaties. The first of the three stages they identify, ‘norm emergence’, envisages persuasion by ‘norm entrepreneurs’ as central. Using this typology, SGE has clearly emerged in that it is under active consideration and is no longer ‘taboo’. But it has not reached a ‘tipping point’, as they describe it, leading to stage two, where it disperses and ‘cascades’ outwards as a norm. Indeed, those pushing for SGE have faced significant pushback. SGE is some distance, therefore, from becoming ‘internalized’ and essentially taken for granted or regarded as self-evident (stage three). By contrast, using Finnemore & Sikkink’s

* Clockwise starting top right: Royal Society (2009:23); NRC (2015a:30); German Environment Agency (Umweltbundesamp) (2011:11); and Bipartisan Policy Center (2011:25).
schema, climate mitigation through emissions reduction could be regarded as a widely-
dispersed norm, and substantially, if not yet universally, taken-for-granted.

As Finnemore & Sikkink point out, ‘[m]any emergent norms fail to reach a tipping point’
(1998:895). SGE has manifestly not yet crossed the norm tipping point. Certainly,
geoengineering has its enthusiasts and proponents, its ‘norm entrepreneurs’: the knowledge-
brokers described in the Introductory Chapter, or the ‘geo-clique’ as they have been labelled
elsewhere. But they are not, currently, persuading a sufficiently large or important enough
constituency for norm ‘cascading’ to have occurred.

In some respects, the inability to normalise SGE to date is surprising. After all, it has re-
emerged out of the existing domains of expertise on climate change. It is compatible with
some of the dominant narratives and framings of climate change since the mid-2000s
described earlier: of impending climate catastrophe or crisis requiring ‘action’, of climate being
understood primarily as a physical phenomenon (notwithstanding the anthropogenic
attribution), and of the compatibility of the economic growth and the climate action agendas.
And it seems to address real concerns that the main policy response, mitigation, is not

Figure 4-5: Representations of the delivery of stratospheric aerosols *

delivering declines in GHG concentrations, or even the stabilisation of these. It has some powerful and influential proponents. It is part of the considerations of the IPCC.

Significantly, there is disagreement about SGE among the climate scientists themselves. This can be seen, for example, in the comprehensive NRC study which decided to treat ‘albedo enhancement’ as distinct from other forms of geoengineering (even isolating it into a separate report) and which recommended that solar geoengineering ‘should not be deployed at this time’ (2015a:7). The report’s summary ‘… reiterates that it is opposed to climate-altering deployment of albedo modification techniques...’ (p.11). It recommends further research, but this is hedged by the need for this to be ‘multiple benefit research’ which enhances climate science generally (p.9), rather than specifically focussed on solar geoengineering. It also argues that any research governance should ensure ‘civil society involvement’ (p.10); and that what is researched should be the subject of ‘a serious deliberative process’ (p.10). On one reading this is simply institutional language in which compromise wording is used to displace controversy, and where disagreements are smoothed over and postponed in the call for further research. But it can also be interpreted as coming remarkably close to a position of saying there should be no further SGE research. As one of the NRC panel members, climate scientists Raymond Pierrehumbert, has noted:

‘Can a serious deliberative process about climate change materially involve a Congress that cannot even muster a Senate majority to agree that humans can and are changing the climate?’ (Pierrehumbert 2015).

How can the failure of SGE to become normalised be explained? This is, of course, one of my thesis questions. I take a first step at answering this by identifying five major reasons, in no particular order, some of which will be explored further in the following chapter.

Firstly, SGE has not been embraced by climate scientists themselves. Whilst there are no published studies to confirm this, my own observations and discussions with others who are knowledgeable, suggest that only a small minority of climate scientists favour SGE, and that this remains a minority even if one adds those who express a favourable attitude to SGE subject to their scientific and governance concerns about it being satisfactorily addressed.

Many scientists cite concerns about the proposed technology’s efficacy and conclude that solar geoengineering is not a wise course of action – that the technology’s unreliability is a major cause for concern (Robock 2008). Others voice concern about what SGE would lock us into and the governance implications: ‘it is not possible to use albedo modification to counteract peak CO₂-induced warming without maintaining the climate intervention without interruption for millennia’ (Pierrehumbert 2015). Alan Robock, a leading climate scientists and
volcano expert, has listed ‘20 reasons why geoengineering is a bad idea’ (2008) and more recently has come up with 5 benefits and 26 risks (2014c:n.p.). His reasons are largely practical and range from SGE’s workability to its (non-)reversibility, from unknown impacts to the ‘degradation of terrestrial optical astronomy’. But Robock’s list of objections also includes ‘Moral authority: Do we have the right to do this?’ (2014c:n.p.). The charge of ‘hubris’ implicit in this objection is frequently made. It looms large in Hamilton’s (2013a) largely oppositional position to geoengineering, and also underpins Hulme’s study where he argues forcefully that solar geoengineering is ‘undesirable, ungovernable and unreliable’ (2014). And it underscores the position of the NGO Hands Off Mother Earth (HOME) which has labelled geoengineering ‘geopiracy’.

This takes us to a second reason for SGE’s failure to be normalised. Values-contestation is at the heart of contestation of SGE but in presenting SGE as a mundane technology, a technoscientific object, such considerations are either ignored (as outside the brief) or displaced (acknowledged and put aside). The Royal Society report acknowledges hubris, but in its brief consideration of ethics, it categorises such concerns as part of ‘virtue ethics’, and seemingly prefers to focus on other philosophical traditions ‘... where a consequentialist case in favour can be made’ (2009:39). The GAO report notes that ‘a small number of the experts we consulted’ viewed climate engineering as ‘technological hubris’ and, here the tone of the report appears shocked, some even ‘opposed starting significant research’ (2011:53). Whilst some proponents reject or sidestep the charge of hubris (see for example Keith, Parson and Granger 2010:426), others share such anxieties (see for example Schneider 2001).

The rationales for embarking on solar geoengineering outlined earlier, rest on contested values and assumptions: assumptions about ‘emergency’ and risk, economy and development, ‘nature’ and society, and about what ethical/values questions are most important, and for whose benefit and at whose behest might SGE be deployed. These questions are the focus of the next chapter. For now it is sufficient to note that the internal instability of the arguments for SGE, the presence of competing epistemologies and ontologies, and differing conceptions of how the world ought to be, all make it harder for SGE to be normalised.

Thirdly, for an idea to be normalised it needs to be presented as something desirable. As I have shown at length above, the idea of geoengineering is difficult to frame in this way, at least when presented in isolation from other positive visions of the future. Solar geoengineering is generally presented as ‘sadly inevitable’, as a pessimistic technology. In later Chapters I will explore some exceptions, which try to portray SGE as essential to tackle
climate change whilst enabling ‘development’ to continue. But such arguments have, to date, been rare and the overall tenor is pessimistic.

Fourthly, for geoengineering to become normalised means diluting (at the very least) one of the key existing norms of climate policy: the need to mitigate by cutting emissions. The ‘alternative climate plan’ rationale outlined above, explicitly presents SGE as a possible alternative to the focus on emissions reduction. But the other two rationales also imply some dilution of mitigation, by adding a new tool to climate strategy, thereby making mitigation one of a number of policy actions. The repeated assertions of ‘Recommendation 1’ in the “official” assessments – that nothing said in the ‘institutional’ reports should be interpreted to undermine mitigation, and that SGE, if deployed, should be seen as a supplement to mitigation – is an attempt to allay precisely such concerns. But the assertion itself does not make it ‘true’. Indeed, the heatedness of debates around whether geoengineering would discourage (or enhance) mitigation, can be seen as recognition that solar geoengineering, whether intended or not, brings mitigation’s centrality into question. A great deal is at stake in seemingly arcane discussions of ‘moral hazard’.

According to Finnemore and Sikkink, the dominant mechanisms through which norms ‘cascade’ are socialization, institutionalization and demonstration. Being officially regarded as a third leg of climate policy would go a long way towards the institutionalisation and socialisation of SGE. But this recognition is still being withheld by the key institutions, such as the IPCC.63

63 An intriguing micro-insight into geoengineering’s failure, to date, to achieve ‘3rd leg of climate policy status’ can be found when looking at the finalisation of the relevant sections of the IPCC’s Fifth Assessment Report. The IPCC process is that comments on the draft report are called for. The multitude of comments are collated onto vast spreadsheets and must then be acted upon by the lead authors and their teams. Some comments are rejected and ignored, others are accepted in whole or part, resulting in amendments before the report is finalised. Here is one comment on a graphic in the draft report:

“The graphic has the effect of suggesting that geoengineering IS a climate change response strategy on par with mitigation and adaptation. It is fundamentally flawed and unethical to treat adaptation on par with geoengineering vis-a-vis mitigation and in the overall policy landscape -- i.e., to play down real, on-the-ground adaptation strategies. Adaptation is the only option for many developing and least-developed countries, and geoengineering has a highly debatable role in the overall climate policy anywhere. Though one point of the graphic seems to be that geoengineering would compete with R&D and investment resources, the "competition" aspect is not apparent in the graphic, as is -- it appears as if the point of the graphic (and the accompanying text) is to elevate geoengineering to the level of mitigation and adaptation -- which would be a radical and controversial position for the IPCC to take.”
(IPCC 2013e)

I have been unable to obtain the deleted Figure, but I understand it to have been something like Figure 6-3 in this thesis. The spreadsheet notes the response of the lead authors: ‘Taken into account--figure and text deleted’ (IPCC 2013e). Strong oppositional stances towards SGE, intersect here with
Finally, solar geoengineering as technology lacks a clear demonstration path. It is still a technology operating in the space between imagination and demonstration. It is more than a speculative technology, in that time, money, research and limited trials are involved too. But it does not yet exist as an operating, deployable technology. It can be imagined but it is not easily assessed, and assessment to date relies heavily on modelling. This requires a high level of confidence in climate models which themselves are prisoners of their own assumptions, as I shall explore in the next Chapter. Indeed, arguably, SGE can only be assessed through practical experiment, using trial and error methods and making adjustments along the way. In the absence of field experiments (which key proponents are urging), Finnemore and Sikkink’s demonstration mechanism is effectively unavailable.

All these reasons have contributed to the inability of SGE to become normalised and an inability to push dissenting voices to one side.

* * * *

To conclude: geoengineering has now entered the climate policy mainstream, but it has not yet been generally embraced or normalised. It faces substantial resistance. But even amongst its proponents SGE is advocated for a range of different reasons, framed in a variety of ways, and the climate changes which it is intended to respond to are variously understood. A range of value differences and assumptions about what it is and is not acceptable for humans and scientists to do, appears to underpin the differences between proponents and opponents of SGE, and even between different proponents of SGE. Conflicts over geoengineering will not evaporate if only more research could be done, and ‘knowledge gaps’ filled. Clearly bigger issues are at play than disputes about the efficacy of the proposed technology itself. In the next Chapter I will delve more deeply into the most contested components of the idea of solar geoengineering.

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consensus-seeking administrative and drafting practices. The lead authors can be assumed to be either sympathetic to the comments, or lacking the confidence or authority to declare a new consensus of this sort. The result being that geoengineering was, thereby, not elevated to being recognised as a third leg of climate policy.
‘It is not possible to quantify or even identify other environmental, social, political, legal, and economic risks at this time, given the current state of knowledge about this complex system’.  
(NRC 2015a:6-7)

‘This is an emergency and for emergency situations we need emergency action’
(Ban Ki-Moon, UN Secretary-General, November 2007)

‘Which is the more environmentally sensitive thing to do: let the Greenland ice sheet collapse and polar bears become extinct, or throw a little sulfate in the stratosphere?’
(Ken Caldeira, climate scientist and geoengineering proponent, October 2007)

In the previous Chapter we saw that there are different understandings of solar geoengineering’s purpose, that its naming remains unsettled, and its desirability as intervention is deeply contested. Despite its re-emergence into mainstream policy consideration, SGE has not been stabilised as an object of analysis, or widely embraced as a desirable technology, or normalised as an acceptable addition to existing climate policies. In its shift from Taboo to Possibility, the question of why it had been taboo was largely glossed over. This can be seen in Crutzen’s 2006 article, where the taboo was acknowledged but not reflected upon. Whether to geoengineer was quickly supplanted by more narrowly functional and facilitative questions, such as ‘what are the particular reasons’ and rationales for why geoengineering may be needed? Crutzen’s primary answer was ‘in case of climate emergency’, although, as we have seen, other answers were also offered.

‘Whether to geoengineer?’, a quintessentially values-based and political question, soon came to be understood as primarily dependent on more research into ‘how’ questions (what particles, delivered where and how, in what quantities, and so on), expected impact questions (on precipitation, temperature, food production and, very occasionally, the natural world), and ‘how much’ questions (typically the direct costs of transporting sulphur dioxide aerosols into the stratosphere on an ongoing basis). In moving away from ‘whether’ questions geoengineering quickly came to be presented largely in technical terms, drawing on recognised scientific expertise (see for example Royal Society 2009; Launder and Thompson eds. 2010). But this de-politicisation has struggled to take hold.

Indeed, the ‘institutional’ literature cannot avoid acknowledging that other ‘not-strictly-technical’ questions remain, and it engages with these in a limited fashion (NRC 2015a:ch.4;
Royal Society 2009:ch.4). Governance issues are repeatedly cited: who would decide to deploy geoengineering? Whose hand would be on the thermostat deciding the temperature/precipitation setting? Under what governance arrangements should research be pursued?, and so on. Relatedly, the implications for international relations and the possibility of provoking inter-state conflict are widely acknowledged. So too is the importance of ethical questions. When one embraces SGE what values are being endorsed, what ordering of the world is being sustained? How questions such as these are engaged with shines a light on how SGE is understood and this, in turn, affects whether SGE is normalised as an idea and legitimised as an intervention.

In this chapter I take a deeper dive into SGE today. I aim to explore what travels with the idea of SGE as it re-emerges. I want to understand what shapes the sociotechnical imaginary of SGE. I want to unpack how the ‘is’ (what the world is held to be and how this is known) and the ‘ought’ (what world is imagined as desirable) combine to co-produce this emergent technology. As I outline in my Introductory Chapter, values, or ‘visions of desirable futures’, are central in the emergence of new technologies. The resultant imaginaries are both prior to and concurrent with knowledge about SGE. They are heavily shaped by the epistemological assumptions and practices they conscript and the disciplinary lens through which they look. Imaginaries are also entwined with power. Not only do imaginaries have power effects but they are understood and evolve in relation to the existing global ordering, and are championed (or not) by powerful institutions, individuals, and regimes. In this Chapter I examine the ways in which power, knowledge/s and values accompany, shape, enable and constrain SGE’s re-emergence. At the risk of putting a complex relationship in overly simplified terms, knowledge, values and their accompanying discourses have power effects, and power shapes both what is valued and the structures of knowing.

I do this by exploring some telling examples, drawn mainly from the ‘institutional’ and ‘policy-influential’ literature, whilst also engaging with key arguments emerging from the academic literature. In considering Knowledge/s I note the elevation of scientific and engineering expertise in considerations of geoengineering and the implications of this for engagement with other disciplines and with more-than-science concerns. I examine too, the way in which uncertainty about what is unknown is dealt with and managed. I also explore the reliance on the calculative and utilitarian logic of cost-benefit analysis when the economics of SGE is considered. This provides a neat bridge to my consideration of Power, since the cost-benefit approach largely assumes the continuation of the existing economic order, or at least SGE’s compatibility with it. I go on to look at the ways in which the notions of ‘emergency’ and risk
are mobilised, and some of the implications of SGE for capitalism and the dominant order of imperial ‘market globalism’ (Steger 2009) and its associated geo-politics. Finally, in delving into Values I examine the ways in which the many and profound ethical questions which geoengineering raises are acknowledged but also narrowed and marginalised.

The ways in which all the above are engaged with in the institutional literature largely works to enhance the respectability of SGE as an imagined climate intervention, and thereby legitimise its further development and potential deployment. This effect may occur even when a standpoint critical of SGE’s speedy progression is adopted. I show how some aspects of the predominant approaches can be seen to be unpersuasive and occasionally even incoherent or paradoxical. The argumentation used nevertheless needs to be clearly understood since it may provide a basis for normalising SGE as part of a coherent and positive view of a future geoengineered world.

Knowledge/s
In this section I will look at three instances of how knowledge about SGE is developed. I first look at the elevation of technoscientific knowledge and paradigms in the analysis of SGE. I then look at the ways in which the many uncertainties about SGE and its possible impacts are handled, before examining the reliance on narrowly utilitarian approaches when engaging with the economics of SGE.

Epistemic hierarchies and the elevation of the techno-scientific
It is immediately apparent, on reading any of the ‘institutional’ studies on geoengineering, that some forms of expertise are assumed to be primary, whilst others are secondary. The reports all privilege particular forms of scientific knowledge and expertise: involving disciplines such as chemistry, atmospheric climate science, physics, vulcanology and similar. Climate modelling plays a particularly significant role. Only slightly down the hierarchy are engineering and economics and law. Further down still are the various social sciences and cognate disciplines (such as ethics). Finally, non-specialist expertise is occasionally acknowledged, often in the form of public opinion or focus group and perception studies. This privileging takes place despite the widespread acknowledgement, in almost every ‘official’ report, and by even the most technically focussed researchers, of the significance of the ethical, the geo-political and the social in any consideration of geoengineering.

At the most obvious level one can point to the leading role taken by scientists in almost all ‘institutional’ reports on and assessments of SGE. The working group responsible for the first major ‘official’ report, by the Royal Society (2009), only three years after Crutzen’s intervention, included an international lawyer, and two science and technology specialists in
its otherwise science-heavy twelve-person team. The 2011 IPCC Expert Meeting on Geoengineering was likewise overwhelmingly a meeting of physical scientists, with a handful of governance specialists included (IPCC 2012:iii, 97-8). The NRC report was similarly led by physical scientists, but was slightly more inclusive. Among the non-scientists on both the committee and the review panel, were experts with overtly sceptical, critical, and historical perspectives on climate engineering (2015a:v). A science-heavy focus can similarly be found in other reports, occasionally with a gesture to other disciplinary fields (see for example BPC 2011; GAO 2010 and 2011; NASA 2007).

The inclusion of non-scientists, combined with the ethical disquiet regarding geoengineering felt by some of the participating scientists, has meant that the social is not ignored. For example, whilst the focus and ‘feel’ of the Royal Society report is physical-science heavy, attention is drawn to the need to take account of both ‘the technical and political reversibility of each [geoengineering] proposal’ (2009:7, my emphasis). Further, amongst its conclusions is the following acknowledgement:

‘The greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance, rather than scientific and technical issues’ (2009:xii).

The point being made is that there are more than scientific issues involved in geoengineering. But the parallel implication is that there is ‘governance’ on the one hand, and ‘scientific and technical issues’ on the other, and that only the former has ethical/social/legal/political issues, whilst the latter, by implication, is values and politics-free. Similar formulations can be found in the IPCC expert meeting, with its focus on how various geoengineering technologies might be better evaluated; and in the IPCC 5th Assessment Reports (2013a; 2014a; 2014b). Indeed, the importance of integrated assessments is widely acknowledged as these are held to be the way of taking the social into account.

The NRC report concludes that ‘understanding of the ethical, political and environmental consequences of an albedo modification action [their preferred term for solar geoengineering] is relatively less advanced than the technical capacity to execute it’ (2015a:ix). The NRC states

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64 The general point is being made here, even whilst the categorisations of specific individuals with various combinations of science, engineering and policy expertise, may be disputed.

65 The exceptions can be found in reports which emanate from policy advocacy organisations which I have not included in the ambit of ‘institutional’ assessments: such as the enthusiastic reports sponsored by the ideologically free-market American Enterprise Institute (2013), where the lead author has a policy background, as well as the related Copenhagen Consensus Center report on geoengineering (Bickel & Lane 2009), and the oppositional reports compiled by The ETC Group, an NGO (2009; 2010a).
in the summary of its report that it intends “to provide a thoughtful, clear scientific foundation that informs ethical, legal, and political discussions surrounding these potentially controversial topics” (2015a:1). In short, the extra-scientific is acknowledged but it is ‘extra’, and the scientific is regarded as foundational and, implicitly, value-neutral.

This privileging of the scientific/technical is further evidenced in the ubiquitous distinction which is made in the ‘institutional’ reports between Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) geoengineering techniques. I discuss elsewhere why this is a far from obvious way of differentiating geoengineering technologies. But the significance, for now, is that the SRM/CDR binary frames the issue in a largely physical and mechanistic manner – the climate as like a ‘heating system with two knobs’ (NRC 2015a:27) where adjusting one is SRM and the other is CDR – and the views of scientists and engineers are assumed to be primary. To this binary is added the practice whereby factors such as cost, effectiveness, and risks of deployment are regarded as central to any comparative assessment or evaluation, and each is assigned numerical values to make them commensurable with the physical sciences and allow their integration into climate models. As Szerszynski and Gallaraga have pointed out: ‘… certain disciplines are given the task of problem definition and others – typically the social sciences – are allocated the task of filling in gaps within that given frame’ (2013:2817. See also Heyward & Rayner 2013).

Three related effects flow from this hierarchy, and each acts to normalise SGE. Firstly, the presentation of geoengineering options emphasises their technical efficacy (will it temper global warming?) and their cost. This makes SGE appear to be the ‘best’ option, as indeed it is if these are the prime criteria. Figure 5-1, taken from the Royal Society report is the most obvious example of this move (2009:49). This presents various geoengineering alternatives, complete with error bars suggesting scientifically credible findings and certainty about the level of uncertainty. Only SGE (which the report labels ‘stratospheric aerosols’) makes it into the quadrant where techniques are considered both effective and affordable. Some ‘social’ considerations can be said to be included indirectly in the sub-criterion ‘Safety’: the report notes that it is “… coloured amber, because of uncertainties over its side-effects” (2009:49).

The NRC report likewise does a largely technical assessment comparing the stratospheric aerosol technique (SGE) with the technique of marine cloud brightening. A judgement is made giving one of three possible answers to a series of questions, and with each judgement

66 In the text of the report it is noted that, to avoid confusing the diagram, ‘the error bars are not really as large as they should be’ (2009:49). And it is implied that “more research” would reduce the error range: ‘when more and better information becomes available’ (Royal Society 2009:49).
allocated a ‘high’, ‘medium’ or ‘low’ level of confidence. Here too the questions focus on efficacy (stratospheric aerosol’s ability to cool), availability (its technological readiness, and the time needed to develop and deploy it) and cost. Environmental and socio-political consequences are touched upon, but this is limited to noting (at a ‘high’ level of confidence) simply that there would be global and multinational consequences (2015a:116-20), and it is left unstated whether these consequences would be welcome or unwelcome.

Figure 5-1: Royal Society summary evaluation of geoengineering *

Secondly, the knowledge hierarchy shapes the way in which expertise from other disciplines is engaged. Where law is engaged it is as legal expertise and is typically given the task of assessing the extent to which existing regulatory regimes apply to geoengineering, and what existing regimes it might be best attached to (for example Armeni & Redgwell 2015). Where economics is brought in, only the most narrowly technical, cost-benefit focussed economic traditions are relied upon, which are those most amenable to being added into models. Where political and ‘justice’ questions arise then power is typically treated as an external consideration rather than as intrinsic to the idea of geoengineering itself. It is operationalised as a need to model the predicted impacts on the world’s poorest and most vulnerable, or as

* Diagram entitled ‘Preliminary overall evaluation of the geoengineering techniques considered in Chapters 2 and 3’ (Royal Society 2009:49)

67 Indeed costing is often limited to estimating the direct expenses associated with delivering aerosols into the stratosphere (McClellan et al. 2012).
requiring attitudinal studies regarding how geoengineering or any ‘deploying nation or group of people’ is or might be perceived (for example NRC 2015a:135-6).

The GAO report makes the hierarchy explicit. It notes that ‘a small number of the experts we consulted’ viewed climate engineering as ‘technological hubris’ and even ‘opposed starting significant research’. Revealingly, the report added a footnote, almost unbelieving in tone, noting that ‘... three of the four opponents of research had primary expertise in fields such as social science, law, ethics or other related fields (rather than physical science)’ (GAO 2011:53). ‘Those crazy non-scientists opposing research!’ is the implicit comment, suggesting too that they were thereby not qualified.

Thirdly, climate modelling becomes the primary way of ‘knowing’ the future. Modelling aims to predict (or, more accurately, calculate the probability of) what climate/s will be like in a range of scenarios, including geoengineering. The ‘institutional’ reports all rely heavily on the extensive modelling work which has been undertaken for their assessment of the effects of SGE. Climate modelling has its own limitations: there are major data gaps; the workings of the complex, dynamic system that is climate can never be fully understood; like all models it is highly dependent on the underlying assumptions; prediction is impossible and only a best estimate of the probability of a particular outcome, with a higher or lower degree of confidence, can be hazarded. Further, what is being modelled is essentially the physical aspects of the climate system, and with emphasis on temperature and precipitation variations. The social effects are “read off” the physical even as it is widely acknowledged that the climate is part of a range of coupled Earth systems, including social systems, themselves embedded in the human—more-than-human interaction which constitutes the environment.

This not to argue that the models and climate simulations can say nothing, only that they have significant limits. Indeed, the NRC report, for example, acknowledges that ‘models provide a complete and imperfect picture of the world’ (2015a:25), and that there are particular weaknesses in current modelling of both clouds and aerosols (2015a:6) both critical for SGE. Further the local and regional weather effects of SGE are expected to be very different depending on where (in what hemisphere and at which latitudes and altitudes) and when (in what month or season) sulphate injections might occur (Irvine et al 2016). The limitations of existing attempts at modelling SGE and its impacts are widely understood. As the NRC report puts it, almost all the model results:

68 This has often occurred as part of the Geoengineering Model Intercomparison Project, or GeoMIP, and builds on existing climate models.
‘... are based on a limited set of idealized studies, many of which considered dimming the sun instead of actually representing atmospheric aerosols ... All such simulations are greatly simplified compared to the real world, and further work is required to reduce the uncertainty in these projections’ (2015a:73).

“More research” is needed, in this instance to refine and improve the models. Elsewhere the report notes that:

‘It is not possible to quantify or even identify other environmental, social, political, legal, and economic risks at this time, given the current state of knowledge about this complex system... [It is] impossible today to provide reliable, quantitative statements about relative risks, consequences, and benefits of albedo modification to the Earth system as a whole, let alone ... to specific regions ...’ (NRC 2015a:6-7, my emphases).

The suggestion here is that, in time, the social dimension may be able to be quantified and included in models, that social knowledge and science knowledge are commensurable. All the official reports include the repeated trope that ‘more research is needed’. At the same time, is the magnitude of the knowledge gap identified an acknowledgement that the gap will never be filled?

The idea of geoengineering is a particular outgrowth of the climate sciences and so perhaps the secondary role allocated to others should not surprise. But the effects are to prioritise particular understandings climate and climate responses which privilege technical, rather than sociotechnical, ways of addressing the challenges raised.

Hulme has written critically about this kind of ‘climate reductionism’ and the re-emergence of environmental determinism:

’a form of analysis and prediction in which climate is first extracted from the matrix of interdependencies that shape human life within the physical world [and] [o]nce isolated, climate is then elevated to the role of dominant predictor variable’ (2011:247).

In the humanities and social sciences there was a sharp turn away from environmental determinism in the aftermath of the Nazi holocaust. What explains its re-emergence in

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69 Note that research into geoengineering modelling by Hansson suggests that accommodating uncertainty and making the models more complex does not appear to increase their accuracy (Hansson 2014). Relevant too is the distinction made by Curry and Webster (2011) when analysing climate science more generally, between epistemic and ontic uncertainties. Whilst the former are reducible, at least in theory, by more research, the latter are associated with the inherent randomness and variability of complex systems.

70 Environmental determinism was widely relied upon, especially until the mid-twentieth century, to legitimate racist and imperial practices. In its crude form this took the shape, for example, of arguing that tropical climates cause promiscuity and laziness, a belief that underpinned the eugenics movement and was widespread in the academic literature and dominant Western popular imagination of the time.
recent years? Hulme acknowledges Sluyter’s argument that neo-environmental determinism emerges out of a belated recognition of the entanglement of nature and culture, since it offers a ‘quick and dirty integration of the natural and social sciences’ (cited 2011:255). But he favours another explanation rooted in ‘the hegemony held by the predictive natural and biological sciences over visions of the future’ (2011:255). The knowledge claims of climate models lacked a counterpart in the humanities and social sciences having comparable epistemological reach. In recent decades the humanities and social sciences, in reaction against earlier environmental determinism, had avoided trying to theorise environment-society relations. The consequence was ‘model-based descriptions of putative future climates’ gaining ‘disproportionate discursive power’ when thinking about social futures. Hulme calls this ‘transfer of predictive authority’, which occurs almost accidentally, ‘epistemological slippage’ (2011:256; see also Castree, Demeritt & Liverman 2009; Castree 2015).

In the process, climate reductionism predominates in thinking about the future. Physical climates are modelled at increasingly granular spatial resolutions and used to generate predictions for particular regions and even locales about temperature and rainfall, and over increasingly long spans of time. The impacts and effects – on food production, disease patterns, population movements, sea levels and so on – are then largely read from these models. Essentially ignored in the major studies are things like social values, ideologies, and the adaptability or resilience or vulnerability of (complex) communities in particular situations. In Hulme’s words: ‘the future is reduced to climate’ (2011:264). And yet it is now clear, Hulme argues, that competing and highly-contested visions and imaginations of the future will shape the impact of climate change at least as much as physical changes in the climate. Whilst the models may help one understand what the future may hold they need to be complemented and balanced by ‘other ways of envisioning the future’ (2011:266).

Managing uncertainty

The NRC report into SGE notes that it is ‘...impossible today to provide reliable, quantitative statements about relative risks ...’ (2015a:7). Throughout, it appears torn between positing further research and a risk governance system as the way forward, and acknowledging that any decisions to deploy SGE ‘... will ultimately involve values and relative acceptability of various kinds of risks, factors that are outside the scope of science’ (p.146). The Royal Society report notes that a precautionary approach should apply where ‘the impacts of geoengineering on the environment are not yet fully known but believed potentially to be
It acknowledges that geoengineering technologies are so embryonic and knowledge so limited that this may be ‘... a situation of “indeterminacy” (or “ignorance”) rather than risk’. But it appears uncomfortable with indeterminacy when it expresses the hope that ‘[t]hrough research, and the accumulation of empirical evidence, uncertainties can sometimes be recast as risks and expressed as probabilities’ (2009:37-8).

The pattern in the institutional literature is to acknowledge ignorance and uncertainty in relation to SGE, but then to understand this in limited terms or as something solvable. This manifests as reverting to, or recasting, uncertainty as, risk. A text search of the institutional literature which constitutes my archive revealed the word ‘risk’ occurring thousands of times! The term ‘uncertainty’ (and its variants) occurred far less frequently, and was generally attached to acknowledgement of an inability to quantify risk adequately. The implications, epistemologically, of acknowledging radical uncertainty are avoided. So too is the possibility that the complex non-linear climate system may never be sufficiently ‘knowable’ to make any half-way reliable predictions about the effects of deploying SGE.

In the institutional literature the language of ‘risk’ functions to normalise SGE as a manageable object. It does this by treating risk in the narrow sense of actuarial likelihood, and by limiting the meaning of ‘ignorance’ to that which is knowable, but simply not yet known. If the risk can be calculated then it can be placed on the scales of costs and benefits, each with known probabilities. And it can be managed. But what if both the climate system and the effects of deployed SGE can never be sufficiently known to make a meaningful calculation of risk? What if it is indeterminable?

Wynne, working from a Science and Technology Studies (STS) perspective, distinguishes ‘risk’ (where the odds are known and quantifiable), from ‘uncertainty’ (with known system parameters but unknown odds), from ‘ignorance’ (where we don’t know what we don’t know), from ‘indeterminacy’ (which intersects with the first three but captures contextual socio-

71 The precautionary principle is itself a controversial one, and has been formulated in a variety of ways. The version most commonly used in a policy context is that formulated by the United Nations in 1992: ‘where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.’ (United Nations 1992). Here the emphasis is on enabling action. The principle is often also invoked to prevent or delay the utilisation of technologies or substances whose effects are believed to be harmful although not sufficiently understood (eg GMOs). See Whiteside (2006) for a general account of the principle.
political factors as well as the conditionality of knowledge) (1992). Stirling (2010) draws on Wynne when he writes about risk, uncertainty and ignorance, but rather than ‘indeterminacy’ he uses a fourth category of ‘ambiguity’: ‘when experts disagree over the framing of possible options, contexts, outcomes, benefits or harms’ (2010:1030). Rayner’s insightful paper, ‘To Know or Not to Know?’ discusses the rhetorical deployment of ignorance in relation to SGE. He notes the tension between SGE’s proponents who argue that ‘conducting some research is the only way to reduce ignorance about the technology’, and opponents who rely on a two-fold argument: ‘Ignorance is a binding constraint – “we simply cannot know” – and ignorance is a source of virtue – “it saves us from folly”’ (2014:12).

By presenting ‘ignorance’ and ‘indeterminacy’ as variants of ‘uncertainty’, and thereby reducible through further research to measurable risk, the institutional literature places itself in a conundrum. Especially where some variant of the precautionary principle has been embraced, as it is in the European-based studies, this effectively blocks SGE from proceeding. If SGE’s deployed effects are indeed marked by radical uncertainty and un-knowability, then the risks must remain unknown and potentially dangerous, and the precautionary principle acts as a presumption against proceeding.

This line of argument elicits at least two responses. The first is to invoke precaution in relation to both the climate change problem anticipated and the proposed technological solution of SGE, but to argue that the climate risk trumps the technology risk. A second line of argument is to acknowledge the deep uncertainty and treat SGE as a practical challenge to be resolved through trial and error. David Keith’s approach comes close to this (2013). He makes the case for commencing by injecting stratospheric sulphate aerosols in minimal quantities, then slowly ramping the dosage up (or down), all the while monitoring the climate system and the actual effects and feedback loops observed. But no institutional report suggests or endorses this approach.

It is an approach that has some commonalities with concepts such as ‘post-normal science’: where ‘facts are uncertain, values in dispute, stakes high and decisions urgent’ (Funtowicz & Ravetz 1993:739). There is commonality too with its implications: that since uncertainty cannot be eliminated, it must be managed, and that values must be made explicit rather than be left assumed. Whilst a number of academic papers situate geoengineering proposals within

72 One can also note Zizek’s perspicacious comment, in a context unrelated to geoengineering, that there are also ‘unknown knowns’, things we don’t know that we know: ‘...all the unconscious beliefs and prejudices that determine how we perceive reality and intervene in it’ (2008).
the realm of post-normal science (for example Bellamy et al. 2012:610), the concept is not embraced in the institutional literature or in the IPCC more generally (see Werner Krauss et al. 2012). To do so risks challenging the prevailing assumptions and claims about how truth claims are made and knowledge and ‘consensus’ arrived at.

**Counting without taking account**

In the knowledge hierarchy that prevails in the institutional accounts and assessments of SGE, economics occupies the rung below science and engineering. Most of the reports devote some space to analysing what Scott Barrett, who led the economics discussion at the IPCC Expert meeting in 2011, has elsewhere called the ‘incredible economics of geoengineering’ (2008). Almost all the institutional literature includes cost estimates for deploying SGE and, as we have seen in the Royal Society example above, cost criteria are typically included as part of the assessment process.

SGE is, on the face of it, incredibly cheap, easily affordable by a single middle-income country, and even by a super-wealthy individual. The NOVIM study regards the costs as so low, as to not be an obstacle (Blackstock et al 2009). A study for the German government concluded that operational costs per watt per square metre (W/m²) of incoming solar radiation compensated for, could go as low as $2bn per annum (Rickels et al 2011:57). The NRC report cites McClellan, Keith & Apt (2012), SGE proponents, who estimate that delivering 5Mtonnes of sulphur per annum into the stratosphere (20-30kms up) would cost between $2bn - $8bn per annum. The report does caution that these estimates exclude a number of things: the costs of producing the aerosols, potential damage to aircraft of operating in a high sulphate environment, the cost of observing systems (such as satellites) to monitor the climate effects, and the fact that large-scale engineering projects often experience cost escalation (2015a:78-9). But even taking these into account, it is clear that the report too believes the direct costs of deploying SGE are low.

Importantly, all the institutional reports also conclude that SGE would be much cheaper than both mitigation and unmitigated climate change. The Royal Society report concludes that the direct financial cost of deploying SGE ‘... is small compared to the costs of the impacts of foreseeable climate change, or of the emissions reductions otherwise needed to avoid them’ (2009:49). It cites the Stern report which estimated the costs of conventional mitigation to be

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73 As a broad indicator, to balance the warming effects of a doubling of CO2 concentrations would require a compensation of about 4W/m² (Royal Society 2009:23). To deploy SGE now as a pre-emptive strategy would need a smaller W/m² compensation in the order of 1W/m².
in the order of $1 trillion per year (2009:44). The NRC too, in its summary report, concludes that SGE is ‘inexpensive to deploy (relative to cost of emissions reduction)’ (2015:3), by ‘at least an order of magnitude’ (2015:6). One of the main take-home messages received by policymakers and also conveyed in the media, is that SGE is cheap and cheaper than mitigation (NRC 2015a:3; Curvelo 2012:190).

Calculating the direct costs of SGE is relatively easy. Whether the indirect costs are effectively captured is invariably more contentious (see also MacKerron 2014). Stilgoe argues that SGE is only cheap ‘... if we choose to do some sums and not others; if we internalise some costs and externalise others ...’ (2015a:87). This echoes the IPCC Expert Report which stresses that direct costs and benefits associated with implementing and operating geoengineering need to be considered alongside ‘cost valuations for potential social and environmental externalities’ (2012:4): an enhanced drought in one area, an increased likelihood of flooding in another, reduced crop damage in yet another. This point is also noted in the RAND Corporation report. An SGE system, it notes citing work by Goes et al. (2011):

‘will appear cost-effective if decisionmakers are very certain—on the order of 90-percent confident—that it can be maintained for decades and that its adverse impacts will prove smaller than about 0.5 percent of gross world product. Otherwise, the study finds that the system’s risks outweigh its benefits’ (RAND 2011:7-8).

These are weighty conclusions which, in effect, rule out SGE producing benefits exceeding the costs. It is unclear, given the high levels of uncertainty regarding the likely ‘adverse impacts’ from deploying SGE, how even these calculations and probabilities can be derived with any credibility. Leaving aside the NRC report conclusion that maintenance would be needed for centuries rather than decades, is it plausible to imagine decision-makers reaching ‘90 percent confidence’ that a deployed system of SGE could ‘be maintained for decades’? What does 90 percent confidence even mean in this context? Further, the conclusion rests on comparing one scarcely-known (although presumed in theory to be knowable) and uncertain future (SGE-altered) with a perhaps more predictable, but still speculative, climate changed future. This is a recipe for self-serving modelling!

Not surprisingly, other studies critique Goes et al. (2011) and come up with entirely different conclusions (for example Bickel & Agrawal 2013). In its report, the American Enterprise Institute, an organisation strongly committed to free market capitalism and typically associated with climate change denialism, draws on these alternative studies. The AEI report argues that SGE would create net benefits of up to $10trillion in comparison to unmitigated climate change (Lane & Bickel 2013:13). The papers prepared for the Copenhagen Consensus report, by the same authors as the AEI report, estimate a direct benefit-cost ratio of 25 to 1
and use this to argue that it makes sense to use SGE to enable mitigation efforts to be decelerated (Bickel & Lane 2009 and 2012).

Whether used by proponents or opponents of SGE, the language of “cost-benefit” is ubiquitous. The NASA workshop in 2006, for example, gives an indication of the utilitarian lens commonly used:

‘In principle and under favorable circumstances, this strategy [using SGE pre-emptively] could be consistent with an economically efficient climate policy. Economic efficiency requires minimizing the present value of the sum of the damages from climate change and the costs of reducing those damages’ (2007:11).

The internal logic of this position is hard to fault provided one accepts the normative centrality of “economic efficiency” and the associated methods of cost-benefit calculations, including the belief that all costs and benefits of SGE can be converted to a single monetary measure.74

These are heroic assumptions, but at the same time are core beliefs of the dominant economic order. It is also the case that the larger climate policy debate is often framed in terms of cost. It is, for example, regularly argued that money spent on cutting greenhouse gas emissions will be repaid in reduced risk of future climate damage, and that any reduction in GDP from action would be less than the eventual reduction of GDP from inaction (see for example the IPCC 2007a and Stern 2007).

The language of “cost-benefit” permeates the institutional literature, as does a methodological reliance on calculability, which in turn requires disparate things to be made commensurable by converting them into dollar equivalents. Other terms drawn from the lexicon of neo-classical economics and the standpoint of maximising utility are also used regularly. These include framing geoengineering as a “global public good” (or bad) as parts of the IPCC Fifth Assessment Report suggests (2014b:1771; see also the so-called ‘Oxford Principles’ in Rayner et al 2013), and understanding its potential deployment as a “collective action problem” (see for example IPCC 2012:24). These terms have drawn the attention of a number of commentators and are not discussed here.75 It is sufficient to note that where economic issues

74 There are many existing critiques of cost-benefit analysis, especially in relation to environmental damage (see for example Wegner & Pascual 2011). See also Porter’s account of the rise of cost-benefit analysis in the United States (1995) and MacKenzie’s analysis, in the context of carbon markets, of ‘making things the same’(2009).

75 See for example the debate on whether SGE is a “public good” between Gardiner who argues that doing so ‘arbitrarily marginalises ethical concerns’ (2013:513 and also 2014) and Morrow who argues that “[f]raming geoengineering as a public good is useful because it allows commentators to draw on the existing economic, philosophical, and social scientific literature on the governance of public goods’
are discussed in the institutional literature they are typically narrowly focussed and derived only from the hegemonic school of economic thinking in the “West”. They are “economics” rather than “political economy”. They are from the tradition of counting the expected dollar costs and benefits, rather than accounting (in the sense of being held to account).

The institutional literature simultaneously relies on the methods, epistemologies and implicit values of mainstream neo-classical economics, but is often uncomfortable with the implication that this promotes SGE: after all cheaper is better if the risks can be minimised or managed. This disjuncture may help explain ‘Recommendation 1’ in almost all the major institutional accounts: that mitigation should remain the primary instrument for tackling climate change, and that so-called ‘moral hazard’ should be avoided and nothing should be done to remove the focus from emissions reductions. In part this is a recognition that SGE only masks the buildup of GHGs and that the concentrations will still need tackling at some point. But perhaps repeated concerns about ‘moral hazard’ may function as an indirect way of suggesting that mitigation should be prioritised despite the costs. It is an acknowledgement that the embrace of counting has resulted in an undermining, when considering climate change, of holding those causing it to account.

In short, in the disciplinary hierarchy of “official” assessments of SGE, economics plays an important role: after climate science, but well ahead of the social sciences. The focus is on the calculation of costs and the application of cost-benefit techniques. The not implausible message is that SGE is cheap, and significantly cheaper than mitigation. Notably absent is any reflection on SGE’s manifest compatibility with the continuation of emissions-intensive and growth-focussed business-as-usual, a point I will return to further on. And the paradox is that whilst SGE’s cheapness is highlighted, it is also generally regarded with discomfort and diverted into discussions about “moral hazard”, a point to which I will also return.

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Epistemologically, the approaches adopted – the disciplinary hierarchy, the assumptions of knowledge commensurability, the possibility of knowing and modelling all that is needed, the privileging of utilitarian conceptions of benefit – are approaches widely enacted in mainstream climate policy-making. But whilst these approaches serve to normalise SGE, add weight to...

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(2014:95). This suggests they are in agreement that the concept is doing normative work, whilst disagreeing about the merits of the normative work it is doing and the framings relied upon.

76 Only the most free-market enthusiastic policy reports, such as those of the AEI and the Copenhagen Consensus Center already mentioned, are enthusiastic about drawing out this implication.
calls for its embrace, and make it possible for SGE to be regarded as a normal part of climate policymaking, they also, under scrutiny, make it harder for SGE to be normalised.

Szerszynski and Galarraga have argued that geoengineering research is characterised by ‘organised epistemological irresponsibility’ (2013:2818). This becomes apparent especially when geoengineering options are appraised. Bellamy et al. (2013) have explored a different approach to geoengineering appraisal than that adopted in the institutional assessments. They note that by opening up appraisal to a wider range of ‘framings, knowledges and future pathways’, different outcomes emerged. Importantly, they conclude that SGE, which typically outperforms other geoengineering options, performed poorly (2013:935).

The ‘subordination-service’ mode, as Szerszynski and Galarraga term it, drawing on the vocabulary of Barry et al (2008), in which disciplines are brought together maintains a particular framing of geoengineering as a techno-scientific response, admittedly controversial, to a global warming problem. It assumes that different ways of knowing can be made commensurable, and even integrated into models as data. Szerszynski and Galarraga have called for new forms of interdisciplinarity – ontological, agonistic, assymetrical – which deepen and open up to scrutiny the conversation about geoengineering. Others have spoken of ‘minority interdisciplinarity’ and ‘radical inter-disciplinarity’ (cited in Castree 2015).

The paradox, therefore, is that even as the centrality of values and visions is widely acknowledged to be central to thinking about geoengineering, the framing of the debate within a particular disciplinary hierarchy largely shuts this down, and proceeds to model options, costs, and effectiveness (in reducing temperature) in standard climate reductionist terms. As Szerszynski and Galarraga observe, there is little recognition that “… the fashioning of climate [is] … a form of worldmaking: a moment of historical rupture in which intentions and ways of thinking may be transformed” (2013:2822-3).

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77 It could even be argued that that the relevant knowledges for understanding geoengineering are primarily those which think about power, ideology and the co-production of the technosocial; secondarily those on the terrain of climate policy considering the implications (and public perspectives) of adding intervention as a new policy leg; and then the relevant fields of physics, chemistry, engineering, various Earth system sciences and cognate disciplines. This is the reverse of the current order of knowledge-privileging.

78 See also Castree’s account of ‘convergence science’, and other attempts from the sciences to “…bring people and nature into a single analytical domain, aspiring to mirror in a computational environment real-world couplings between socio-economic and physical systems” (2015:4).
**Power**

In the Introductory Chapter I have outlined the ways in which I understand the term “power”, and my understanding of the shape of the dominant order of imperial ‘market globalism’ and where power is located in the world, including who and what is powerful. Power, of course, has a number of dimensions including discursive power, institutional power, structural power as well as material and coercive power. SGE, since it aims to engineer and re-shape the global climate, is a manifestly powerful technology. In this section I develop my contention that it is also a technology of the powerful. I explore this in three aspects with the aim of illuminating aspects of the relationship between the SGE, power and the interests of the powerful. Firstly I examine the implications of the invocation of urgency and climate emergency for existing democratic practices. This is an instance of discursive power, arguably with coercive effects. Secondly, I explore the complicated compatibility between SGE and the continuation of the existing economic order of capitalism. Here the material and structural dimensions of power come to the fore. Finally, I touch on the imagined relationship and likely effects of deployed SGE on the existing geo-political order. Institutional/structural as well as material and coercive power all come to the fore in considerations of international order. A great deal of useful analysis has already been published relating to SGE and emergency, geopolitics and global governance, and, to a lesser extent, SGE and capitalism has been examined too. I will therefore be relatively brief in examining these major issues and in doing so I will be standing on the shoulders of others.

**Emergency and Risk**

Nerlich & Jaspal (2012) report that the emergency framing is the preponderant underlying narrative in both scientific and popular discussions of geoengineering (see also Bellamy et al. 2012). A sense of “emergency” is pervasive and widespread as evidenced by the regular appearance in the literature, both ‘institutional’ and ‘policy-influential’, of references to “urgency”, “tipping points”, “dangerous”, “abrupt”, “rapid” and “non-linear” climate change. However, the reliance on ‘emergency’ takes two slightly different forms. There are those who imagine, quite literally, an event or set of events occurring which would result in the deployment of SGE: as explored in the previous Chapter in my account of the ‘climate emergency’ rationale. David Victor, an influential voice in climate and SGE policy, imagines SGE as ‘a last resort’ and triggered by the crossing of tipping points or thresholds, although no particular one is promoted (Victor et al 2009). “Emergency” framings are also prevalent in
popular and press accounts of SGE.\textsuperscript{79} And then there are those who argue for SGE to be
developed and possibly deployed in order to reduce climate risk, the ‘risk reduction’ rationale
outlined in the previous Chapter, because a climate emergency in a \textit{generalised} sense exists.
In short, the idea of “emergency” is invoked even when the term itself is not used and even
where a literal climate emergency is not imagined (Markusson et al. 2014:282).

The literal emergency rationale typically imagines the technology being readied for
deployment in the event of a climate crisis, as a fast-acting antidote (ideally temporary) to
tackle, say, “runaway climate change”. The Royal Society report, for example, argues that SGE
‘... may provide a potentially useful short-term backup to mitigation in case rapid reductions in
global temperature are needed’ (2009:59).

The many difficulties with the emergency argument have been well-rehearsed elsewhere (see
for example Markusson et al. 2014; Horton 2015; Sillman et al. 2015) and need only be
outlined briefly here. Firstly, whilst the term “emergency” is often mobilised, it is almost
always used in a vague and imprecise sense. What would constitute an emergency is rarely
made clear and never attached to a specific indicator. The NOVIM report, \textit{Climate Engineering
Responses to Climate Emergencies}, imagines as an emergency the situation where ‘the impacts
of a warmer world on humans and natural ecosystems ... [are] more severe than current
median predictions’ (2009:1): a strange combination of the language of “median” and
“emergency”. In a report whose overwhelming focus is on climate emergencies and SGE, it
defines climate emergencies as ‘those circumstances where severe consequences of climate
change occur too rapidly to be significantly averted by even immediate mitigation efforts’
(2009:1). The solution to such vagueness, according to the GAO report, was more data on
climate thresholds and ‘a way to determine when a “climate emergency” is reached’ (2010:16).

For the chair of the US Congressional Science & Technology Committee this is a decision for
the experts: ‘the global climate science and policy communities should work towards a
consensus on what constitutes a “climate emergency” warranting deployment of SRM [SGE]
technologies’ (CONG S&T 2010:40).

On the few occasions in the institutional literature where a particular emergency is envisaged
it is typically imagined as an event. The IPCC Expert report notes that the ‘most discussed of
the possible emergencies have been a methane burst as a result of the rapid thawing of
permafrost and/or clathrates trapped in the sediments of the continental shelves, the rapid

\textsuperscript{79} A typical example from a BBC website report: ‘If Planet Earth is facing a climate “emergency”, as some
people believe we are, then we should leave no option for combating it unexplored’ (Black 2012).
loss of ice mass from the Greenland and/or Antarctic ice sheets, collapse of the Amazon rainforest, or greatly accelerated, runaway warming’ (2012:55). But what, for example, would indicate the collapse of the Amazon rainforest, or indeed signal its impending collapse, or be clearly not attributable to, say, logging? And how much more rapid than it currently is would Greenland ice loss need to be? To pose such questions is to suggest their unanswerability.

The NRC report, which generally eschews the literal emergency rationale, mentions one scenario which they deem ‘hypothetical but plausible’:

‘If, for example, global warming resulted in massive crop failures throughout the tropics (e.g., Battisti & Naylor 2009), there could be intense pressure to temporarily reduce temperatures to provide additional time for adaptation.’ (2015:32)

But who would exert this pressure and how? Would, for example, the massive crop failures and droughts of 2015/6 count? And how would the global warming effect and the El Nino effect be disentangled? To date the only explicit call for an event-linked use of SGE has come from the Arctic Methane Emergency Group (AMEG), a grouping of Arctic scientists and others. They argue that the emergency is already upon us and have called for immediate geoengineering to re-freeze the Arctic (AMEG 2014). But they have found few supporters for their call, even though the emergency rationale is embraced by many, and the evidence for the Arctic having crossed a tipping point of some sort is compelling (Lenton 2012). In short, the emergency argument lacks precision even whilst it appears to envisage a threshold determined by scientists being crossed, leading to the deployment of SGE. Perhaps the clearest implicit threshold can be attached to the 2°C target contained in the Paris climate agreement with its suggestion that this is the zone of ‘dangerous climate change’ (UNFCCC 2015). But, to date, no one has suggested that crossing this threshold should trigger the deployment of SGE, although there are emerging signs that such calls will be made, especially by those located in the global North (see for example Keith & Wagner 2016).

A second difficulty with the emergency argument can be derived from the work of a number of leading climate scientists. Tim Lenton has cast doubt on whether a precise ‘tipping point’ in any major physical component of the climate system could be predicted or observed in time to be reversed (2013; see also Sillman et al 2015). ‘[B]y the time you detect that abrupt change is either imminent or underway, the tipping point may long since have been passed and the change simply cannot be reversed’ (2013:1). Any element of the climate system which has ‘tipped’ is on its way to an alternative state. So whilst in principle reversible, ‘it could demand a reduction in radiative forcing well below the pre-industrial level’ (2013:2): in practice this would entail an especially high dosage of sulphate aerosols into the stratosphere to achieve
the desired effect. Since the concepts of ‘non-linearity’ and associated ‘tipping points’ is the most scientifically plausible justification for an “emergency”, the fact that these could only be detected after the event and then be irreversible, would appear to be a fatal flaw.

Lenton does acknowledge that SGE may be viable ‘... for a subset of tipping points’, fast-responding systems ‘that are directly related to temperature change’: notably Arctic sea-ice (not land-ice) or monsoons. In the case of monsoons he notes that they ‘are particularly sensitive to aerosol forcing and may actually be disrupted rather than protected by deliberate aerosol injections’ (2013:3). In short, of all the emergency triggers envisaged earlier, none remain scientifically credible as ‘solvable' by SGE.

A third difficulty is that “emergency” is fundamentally a social category, although it is not treated as such in the institutional literature on SGE. As Hulme has observed, from a social perspective, emergencies never simply happen, they are always declared (2014:21-6). Who declares this emergency and thereby triggers the deployment of SGE, and at what spatial scale? And for whom is it an emergency? There would clearly be competing interests and views, and already-established relationships of power.

In its literal version, the emergency notion appears to be internally incoherent and impossible to operationalize, a reality now widely recognised, even by some sympathetic to the development of SGE (Horton 2015). In the more generalised version it does other work. Calhoun, in his work on the emergency imaginary, has described ‘emergency’ as ‘... a way of grasping problematic events, a way of imagining them that emphasizes their apparent unpredictability, abnormality and brevity, and that carries the corollary that response – intervention – is necessary’ (Calhoun 2010:25). And this appears to be the effect of the “emergency” argument when it comes to SGE. Since it seems clear that SGE cannot “prevent” or reverse climate emergencies, then the effect of relying on “emergency” rhetoric can only be to mobilise a response in favour of SGE, to act as a call to action. Further, by suggesting we are in exceptional times, it is implied that exceptional interventions are needed, perhaps even that a ‘state of exception’, in the Schmittian sense, exists. This is coercive rhetoric. No wonder some observers have questioned whether SGE is compatible with democracy (Szerszynski et al. 2013) and argued that, ‘by its social constitution [SGE] appears inimical to the accommodation...”

80 See also McCusker et al (2012) whose modeling work casts doubt on the ability of SGE to prevent polar climate emergencies.

81 In the case of SGE, clearly, there can be no suggestion that the emergency will be brief.
of difference’ (Macnaghten and Szerszynski 2013:472). Hamilton has speculated that SGE might be the dictator’s technology of choice (2013a).

The temporal dimension of SGE is intriguing in other respects too. On the one hand it is imagined as a temporary technology, to deal with an emergency. On the other hand it is widely acknowledged that embarking on SGE is likely to be a ‘millennial commitment’ or at least a multi-decadal one (see NRC 2015a and Pierrhumbert 2015). Troublingly, therefore, the suggestion is that both the climate emergency and the SGE intervention are unlikely to be brief, and that we may be entering a permanent emergency, if that is not a contradiction in terms, a “state of exception” as the normal state of affairs.

The risk reduction rationale for SGE retains a generalised sense of a climate emergency whilst acknowledging Lenton’s argument presented above, that ‘tipping points’ may be impossible to determine ahead of them occurring, and by then would be largely irreversible. Michael McCracken is broadly favourable to the development and deployment of SGE. In his participant presentation to the IPCC expert meeting on geoengineering McCracken notes that an implicit assumption of the emergency formulation ‘... is that climate is reversible, and this is not at all clear. In addition, adaptation is likely to have spread out the range of optimal temperatures for various societal and environmental systems, such that a sudden, sharp cooling might be very disruptive’ (IPCC expert meeting 2012:55). For McCracken this is reason to deploy SGE as a precautionary measure, a prudent action, prior to any ‘tipping’. Keith, for example, explicitly argues for research leading to the ‘wise use of geoengineering’ (2013:174) as a preventative technology aimed at flattening the peaks of global warming and reducing the sharp incline of our current temperature trajectory. His essential argument is that in the context of a generalised climate emergency, SGE should be used pre-emptively in a moderate dosage.

This approach avoids the manifest incoherence in the literal emergency argument, whilst retaining the general framing of a climate emergency. It has its own assumptions which some may contest. It requires climate risk to be prioritised over any risks which may flow from using SGE technology. It assumes that an engineered reduction in global average temperature will, on balance, be positive, and certainly better than continued global warming.

These are clearly more plausible propositions than those contained in the literal emergency version. But the risk framing still requires a generalised sense that we face a climate emergency in order to justify such an intervention as SGE, and the coercive work that risk does cannot be ignored. As Ulrich Beck, the pre-eminent contemporary theorist of risk, has argued:
‘Risk society means that the past is losing its power of determination of the present [and] being replaced by the future ... as the basis for present day action. We are talking and arguing about something that is not the case, but could happen if we do not turn the rudder immediately. Expected risks are the whip to keep the present in line. The more threatening the shadows that fall on the present because a terrible future is impending, the more believed are the headlines provoked by the dramatization of risk today’ (Beck 1997:20 my emphasis).

Risk, Beck argues elsewhere, is not only chance and side effect, it can also be understood as ‘the way of being and ruling in the world of modernity’ (Beck 2006:330).

In short, the literal emergency argument for SGE is incoherent and unpersuasive. But ‘climate emergency’ as a generalised framing does legitimating work by making SGE appear both necessary and vital: who could oppose ‘action’ when faced with an emergency? Both ‘emergency’ and ‘risk’ are coercive rhetoric, and undemocratic assertions of power. This may help explain why there are no calls for SGE coming from the global South.

Capitalism
What is the relationship between SGE and the capitalist socio-economic order? At one level SGE is manifestly compatible with the continuation of the dominant existing economic patterns. These entail the pursuit of output (or GDP) growth, achieved largely through modes of extraction, production and disposal which are environmentally-intensive – what has been described as the ‘take-make-waste’ system (Doppelt 2012). Both the amount of growth and the negative environmental effects have been amplified by dramatic increases in international trade over the past decades. It is precisely these economic patterns that have driven the rise in anthropogenic emissions of CO₂ and therefore increasing global warming. Indeed it has been suggested that tackling climate change requires the assumptions and practices of capitalism itself to be confronted (for example Klein 2015), although others have argued that reforming capitalism by de-coupling it from environmental degradation will suffice (for example World Bank 2012b).

Mitigation strategies are the currently preferred climate policy. These aim to reduce emissions but they are expensive. They also require significant changes to energy and transport systems and to patterns of land-use, all of which takes time and require new coalitions of support to be built and existing vested interests to be overcome. Historically, output growth (GDP) and CO₂

82 I fully accept that similar, often higher, levels of environmental degradation could be found in the planned economies of the former Communist states, which equally applied ‘take-make-waste’ approaches, and that environmental degradation is also a feature of state-capitalist economies such as in contemporary China.
growth are closely correlated, although there are signs this may be changing (IEA 2016). There have been improved eco-efficiencies (creating more output at lower environmental cost per unit than previously) over the past two decades. But the ‘take-make-waste’ approach persists and the objective of what is sometimes called ‘green growth’ is proving elusive. There is evidence of relative de-linking of the relationship between growth and negative environmental impacts, but there has not been the absolute de-linking (GDP growing with GHG emissions declining) which is a pre-condition for stabilising GHG concentrations at a lower level than they are currently.\(^{83}\)

Given this context, SGE offers the possibility of masking the warming effects of rising GHG concentrations whilst enabling the existing economic patterns to continue. This is why SGE can be seen as compatible with the dominant economic logic of our times. Further, as I have previously discussed, if cheapness is understood as a monetary measure of cost, then SGE is probably cheap and almost certainly cheaper than mitigation. Since cost-benefit and market-friendly approaches have been central to climate policy discourse and practice since at least the Kyoto agreement, then it is hard to see why policymakers should not choose the cheaper option, especially if its benefits outweigh its costs.

As I have shown previously, only a few policy think-tanks (such as the American Enterprise Institute and Lomborg’s Copenhagen Climate Consensus) and a few politicians (such as Newt Gingrich) have explicitly embraced such arguments. They are commonly enthusiasts of the ‘Alternative Climate Plan’ rationale for SGE, discussed in the previous Chapter, a clear minority view amongst climate policy-makers. They alone make it explicit that they find SGE attractive because it allows ‘politically bankrupt’, expensive and growth-reducing mitigation to be avoided (Lane & Bickel 2013:20).

Proponents of SGE who rely upon the ‘Emergency’ or ‘Risk Reduction’ rationales are less inclined to embrace this logic. So, for example, Keith argues:

‘I embrace this [utilitarian, cost-benefit] framework for making near-term policy trade-offs about air pollution or tax policy, but I think this analytical machinery is far less useful when pressed into service to make global-scale all-but-irreversible decisions that span centuries’ (2013:165)

Turning to the institutional literature, perhaps most notable is what it does not say, its silences, what is simply taken as given. The studies all assume that the seriousness of the climate

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83 The IEA reports that the rise in renewable energy has led, for the first time since at least the 1970s, to GHG emissions flatlining (neither rising nor falling) since 2015 (IEA 2016). Other negative environmental impacts continue to rise alongside GDP growth (Steffen et al 2015).
situation is such that a radical intervention, SGE, may be needed to re-shape the planet’s climate. But they are almost all silent about the dominant model of growth and consumption that has created a climate situation of such seriousness. Capitalism is nowhere directly addressed in the institutional assessments. Perhaps it is alluded to in the German Environmental Agency report which notes, not with approval, that with SGE ‘little or no behavioural change has to be demanded from society for the reduction of CO2 emissions’ (Ginzky et al 2011:41).

In the ‘policy-influential’ literature too, capitalism is rarely touched upon. Keith is unusual in addressing the question of capitalism directly when he argues that:

‘... environmentalists have conflated two different causes: repealing the excesses of aggressive capitalism and minimizing harm to the environment ... [which] while they are connected, I don’t see a tight one-to-one linkage between them’ (2013:143).

Keith accepts there have been difficulties in minimizing harm to the environment. But this is ‘... not because political and economic liberalism are inherently anti-environmental, but because an accumulation of [corporate] power and private political money has frustrated the ability of government to act in the public interest’ (2013:148). In this view, rather than attributing a role for liberalism in that accumulation of money and power, it is understood that the ideal of independent and public-spirited government may have been corrupted. This leads him to ask, rhetorically, ‘must we fix capitalism in order to fix the climate?’ (2013:143). ‘No’ is the implied answer, although Keith acknowledges the need to address some of capitalism’s ‘excesses’. It is the mirror response to Naomi Klein’s argument in This Changes Everything (2014). Elsewhere Keith asks, again rhetorically, ‘should we prefer social fixes to technical fixes?’ (2013:147).84

Such reflections on capitalism in the policy-influential literature are rare. In the institutional literature on SGE there is no mention of capitalism, nor any consideration of the relationship between SGE and the larger economic system. SGE is repeatedly acknowledged to be an environmentally masking technology – it deals with the symptom of planetary warming, not the physical drivers. All the institutional reports acknowledge it does nothing to reduce GHG concentrations, ocean acidification and so on. But no mention is made that it may be a

84 The suggestion is that these are distinct approaches, although numerous studies reveal that the social and the technical are always entwined (see for example Pinch and Bijker 1987), indeed that in the emergence of new technologies the social and the technical are imagined together (Jasanoff 2015), and that technical “fixes” are socially shaped and have social effects. The suggestion too is that what the climate problem lacks is a mechanism or mechanisms to “fix” it.
masking technology in other ways: that it masks, conceals or postpones the need to shift from the current patterns of extraction, production and consumption, and the associated pursuit of endless growth. Through such silences the existing economic order and the structural and institutional power which holds it in place, are left unchallenged, and discussion of SGE is detached from discussions of power and the dominant order.

But this throws up a paradox. Given the compatibility between the maintenance of the dominant order and the technology of SGE, and given the cost of existing mitigation strategies and the potential for climate change to have damaging social and economic effects, why then, to date at least, has “official” governmental and institutional enthusiasm for SGE failed to materialise? Whilst individuals amongst the political elites and the super-rich have shown interest we do not see evidence, as we have seen and will see in future Chapters, of broader enthusiasm for SGE among climate policymakers, in UNFCCC talks and similar inter-governmental encounters, or in elite forums such as the World Economic Forum. There are some, but not many, business interests (such as patent holders or companies hoping to benefit from new technologies) but no business lobby for SGE. There is no policy champion for SGE among leading world politicians, in the way one might be able to identify champions for climate mitigation.

How to explain this paradox? Perhaps the climate situation is not perceived to be sufficiently serious or imminently threatening on the short timescales of the electoral and business cycles. Perhaps what is revealed is that capitalism, as a system, is essentially reactive. It has little ability, as a system, to anticipate change or actively choose technological directions. In the drive to accumulate it generates social upheaval, technological disruption and environmental collapse/s, and then finds ways to adapt and reconstitute itself, in the process generating further upheaval, disruption and collapse. On this reasoning SGE may be conceptually facilitative of capitalism’s maintenance but will not be pre-emptively embraced.

Or perhaps the answer to the paradox may lie in a double feature of SGE – that it is both stabilising and disruptive of the dominant order of ‘imperial market globalism’ (Steger 2009). SGE does indeed have the character of a technical solution to an ecological problem and appears compatible with ‘business-as-usual’. But it also seems to entail at least the possibility of substantial disruption of existing institutions, as my discussion of democracy and geopolitics in the next section will suggest. SGE might therefore be ‘hyper-compatible’ with the dominant order: its compatibility is accompanied by disruptive characteristics. This can make SGE unattractive to those elements of the dominant order for whom the predictability and continuity of existing institutional structures and investment horizons is important, and
disruption threatening. The more so because it is precisely the richest and most powerful inhabitants of the Earth who have the greatest capacity (by moving, cocooning and air conditioning) to put up with climate changes which exceed rises of two, three or even four degrees Centigrade.

**Global order**

Power effects are evident when considering the international and geo-political implications of SGE. Here I will touch on two related concerns which emerge repeatedly in the literature: the fear of unilateral deployment and the related question of ‘who decides’ on the use of SGE. Both concerns operate at the intersection of climate policy and geo-politics. In both cases it will become evident that, in the institutional literature, they are typically handled from the standpoint of the already powerful.

The Bipartisan Policy Center report calls for the US to play ‘a pivotal role’ in engaging with ‘other major countries’ on SGE policy (BPC 2011:28), although which countries these are is left unspecified. A paper on ‘Unilateral Geoengineering’ was at the centre of a workshop convened by the influential US Council on Foreign Relations in May 2008, and attended by a range of SGE policy-influential individuals. This paper stressed the need to build norms for ‘responsible geoengineering’ much like those governing first use of nuclear weapons or the safe testing and deployment of GM crops, and to roll these out globally. But it expressed anxiety about constraining “responsible” countries, implicitly the US:

‘Aggressive norms might stymie research on geoengineering within countries that are most likely to honor the norms – that is, the countries that are most likely to give closest attention to possible collateral damage from geoengineering – while doing little to thwart dangerous unilateral geoengineering by countries and institutions that care less about international norms’ (Ricke et al 2008:12).

But it is the NRC report (2015a) which is most relevant when exploring security concerns associated with a fear of “unilateral” use of SGE, since the US security establishment played a leading role in it as both a funder and a participant. The report expressed concerns about ‘unilateral’ deployment of SGE (2015a:122ff). In an echo of the post-2001 discourse around ‘weapons of mass destruction’, the terms ‘irresponsible’, ‘uncoordinated’ and ‘rogue’ deployment are also repeatedly used.

The NRC report notes the need for ongoing satellite capability able to both detect unilateral deployment and monitor SGE’s climate effects if deployed non-unilaterally. It suggests supplementing this surveillance capability with intelligence gathering ‘on the movement or use of albedo modification agents (e.g., chemical feedstock transport, manufacturing, injection
facilities)' (2015a:111-113). Although not made entirely explicit in the NRC report, ‘unilateral’ appears to mean any deployment not conducted by or coordinated with the United States.

A July 2016 speech by John Brennan, the head of the US Central Intelligence Agency (CIA) suggests he is paying close personal attention to SGE, seeing it as a ‘beneficial advance’ but one which might have ‘destabilizing effects in the long run’. He appears to regard SGE in a positive light as a means to limit temperature increases and some of the associated risks, and give time to transition from fossil fuels. SGE’s cheapness is also attractive and here he cites the NRC report’s cost estimate of $10bn per annum, but fails to cite the many caveats which surrounded this estimate. For Brennan the downsides of SGE include that greenhouse gas reductions would still be required to address ocean acidification, that it ‘could trigger sharp opposition by some nations’, and a lack of ‘global norms and standards ... to guide the deployment and implementation’ (Brennan 2016: n.p. for all the above). As this thesis was being finalised it has become evident that Brennan’s perspective is not unique within the US security establishment. A 2016 study by Engelke and Chiu, for example, entitled Climate Change and US National Security, repeatedly refers to geoengineering in the context of a broader plea to ‘make the climate security concept part of a comprehensive narrative tying climate insecurity to the United States’ core national interests’ (2016:2). In the more general securitisation of environmental and climate policy (see Dalby 2013) geoengineering is playing an increasingly prominent role.

I do not intend to suggest that concerns about unilateral deployment are without foundation. Healey and Rayner provide a plausible example of the potential for deployed SGE to generate inter-state conflict. They ask us to imagine India having conducted SGE experiments shortly before the devastating 2010 floods in Pakistan. ‘It is hard to imagine that members of the Pakistani public, and certainly Pakistani politicians would not have held India responsible for the damage that had been caused by the floods... [especially given that] attribution for climatic events is unclear’ (2015:14). Both countries, of course, have nuclear weapons.

What I am suggesting, however, is that in the institutional literature when unilateral deployment is imagined as a problem, the concerns emerge from the standpoint of the already powerful, and from those who imagine deploying it themselves. Deployment by the US is not considered to be ‘unilateral’ although there is occasionally acknowledgement that, as a matter of necessity, some form of consent might be required from a few other ‘countries that matter’ (Victor 2011).

Unilateral deployment is closely associated with another issue which reveals the workings of global power: who decides whether, when, where and how to deploy SGE? The Royal Society
noted that, ‘[a]lthough the analogy is flawed, some commentators have asked “Whose hand will be on the global thermostat?”’ (2009:40). The issue is commonly raised but rarely addressed in detail in the institutional literature. In general, the non-US reports tend to imply that some form of global, international governance is needed, whilst the US-based reports do not.

A large number of writers, generally European, take a nominally universalist view and argue for some form of global governance/regulation. For legitimacy this should involve, at least in theory, all the nations of the world (see for example Virgoe 2009). The Royal Society report suggests that perhaps the UN or one of its agencies should govern geoengineering (2009:60). New Zealand law academic, Karen Scott, proposes the development of a geoengineering protocol to be attached to the United Nations Framework Convention on Climate Change (2013). However, policy-influential US academic, David Victor, urges the United States to oppose any such initiative as, he argues plausibly, it would in practice amount to a ban on geoengineering and geoengineering research (2011). It is hard to see the suggestion that all the nations of the world might voluntarily agree on a planetary thermostat and SGE as anything other than naïve.

The US institutional reports generally avoid addressing the issue directly or else limit their focus to research governance rather than the governance of deployment (see for example the NRC report 2015a). In the broader academic literature on SGE there are some, most notably UK-based climate scientist and geographer Mike Hulme, who argue that ‘a planetary thermostat in the stratosphere would be ungovernable’ (2014:86). In Hulme’s case this is an important reason to reject SGE and even research into SGE. Contrast this to the view of Bickel and Lane, in their work for the American Enterprise Institute (2013). They explicitly reject any notion of global governance, arguing instead ‘... for a coalition with enough bargaining power to impose its preferences over global climate’ (2013:20).

The AEI is an outlier more generally but this “climate policy realism” is perhaps the dominant view in the US-based ‘policy-influential’ literature although it has struggled to find formal expression in the institutional literature. David Victor implies that this is because environmental scholars ‘care too much about their subject’ and are too caught up in ‘green evangelism’ (2011:x-xi). Victor is especially influential in articulating what he calls the ‘hard-nosed politics’ of climate change including the need to develop and probably deploy SGE. His views are analysed in some detail in the next Chapter. Where the view that developing and deploying SGE should be the decision of a handful of nations is expressed it feeds the fears,
especially in the global South, that SGE will mean a coalition of the powerful imposing their desired climate on the majority, and perpetuating the existing, unequal, global order.

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We can see the workings of power – discursive, institutional, material and structural – in the emergence of SGE. We see it in the embrace of the rhetoric and internal logic of emergency, in the undemocratic directions towards which it appears to lead, in the apparent compatibility with the continuation of business-as-usual capitalism, in the increasing securitisation of SGE, and in the resistance among the most powerful to the adoption of globally inclusive governance frameworks. It is apparent that SGE is not only a powerful technology but that it is also, in many respects, a technology of the powerful.

Values

As I have shown above, knowledge claims about SGE – what counts and whose authority counts – are infused with implicit and explicit value choices, which the dominant knowledge claims, in turn, legitimate and replicate. Similarly, the relationship of SGE to current orderings of power, is connected to expectations about what climate change and SGE might do to these orderings, and normative stances as to what needs changing and what needs conserving. Values, in the sense of who and what counts and how the world ought to be, are pervasive and visible in considerations of and contestations over SGE but rarely made explicit. In the institutional literature this is sometimes acknowledged, as I will show, although typically it is then ring-fenced into a short separate consideration of “ethics”. In this section I will show how values considerations are typically narrowed in scope to be mainly about who decides on SGE and how (reprising standard climate ethics concerns and making it a governance matter), rather than on “human values” questions (such as what sorts of humans do we want to be) and relational questions (such what relationship with the more-than-human world we aspire to, and with what limits). I label these here “intrinsic values” questions.85

It is important to note that there is now an extensive academic literature, and from a range of ethical perspectives, exploring the ethics of SGE (see for example Preston 2012a; Gardiner 2011a; Corner & Pidgeon 2010; Di Paola & Pellegrino 2013). The issues explored are many and various. Questions of consent (and authority) arise repeatedly. Who gets to decide to embark upon, or even experiment, with this planet-changing technology? And, if embarked upon, who gets to set the global thermostat, or decide on termination of the intervention? Such

85 I concede the inadequacy of this label but wanted to avoid the term “human values” as both anthropocentric and failing to capture that more-than-human relations are at stake too.
questions are deeply bound up with justice concerns, such as whether the voice of the few overwhims the voices of the many (see for example Macnaghten & Szerszynski 2013), or the imagined effects of SGE on the world’s poorest.

Justice concerns also have an inter-generational dimension. Given that SGE, once embarked upon, entails a multi-generational, even ‘millennial’, commitment, what obligations do current generations have towards future ones? (see for example Gardiner 2011a; Hordequin 2012; Preston 2016). Gardiner has suggested it is especially challenging to avoid ‘moral corruption’ – the ‘subversion of our moral discourse to our own ends’ (Gardiner 2011a) – when we consider questions such as these.

Consent and justice concerns about SGE reprise existing debates around climate ethics (Gardiner 2011a; Garvey 2008) and climate justice (Baskin, 2009) and often reflect the global North-South divide. Healey and Rayner assert that SGE raises no new and distinct ethical problems not already raised in general considerations of climate change (2015:11-12). I do not fully agree. There is a whole category of existential or “intrinsic values” which are either absent or significantly less pronounced in general considerations of climate ethics. And indeed, Healey and Rayner do concede that the ‘ethical theme’ of the human-nature relationship, is ‘underdeveloped in the mainstream climate change literature’ (2015:12).

Competing perspectives around intrinsic values are at the heart of disagreements around the desirability of SGE. Is the very idea of SGE and controlling the skies something both brazen and ‘un-natural’, a sign of hubris? Or have circumstances on Earth changed so much that it is necessary to embrace our allocated role as the ‘God species’ (Lynas 2011), ‘...consciously admitting that we live on a managed planet’ (Keith quoted in Goodell 2010:45)? Such questions, rooted in contested values, in some respects reflect pre-existing arguments within environmental discourse (Dryzek 2005). But they do so in greatly sharpened form. As Hamilton has put it: ‘what matters ethically about geoengineering is not only the outcome but also the human disposition it reveals’ (Hamilton 2011:18).

In short, many of the ethical questions which geoengineering prompts are ‘big’ ones and revolve around deeply-held values and visions regarding how the world is and how it should be. They are bound up in attitudes towards technology, and rooted in assumptions about nature, the human-nature relationship, and the permissible bounds of human action. There are a range of views on these issues within ‘modern’ Western cosmologies, even before coming to the range of views contained in competing ontological perspectives on the relationship between nature and culture (see Descola 2006, 2013[2005]; and Wong 2015). My purpose in this section is not to explore these ethical questions in detail, nor to understate their
complexity. Rather I want to understand how the more mainstream ‘institutional’ literature handles the ethical questions. Typically, as we will see, these acknowledge that there are ethical issues but then narrow and marginalise them.

The Royal Society study states that ‘the greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance’ (2009:xii). It notes the view that geoengineering ‘may be intrinsically unethical’ (2009:46), but then does not engage with this troubling observation, thereby effectively discarding it. The study notes that there are different generic schools of philosophical thought (although only European traditions are considered). In practice it favours utilitarian/consequentialist approaches, but acknowledges that these ‘probably tend towards a more favourable view’ of geoengineering (p.46). It treats the ‘justice’ questions as largely resolvable through the development of good governance frameworks (p.46). Its overall discussion of ethics prioritises ‘moral hazard’ and argues that ‘if it could be shown empirically that the moral hazard issue was not serious, one of the main ethical objections to geoengineering would be removed’ (p.39).86 Not surprisingly, Gardiner has charged the Royal Society report with having a simplistic account of the ethical issues (Gardiner 2011b).

Throughout the NRC report (2015a) there is repeated reference to the phrase ‘social, political, legal and ethical issues’, but only one page (out of 235) specifically exploring ethics. To the extent there is a focus, it is on the specific and narrower question of research ethics. ‘Moral hazard’ is touched upon. It is noted, in passing, that ‘[p]otential intergenerational implications compound the ethical issues regarding who has authority’ to solar geoengineer (2015a:135).

The report mentions ‘potential psychological effects’ of SGE and that there are debates over ‘the morality of deliberately taking control of the planet’s temperature’ (p.135). The report concludes that ‘it is clear that further research on these ethical questions is required’ (p.135), although it seems far from clear that the need for ‘more research’ is self-evident, other than by taking a narrow view of the ethical issues. The instrumental nature of what is imagined (that ethics = ‘moral hazard’ problem?) becomes clearer in the subsequent sentence: ‘Research on the social implications and ecological and economic ramifications of deployment could better define if it is possible to mitigate societal concerns’ (p.135).

86 The widespread assumption has been that SGE would divert attention from mitigation and adaptation efforts and thereby encourage ‘business-as-usual’ by making emissions reductions appear less urgent or necessary (see for example Hale 2012; Lin 2013). More recently, a substantial, largely speculative, literature has emerged which challenges these assumptions and argues, variously, that ‘it would not’ to ‘it would encourage more mitigation’ to ‘if it reduces mitigation would that be a bad thing?’ For a survey of some of the arguments see Morrow (2014).
Working Group 1 of the IPCC Fifth Assessment Report, which is generally unenthusiastic about SGE (or at least reflects the lack of agreement about its desirability), notes that ‘[t]here are also many (political, ethical, and practical) issues involving geoengineering that are beyond the scope of this report’ (IPCC 2013a:632). The Working Group 2 portion of the report mentions, but does not explore, possible ‘moral hazard’ (IPCC 2014b:1066). Chapter 3 of Working Group 3’s report covers ‘social, economic, and ethical concepts and methods’ (IPCC 2014c). Only six pages (out of 49) cover climate ethics, and one page within this focuses on geoengineering. This merely summarises the academic literature for and against geoengineering and notes that the ‘moral hazard’ argument is among the most prominent. The lead-up work for the Fifth Assessment Report, the expert group on geoengineering, acknowledges ethics but not altogether coherently. The dominant perspective is best summed up by the assertion of one of the main contributors, Scott Barrett: ‘The central social, political, legal, and ethical challenges posed by this technology all concern governance’ (IPCC 2012:24, *my emphasis*).

A similar ‘ethics = governance’ approach can be found in the report of the Bipartisan Policy Center. It notes that research on ‘climate remediation’ may ‘raise new ethical, legal, and social issues of broad public concern’. It doesn’t specify what these might be, but does recommend an advisory council to set ‘standards of oversight’ (2011:19), presumably of research oversight. The GAO study similarly suggests that ‘engagement with the public and U.S. decision-makers’ may require ‘studies of economic, ethical, legal, and social issues and studies of systemic risks’ (2011:vii). It cites, approvingly, a suggestion to bring ‘social scientists, ethicists, or trained risk assessors directly into laboratories to ensure early accounting for risks and social and ethical issues’ (p.52). Here ethics is treated as essentially risk management of potentially negative side-effects.

When it comes to the question of what “intrinsic values” or deeper ethical stances SGE assumes or requires, then this is either ignored or addressed perfunctorily. There are a few exceptions. The German Environmental Protection Agency (GEPA) report, the institutional report most sceptical of SGE, notes that to gain societal acceptance involves asking ‘[w]hich ethical, moral, religious or aesthetic principles are touched on by application of this technology?’ (Ginzky *et al* 2011:40). The SRMGI study, with its focus on governing research, lists ‘hubris and interference with nature’ as one of eight potential concerns about SGE (2011:22). The Novim study’s framing of the ethical issues is unusually broad in scope, for the institutional literature. It cites the centrality of ‘beliefs about humanity’s role in the natural world that are opposed to intentional human modification of the Earth’s climate’ (Blackstock *et al* 2009:v). Almost alone in the institutional literature it regards ‘moral hazard’ as a socio-
political rather than an ethical issue. But, other than these observations, it sees ethical and socio-political issues as beyond the scope of its study. Indeed, none of these reports takes the intrinsic values issues much beyond the brief comments cited here.87

Overwhelmingly, the substantial ethical concerns which surround SGE are either glossed over or narrowed substantially in the ‘institutional’ literature. Whilst these may note the big “intrinsic values” questions as well as the intergenerational issues, or even acknowledge that SGE may be ‘inherently unethical’, they then largely ignore these observations. An obvious manifestation is that whilst ethical concerns may be conceded to be central, they are absent from the proposed criteria for evaluating geoengineering. For the Royal Society affordability, effectiveness, timeliness and safety are the key evaluation criteria (2009:48). For the NRC a similar, albeit more elaborate and complex, set of criteria is adopted.88 Criteria related to justice or consent concerns do not make an appearance, and neither do “intrinsic values” concerns.

In summary, SGE raises major ethical questions, including about how humans are and should be in the world, and whether they have the right to re-mould it so fundamentally, and whether it is ‘inherently unethical’. But in the ‘institutional literature’ the ethical questions are persistently ignored or narrowed in three key ways. Firstly, the intrinsic values issues are glossed over, ignored or simply noted without further reflection.

Secondly, ‘moral hazard’ is treated as the most important ethical issue. It occupies centre stage in almost all the ethical sections of the institutional reports. Whilst the word ‘moral’ suggests that ethical questions are in play, it is hard to understand why the possibility of SGE leading to reduced mitigation should be treated as an ethical issue rather than a socio-political one, a question of climate policy choices. Further, what does it mean to centre ethical attention around a concept drawn from actuarial science and insurance economics? Reducing

87 My point here is that concerns about intrinsic values are largely absent in the institutional literature. I acknowledge that values questions are widely recognised in the broader field of SGE research, by writers and researchers coming from both the sciences and social sciences. For example, atmospheric scientists and volcano specialist Alan Robock includes such reasoning in his widely published list of objections to SGE (2008). And Keith states that ‘[c]ritiques of geoengineering arise from diverse worldviews’ (2013:125) … although it might be more accurate to state that this proposition applies to both critics and proponents of geoengineering.

88 In the NRC report, the cost and effectiveness (will it cool?) criteria used by the Royal Society are retained. Timeliness is subdivided into time to scale-up (essentially in an emergency), time to deploy in a well-planned manner, and time for the radiative effects to dissipate if terminated. Technological readiness (both at device and systems level) is an additional criterion compared to the Royal Society report, as are a number of measurement, surveillance and geo-political indicators, such as whether any ‘unsanctioned’ SGE could be identified (2015a:116-120).
ethics to ‘moral hazard’ not only silences ethical concerns. It also, in effect, privileges a cost-benefit way of looking at the world and of containing ethical concerns within that framework.89

Thirdly, the ‘institutional’ literature typically reduces consent and justice questions, which revolve around ethical accountability, to governance questions.90 And governance is, in turn, as Gardiner notes, narrowly construed as institutional arrangements regarding which law or institution should take charge (Gardiner 2011b:170). As noted earlier in this chapter, there is reluctance among the most powerful to the adoption of globally inclusive governance frameworks. Perhaps not surprisingly then, governance questions are narrowed further and commonly end up focussing on research governance. In the institutional literature this is typically operationalized as the need for research protocols outlining the conditions under which experiments might take place or field testing be permitted, and has resulted in the Solar Radiation Management Governance Initiative (SRMGI 2011), the Asilomar initiative (ASOC 2010) and the Oxford Principles (for an account by the authors of these principles see Rayner et al 2013), and debates as to whether any rules should be more or less voluntary. These appear to draw on the important, but narrow, field of laboratory and research ethics. Paul Nurse, the President of the Royal Society, has argued, for example, that geoengineering is akin to testing pharmaceuticals and should be similarly encouraged (2011). A more sceptical observer might note the absence, in this analogy of the associated principle of ‘informed consent’ and how this might be applied when experimenting with the Earth itself!

In glossing over, ignoring or narrowing the ethical issues, it is hard not to conclude that the institutional literature largely inhabits the terrain of what Gardiner labels ‘moral corruption’ – the self-interested subversion of moral discourse. Perhaps awareness of this and discomfort about it helps explain the ubiquitous presence of Recommendation 1 in most of the ‘institutional’ reports.

Conclusion
In this Chapter I have attempted to delve more deeply into SGE today. The picture which emerges is filled with contradictions, silences and paradoxes.

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89 I concede that ‘moral hazard’ sometimes appears to be used as a shorthand for something else entirely – to suggest that SGE enables us to ignore the need to change existing consumption and production patterns. When used in this way it may be compensating for the silences about capitalism which pervade the institutional literature.

90 See for example Armeni & Redgwell (2015) and the Solar Radiation Management Governance Initiative (SRMGI 2011), and the Asilomar (ASOC 2010) and Oxford Principles (Rayner et al 2013) initiatives.
When examining the approach adopted to developing Knowledge about SGE, and the epistemological choices made, I show how these follow the heavily scientised pattern of much existing climate policy. The scientific and the technical are elevated above other forms of knowing, and climate reductionism is the predominant approach used to project what the social effects of SGE might be. The radical uncertainty which adheres to what is entailed by SGE is conceived as a standard risk and probability problem, resolvable if only more data could be gathered. And the utilitarian economic approaches embraced facilitate the calculation of the direct cost of SGE but not its societal and world-making costs. These ways of knowing act to normalise SGE as both potential technology and climate policy. But they seem inappropriate to the task and ill-suited to tackling the questions raised by the proposal that a group of people and governments should reshape our climate/s and remake our world/s. They are more suited to assessing a narrow technical object than the sociotechnical entity which is SGE.

The ethical and Values questions which are raised by SGE are many, complex and substantial, and this is acknowledged by all institutional reports and almost all informed analysts. And yet this acknowledgement occurs alongside the neglect of these questions, and the narrowing of those questions that are engaged with. The assumption appears to be that having laid the scientific and technical foundation for analysis of SGE, the values questions can be handled by others, elsewhere and later. This too is, in effect, a normalising move. Unfortunately for proponents of SGE it sidesteps the widespread ethical concerns, which often have substantial popular resonance: the suspicion that SGE may be, as some have noted, ‘inherently unethical’ and undesirable, that it may be a step too far in what humans can and should do. It is to ignore that such questions are at the heart of the technology itself and not additional to it.

The relationship to Power is more complex. The invocation of climate emergency is rhetorically powerful but, to date, unsuccessful in normalising SGE. The seriousness of the climate situation is used to make radical intervention in the planet thinkable, even as intervention in the dominant order is passed over in silence. Whilst SGE is theoretically compatible with the maintenance of capitalism it is not yet understood to be convenient or essential to the maintenance of the dominant global order. Further, even this potential appeal may be outweighed by the undemocratic implications which appear to adhere to SGE and its potential to exacerbate geo-political instability, which together may contribute to instability more than stability.

In short, the Power, Values and Knowledge/s of SGE contribute to its normalisation and bring it closer to being regarded as a legitimate, acceptable and actionable part of climate policy,
albeit not a desirable part. But equally, the internal incoherence of the knowledge approaches adopted and their inappropriateness for the object being considered, the manifestly inadequate treatment of the widespread ethical concerns, and the destabilising geo-political possibilities have contributed to making SGE difficult to normalise.

There are other explanations too to help understand what is constraining SGE’s normalisation as an acceptable and respectable component of climate policy. One is the obvious resistance by many climate and environmental scientists to the geoengineering turn. There would appear to be a disconnect between the key knowledge-brokers and proponents of SGE and large parts of the epistemic community within which they are located. This constrains the emergence of a large enough coalition of experts able to champion SGE, especially important in the absence of champions with significant political power. I will return to this point in later Chapters.

There is also the manifest lack of a positive narrative for SGE, or even a hegemonic narrative amongst the many which are currently circulating. This will be the focus of my next Chapter. Finally, the actual changes in climate have not yet been large enough, in the locations that matter politically, to make those with power accept the idea that mitigation is failing and SGE may be needed. I will return to this point in the concluding Chapter.

The confluence of particular Power interests, and approaches to Values and Knowledge questions surrounding SGE reveal the normalising moves contained in the institutional literature. But the many contradictions and paradoxes help explain why SGE is currently unable to be normalised and why even research into SGE is struggling to find traction and funding. It is apparent that, as Macnaghten and Szerszynski have argued, SGE is not, ‘a unified, stable technological object with clear intent that can be judged against other [climate] policy options’. Rather, it is ‘a political project with unstable intent whose novelty lies in using mundane technologies to bring planetary systems under human control’ (2013:467). Understanding SGE as technoscientific object aims to normalise it just as failure to understand it as a sociotechnical project constrains this normalisation from occurring.
Chapter 6: Competing narratives of solar geoengineering

‘They call it geoengineering – we call it geopiracy.’ (ETC Group 2010a:1)

‘If we could come up with a geoengineering answer to this problem, then Copenhagen wouldn’t be necessary. We could carry on flying our planes and driving our cars’.

(Sir Richard Branson, industrialist and airline owner, 2009)

‘Even if a large dose of geoengineering is applied, quite a lot of triage may remain as well’.

(David Victor 2011:198)

‘It is hyperbolic but not inaccurate to call [solar geoengineering] a cheap tool that could green the world’.

(David Keith 2013:x)

‘The future is unthinkable. Yet here we are, thinking it.’ (Timothy Morton 2016:1)

In the institutional literature solar geoengineering (SGE) is predominantly understood as a technoscientific project which, regrettably, may be needed to deal with a looming global climate crisis. Whilst the social, political and ethical implications of SGE are acknowledged, they are generally presented as additional complications. They are additive to the challenge of making SGE happen rather than transformative of the way the challenge is apprehended. They are complications needing further research. Yet what has been pushed to the margins is, I argue, central to engaging with SGE. As I argue in the previous chapters, the dominant institutional approach which understands SGE largely as a technoscientific challenge, helps explain why SGE has been unable to be stabilised as an object of enquiry, and to be normalised as a legitimate additional leg of climate policy. To understand SGE, engaging with the idea of SGE, with how it is imagined, and the imagined world in which it is expected to be deployed, is as important as engaging with SGE as a proposed technology. Indeed, understanding how SGE is imagined will undoubtedly shape the form the technology takes and whether it emerges as a deployed technology at all.

In this chapter I will explore the ‘sociotechnical imaginaries’ (Jasanoff 2015) of SGE, none of them hegemonic. I will identify four competing narratives: which I label ‘Un-natural’, ‘Market’,
'Geo-management’ and ‘Salvation’ respectively.91 With one notable exception, these contain, in my view, the key sociotechnical imaginaries of SGE which are in common circulation.92 It may be possible to envisage more than four competing narratives, but these would only serve as further variations on the four narratives rather than a new narrative. It is difficult, for the reasons already outlined, and precisely because none is hegemonic, to extract these imaginaries directly from the major institutional reports, although elements of each of the competing narratives are contained or implicit within each report. I outline each of these narratives by focussing on a representative text, and where appropriate taking a range of other associated sources into account, in an attempt to present each in their ‘best’ and most coherent version. I will explore their assumptions, stated and implicit, about the contemporary world, nature and the environment, technology and science, democracy and climate change, as well as their stance towards the future, their ‘mood’. In doing so I will draw

91 To hold onto the reality that none is currently hegemonic I will commonly call these ‘narratives’, whilst keeping the term ‘imaginaries’ present too. I do this to remind us that each narrative, or a number of narratives in combination, has the potential to become hegemonic, to move from being one account among many to becoming the preponderant, taken-for-granted imaginary of SGE in the sense defined by Jasanoff (see Introduction).

92 The so-called ‘Chemtrail’ narrative around geoengineering has a significant internet presence. The numbers familiar with and accepting of its account exceed those familiar with mainstream geoengineering (see Cairns 2014 for a rare and useful account of chemtrail thinking). In brief, the Chemtrailers argue that a global elite (not clearly specified) is actively, and secretly, poisoning the land, air and water, and spraying toxic chemicals from airplanes for malevolent purposes (such as to cull population numbers). They see more recent discussions of solar geoengineering as evidence that this practice is finally being uncovered, and interpret denials that SGE has yet to be deployed as part of the elite conspiracy of silence. There are many variants of the Chemtrail narrative. From an analytical perspective, on the one hand I am reluctant to exclude consideration of the Chemtrail imaginary since my focus in this Chapter is on what worlds are imagined, rather than the truth or falseness of the claims being made. As Pelkmans and Machold put it: ‘assessments of conspiracy theories should focus not on the epistemological qualities of these theories but on their interactions with the socio-political fields through which they travel’ (2011:66). David Bloor’s injunction is that if we want to understand the causes of why some beliefs and understandings are held, it is best not to begin by making distinctions between ‘true’ and ‘false’ beliefs, but rather to develop modes of analysis able interrogate all knowledge claims symmetrically (Bloor 1991). This, and the size of its imaginative purchase in the United States and other industrialised ‘Western’ countries (Cairns 2014) is grounds for including Chemtrails as a fifth narrative, alongside the four already mentioned. On the other hand, it is difficult to find a single coherent account of the Chemtrail story which could be used as an exemplar: there are multiple, contradictory, accounts. This makes it hard to compare with the four narratives I do analyse. Further, the chemtrail narrative predates the re-emergence of SGE and has been re-formulated and attached to SGE only after SGE’s re-emergence. It also operates with entirely different (and diverse) suppositions about the ‘reality’ of climate change, compared to the other four narratives, and is very different too in assuming that SGE is currently happening and has been happening for a long time. This makes the Chemtrail narrative difficult to interpret using the metrics and frameworks I will adopt. I have therefore chosen to present and analyse the Chemtrail narrative separately, and will reflect there on its relationship to social, economic and political power and to the other four narratives.
on much of the analysis and exposition contained in earlier chapters, without replicating it in any detail. Which, if any, of these competing sociotechnical imaginaries prevails will shape, at least as much as the realities of rising temperatures, whether SGE moves from an imagined to a deployed technology.

I then place these competing imaginaries alongside each other, and try to understand and compare the work that each does in relation to the existing structures of power in the world. I also examine the most recent of the major institutional accounts, the authoritative and substantial NRC report *Reflecting sunlight* (2015a). I show how each of the four imaginaries has a shadow presence inside that report, although never articulated fully, and with the incompatibilities between them unresolved. I conclude by reflecting on why none of the competing imaginaries has, to date, become hegemonic and suggesting that SGE is a sociotechnical imaginary struggling to be born.

### Four competing narratives

In this section I examine the thinking and argumentation which animates four competing accounts of what SGE is, what it is for, where it fits in to broader understandings of the world, and what its future trajectory ought to be. The first, which regards SGE as ‘un-natural’ and perilous is essentially an oppositional and resistant, imaginary. It sees SGE as a dangerous technology of hubris (a techno-fix), a disaster waiting to unfold, and argues it should not be allowed to proceed. The strongest version of this argument can be found in the publications and press-releases of an NGO, the ETC Group, most notably its report *Geopiracy: the case against geoengineering* (2010a). The second, which embraces SGE enthusiastically, often opportunistically, as a market-friendly solution is most eloquently expressed in the work of Bickel & Lane (2010), and by various ‘free-market’ think-tanks. The third sees SGE through the lens of geo-politics regarding it as a powerful instrument, to be wielded by geo-politically powerful nations, in the face of a terrible climate prognosis and a politically unstable world. I analyse David Victor’s book *Global Warming Gridlock* (2011) as a developed version of this view. The fourth sees the use of some SGE as essential to save humanity from the ravages of climate change, and makes the argument that some SGE should be embarked upon, and soon,

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93 Mike Hulme’s book *Can science fix climate change?* (2014) makes similar arguments in some respects. So too does James Fleming (2010a). I decided against using either book as my exemplar because I rely on their analytical perspectives elsewhere in this thesis and because the ETC Group’s approach is more explicitly normative and resistant in tone, which is a more appropriate fit when thinking about imagined futures.

**A brief detour into human engineering**

Before teasing out these four imaginaries I take a brief detour into a radically different imaginary, a proposal for a climate-focussed alternative to SGE other than emission reductions. It is important to note that this proposal has found no support from any institution, indeed what it proposes could be regarded as ‘taboo’. The alternative proposal can be found in a 2012 paper by Liao, Sandberg & Roache entitled ‘Human Engineering and Climate Change’. The authors note that responses to climate change, behavioural and market-based attempts to reduce emissions, have not been effective, and that geoengineering is risky. They call instead for ‘human engineering’ to be considered: ‘the biomedical modification of humans to make them better at mitigating climate change’ (2012:207). Interventions discussed include pharmacologically-induced meat intolerance, gene selection and hormone treatments to make new humans smaller (and thereby literally reduce their footprint), cognition enhancement aimed at reducing birthrates (smarter people apparently have fewer children), and pharmacological enhancement of altruism and empathy (since higher empathy levels are believed to correlate with better environmental behaviours).

Liao *et al* argue, not unreasonably, that human engineering is ‘potentially less risky than geoengineering’ and that it could make ‘behaviour and market solutions [to climate change] more likely to succeed’ (2012:211). They analyse the objections that could be made to ‘human enhancement’ and respond to each one in detail. Many of these are remarkably similar to objections to SGE (including the charge of hubris and being ‘un-natural’). But on the face of it they should be less troubling, especially given the human engineering they propose would be voluntary, albeit incentivised. Assuming it is not intended as parody, why has Liao *et al*’s paper, to the best of my knowledge, received no support from anywhere? Why is this proposal considered to be ‘beyond the pale’ and regarded as taboo whilst the taboo surrounding SGE has dissipated? I make no attempt here to answer these questions. My purpose in posing them is to draw attention to three things, as we start to explore the competing narratives of contemporary SGE. First, that the natural/un-natural binary remains a socially powerful one, notwithstanding that it may rest on analytically shaky foundations. Second, that between taboo and normalisation lies an intermediate zone where a proposal is imagined to be possible, where it is no longer taboo but not yet normal. SGE is currently in this intermediate zone and ‘human engineering for climate change’ is not. Third, that whilst SGE is now treated as familiar, it may be helpful to be able to retain a sense of its strangeness, as this is perhaps how most non-experts still regard SGE.
Un-natural: the perils and injustice of geopiracy
The Action Group on Erosion, Technology and Concentration (known as The ETC Group) is a small Canadian-based global NGO which, according to its website, ‘works to address the socioeconomic and ecological issues surrounding new technologies that could have an impact on the world’s poorest and most vulnerable people’ (n.d.). It campaigns against geoengineering testing, experimentation and deployment under the banner of Hands Off Mother Earth (H.O.M.E.). It has not directly shaped the institutional reports although they could be said to have influenced them indirectly: many of the reports reference ETC’s views and some have included panellists holding views broadly similar, but expressed in less activist terms.

‘Geopiracy’ is how the ETC Group characterises geoengineering (2010a): a ‘gamble with Gaia’ (2010b). Its standpoint is manifest in its choice of cover design for the report Geopiracy: the case against geoengineering (2010a). This consists of an adaptation of Edvard Munch’s well-known painting The Scream said to reflect the painter’s ‘feeling of “a great unending scream piercing through nature”’ (2010a:i) (see Figure 6-1). At stake in geoengineering is ‘international control of planetary systems: our water, lands and air’, as well as retaining existing commitments to mitigation and adaptation. If this ‘quick, cheap fix’ is adopted then rich governments will devote resources to ‘this “scientific solution” and there will be no resources to help the global South fend off the chaos ahead’ (2010a:1). Further, there is no reason why the global South should ‘trust that the governments, industries or scientists of the biggest carbon-emitting states will protect their interests’ (2010a:4).

For the ETC Group ‘a moratorium on real-world geoengineering experimentation is urgent’ and the United Nations and the International Court of Justice should confirm that any experimentation would be in breach of ENMOD (2010a:2), the treaty we encountered in Chapter 2.

The ETC Group is keen to unveil the network of interests, plutocrats and scientists engaged in geoengineering. They talk of a ‘geo-clique’, and itemise the scientists involved in research who have also lodged geoengineering-related patents, and the ultra-wealthy individuals who have engaged with geoengineering (such as Bill Gates).

‘[T]here is a complex web of connections between big capital and the global technofixers, comprised of researchers, multinational corporations and small start-ups, the military establishment and respected think tanks, policy makers and politicians’ (2010a:38).

In the process the ETC Group perhaps assumes a greater commitment to geoengineering, at least to SGE, and a greater unity of purpose amongst such participants than may in fact be the
case. This helps explain the conspiratorial tone which permeates their understanding of geoengineering’s emergence.

In exploring SGE in particular, which ETC Group calls ‘artificial volcanoes’, whilst there are ‘many unknown impacts ... already there is research’ suggesting the likelihood of a range of negative effects. Here they draw on atmospheric climate scientist Alan Robock’s ‘20 reasons why geoengineering is a bad idea’ paper (2008) and mention effects including differential regional impacts, drought, ozone damage, the ‘whitening’ of skies, and the expectation of a ‘bounce-back’ effect after termination. ETC Group also note, as Robock does not, that ‘geoengineering the stratosphere makes it easier for industry to continue its own atmospheric pollution’ (2010a:26).

This concern with capitalism (although they do not name it) and with power relations (especially North-South) permeates the ETC Group’s vision. ‘Should a “Plan B” ever be agreed upon’, patent applications make the prospect of it being private ‘terrifying’: ‘planet-altering technologies should never be undertaken for private profit’ (2010a:33). They are concerned too about ‘the self-serving gambit of climate-deniers and cringing politicians in the temperate zone’ recasting geoengineering as “foreign aid” (2013b:n.p.). As they put it in their Geopiracy report:
'Peoples of the South should be in control of climate response decisions instead of being cast as helpless victims waiting to be saved by the technologies of the North, with lip service to their interests the only acknowledgement of their dilemma’ (2010a:37).

For the ETC Group geoengineering is a manifestation of ‘scientific hubris’, a ‘techno-fix’ and a risky undertaking which ‘flies in the face of precaution’ (2010a:3). They lament an inability to learn the lessons from past weather modification activities. In a neat turn of phrase they ask whether ‘the “Hot Worriers” of today have learned from the “Cold Warriors” of yesterday?’ (2013a:5). Their problem is with ‘Big Science’ rather than science as such:

‘we need a thousand candles of brilliant research rather than a new Manhattan Project. By definition, the practical responses to climate change must change with the latitudes and the altitudes and the ecosystems. ... “Big” Science is going to have to learn to become “diverse” science and to work with Southern governments, local communities, indigenous peoples and peasant farmers already trying to respond to this crisis. Humility will need to replace hubris’ (2009:35).

For the ETC Group, geoengineering is also in some sense “un-natural”, an unnecessary intervention into Gaia (2010c), by which they mean the complex, dynamic and inter-related Earth systems. This approach is manifest in their campaign sticker which depicts a splayed hand signalling “stop”, positioned over the iconic ‘blue marble’ image of Earth (see Figure 6-1).

In short, the ETC Group paint a gloomy and dystopian picture of what a geoengineered world would be like. They imagine SGE to be un-necessary, un-natural, hubristic, risky, driven by self-interest and a desire to avoid mitigation, and against the interests of the global South. It is a technology that should be highly regulated, even stopped. It detracts from tackling the climate crisis.

Market: a techno-fix to enable business-as-usual
It is striking that some of the enthusiasts for SGE come from the ranks of people and institutions often labelled ‘climate denialist’. So, for example, we can find David Schnare of the Heartland Institute (notorious for their annual conferences on de-bunking climate change) arguing for SGE on the grounds it will be quicker and cheaper. The examples of the AEI report or the Copenhagen Consensus reports have been elaborated on in earlier Chapters, including, for example, Bjorn Lomborg’s manifest enthusiasm for geoengineering and similar views from US politician Newt Gingrich. It is to their imaginary that we now turn.

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94 It should be mentioned that Gaia’s ‘inventor’, James Lovelock, regarded geoengineering as an ‘enticing option’ which might ‘buy time’, but also acknowledged it provoked in him ‘a sense of unease’ given the level of ignorance about earth system science (2008).

95 See Schnare (n.d.). See also Klein’s account of the Heartland Institute and its climate conferences (2014:31-44).
To come to grips with this second narrative we must discard, or at least relegate in importance, the notion of ‘climate denialism’ as an explanation for the lack of progress in reducing greenhouse gas emissions. As Pielke has argued, ‘scientific uncertainty is not the main reason behind opposition to action on climate change’. Rather, the political debate over climate ‘takes place in the language of science’. Conflicts over values are framed as scientific certainty/consensus pitted against uncertainty (2007:71-2). It is more fruitful to see that what is discomforting are the presumed implications of acknowledging climate change: that contemporary patterns of consumption, the ideology of limitless growth, and the ‘take-make-waste’ structure of production may be implicated. This is ‘implicatory denialism’ or, more generously if the practices of contemporary capitalism are taken as articles of faith, political difference. It is what President George Bush Snr. meant when he addressed the 1992 Rio Earth Summit and said ‘the American lifestyle is not up for negotiation’ (cited in Singer 2002:2). No wonder differences over the most appropriate actions to take persist, notwithstanding the clear evidence of a warming trajectory driven largely by anthropogenic emissions. And it is undoubtedly the case that prioritising a policy of emissions reductions and de-carbonisation is a policy choice rather than a scientific finding: and, consequently, that other policy options may be valid.

Lomborg, for example, appears to place economic efficiency and growth above all other objectives, or at least to see these as the dominant objectives to achieve ‘development’. He is suspicious of crisis talk in respect of climate, and sceptical of the need for urgent climate action. He reads the genuine scientific uncertainty around climate in that light, downplaying the magnitude and the immediacy of the warming, and emphasising the human capacity to adapt. He is mainly hostile to strong emission cutting policies that may cost a great deal, or may constrain economic growth and development. On this interpretation, he is better understood as a climate ‘inactivist’ rather than a ‘climate denialist’.

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96 I do not contest the evidence presented by Oreskes and Conway in Merchants of Doubt (2010) showing a conscious and well-funded effort to encourage doubt about the science by industries with a self-interest in avoiding the regulation of carbon. Rather, I suggest that this is an inadequate basis for explaining why emission reduction policies have resulted in such modest achievements.

97 Two recent quotes by Lomborg reinforce this point. In December 2013: ‘There’s no question that burning fossil fuels is leading to a warmer climate and that addressing this problem is important. But doing so is a question of timing and priority. For many parts of the world, fossil fuels are still vital and will be for the next few decades, because they are the only means to lift people out of the smoke and darkness of energy poverty’. And in January 2015, following the Paris climate summit: ‘Pursuing this 2C target is very costly and not guaranteed to be successful... If we insist on 2C, we will pay an extra
It is this line of thinking which leads to SGE being embraced by those hostile to existing mitigation policies. It allows them to be scientifically literate on the issue of climate without conceding their core ideology. Indeed this is the basis of the ‘Alternative climate plan’ rationale discussed in Chapter 4. And it is the approach most eloquently and comprehensively expressed in the writings of Bickel and Lane. It is informed by observations, such as that of eminent economist William Nordhaus that ‘geoengineering is at present the only economically competitive technology to offset global warming’ (2007:n.p.).

The business-as-usual, capitalist imaginary about geoengineering is not confined to the fringes. It can be found in comments by the Nobel laureate economist, Thomas Schelling, speaking at an AEI event: that one advantage of geoengineering ‘is that it does not involve drastically changing the way billions of people live and care for themselves on a daily basis’ (2009). And it is essentially the perspective expressed by Richard Branson at the launch of his Virgin ‘Climate Challenge’ in 2009 cited at the opening of this Chapter. Figure 6-2 captures this launch moment and shows Branson tossing a globe of the Earth into the air, alongside Al Gore who looks on with what appears to be a slight sense of discomfort. SGE’s virtue, in this narrative, is that it addresses climate change whilst enabling the fundamentals of the dominant global economic order to continue.

Eric Bickel and Lee Lane have been the lead authors of a number of think tank reports, most notably those of the AEI (2013), and the CCC (2012). Lane was also a co-author of the NASA report on geoengineering(2007). I will not repeat the expositions of their positions contained in earlier Chapters. I will simply recall the main elements relevant for this analysis. On climate change and existing climate policy they argue that greenhouse gas controls have failed and ‘the prospect of an effective GHG control policy remains far in the future, and actual impacts on climate much more distant still’ (AEI 2013:1). In effect, in this argument, there is no reliance on an emergency discourse, and mitigation has not only failed, but was never desirable as the primary policy goal. Some version of a risk argument is implicit in the AEI report, but it is not especially central since the climate effects are seen as more temporally distant. However, in a report for the CCC, SGE’s ability to cool rapidly, it is argued, allows it ‘to play an important risk management role …’ (CCC 2012:4). The main expectation is that people will adapt their ‘customs, dress, crops, structures, locations, and practices to a changing

$60,000 billion, but only prevent a stream of $100 billion damages that begins in 70 to 80 years’. Both quotes cited on DeSmog website http://www.desmogblog.com/bjorn-lomborg#s3.

98 Gore is on record as describing SGE as ‘insane, utterly mad and delusional in the extreme’ (Goldenberg 2014).
climate and its effects’ (p.3). However, adaptation is expensive and will become more so ‘if the change is too rapid or too large’ (p.1). The attraction of SGE, therefore, is that it may slow the pace of climate change and lessen ‘both the harm from climate change and the costs of adapting to it’ (p.1). ‘It represents a possible “force multiplier” for adaptation efforts’ (p.5).

Figure 6-2: Richard Branson playing with planet Earth, whilst Al Gore looks on

Technology is the essential component in the Bickel & Lane argument. The ideal is if ‘green energy technologies’ become so cheap that emission controls become ‘politically more palatable or even superfluous’ (2012:2). But SGE is a stopgap in the absence of this and it is a technology ‘believed to be well within our current capabilities’ (p.20). Bickel & Lane regret that much of the criticism of SGE is ‘tinged with moral censure’, including the charge that government has not achieved enough mitigation, as well as suggestions that the enterprise itself is an example of hubris (p.15).

‘Nature’ does not feature in Bickel & Lane’s argument other than in charging environmental NGOs with seeing ‘any human interference with nature as morally wrong’ and with their being ‘largely deaf to the concept of instrumental rationality’ (2012:17). ‘Democracy’ is also absent, apart from one intriguing reference: ‘[i]t is an interesting question whether democratic forms of government can conduct an R&D program on a concept as polarizing as SRM is at the present time’ (Lane & Bickel 2013:12). This suggests they are alert to, and largely untroubled by, SGE’s undemocratic inclinations. Critics of SGE are charged with having a dystopic view of the technology and its ills (2012:15). But the imaginary implicit in Bickel & Lane’s argument is
not particularly positive or visionary, perhaps because it simultaneously tries to present climate change as not especially urgent or dramatic, whilst being enthusiastic about the potential of SGE. They often seem to cherry-pick facts from the scientific literature relevant to SGE, perhaps even more than the other narratives: for example they persistently downplay the generally-acknowledged risks.

The tone of this narrative is ‘matter of fact’, and its arguments constitute a type of market fundamentalism, where entrepreneurialism, growth and efficiency are the highest purpose. Indeed, the main focus of the work is to model the cost-effectiveness of SGE as compared to mitigation.\(^9^9\) It is simultaneously an argument for SGE and an argument to de-emphasise mitigation as a policy preference.

**Geo-management: taking charge of the climate crisis**

David Victor is an influential and highly respected figure in the shaping of climate and geoengineering policy, especially in the US. His views contain a distinct imaginary, and are worth scrutiny, especially given his involvement as panellist or reviewer in a number of the most influential institutional reports on geoengineering (for example NRC 2015; BPC 2011; IPCC Expert Report 2012; GAO 2010).\(^1^0^0\) Victor’s support for SGE, as found in his monograph *Global Warming Gridlock* (2011), is rooted in a critical account of existing climate policy and its focus on mitigation and adaptation. He examines these issues through the lens of international relations and geo-politics. He is especially influential in articulating what he calls the ‘hard-nosed politics’ of climate change including the need to develop and probably deploy SGE.

For Victor, the existing UN approach to climate policy has not worked because ‘it involves too many countries and issues’ (2011:xxviii). Better to focus on a ‘club’ approach starting with the few ‘countries that matter’, before expanding the club through accession agreements in the manner of the WTO. For Victor any ambition to stay below 2°C through mitigation is ‘probably history’ and ‘we’ need to be ‘bracing for change’ (2011:xxxxii). Adaptation is locally important, but generally not an internationally-effective instrument, and it should largely be left up to each country. Victor acknowledges that adaptation is insufficient or non-existent in many

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\(^9^9\) Bickel has also co-authored with Agrawal a 2013 paper vigorously challenging the economic modelling of Goes *et al.* (2011). This is significant because, as I have recounted in the previous Chapter, Goes *et al.* conclude, using the same style of economic modelling but different assumptions, that SGE would only be economically rational in very limited (and highly unlikely) circumstances.

\(^1^0^0\) Other influential figures in producing institutional reports, for example Granger Morgan (involved in the same reports just mentioned as well as the SRMGI 2011), have co-authored articles with Victor expressing largely identical views to those in *Global Warming Gridlock* (Victor *et al* 2009).
countries, notably those that are not rich enough or ‘smart enough’ to adapt, or have corrupt
governments. The expressions ‘rogue states’, ‘failed states’, ‘weak states’ and ‘small states’
occur frequently in the book and appear to be what Victor has in mind. It is hard not to see in
this an imperial mindset. New technology is therefore critical: ‘technology, not castor oil [ie
bitter medicine], is how most environmental problems get solved’ (xvii). Further, only about
ten countries ‘matter’ when it comes to innovation (2011:xxxii).

For Victor this means geoengineering (by which he means mainly SGE) and ‘Triage’ (a term
derived from emergency medicine), are central ‘bracing for change’ strategies. Triage, for
Victor, is for situations where adaptation has proven impossible, or too expensive, or where
there is not much worth protecting in monetary terms (2011:185). It may entail ‘walking away’
(p.185) – what is meant by this innocuous phrase is not elaborated, but the term ‘triage’ is
suggestive, including as it does the notion of abandoning those who are in any event likely to
die. Victor says new policy options should also be looked into, including ‘for countries that
have consistently failed to create the right context for economic development (and
adaptation)’. He mentions two such options: migration and ‘receivership’, by the latter he
presumably means re-colonisation or resumption of trusteeship of some sort (p.185).

Alongside Triage, and possibly to help reduce the need for it, sits SGE. For Victor, in preparing
for an extreme climate future, and possible climate emergencies, where adaptation is
impractical and costly, we need to develop the ability to ‘mask the horrors with
geoengineering’ (2011:185). ‘We’ need to research and test SGE and government should fund
this. We need to make the public more comfortable with this option. We need to be able to
use it as part of a ‘cocktail’ of interventions in much the way we combat AIDS. For Victor,
working on SGE only with prior international agreement, as some suggest, is misguided and
would result in ‘gridlock’. Any conceivable treaty would only amount to a ban. Making SGE
‘taboo’ would be the worst policy because it is:

‘likely to be most constraining on the countries (and their subjects) who are likely to do the
most responsible testing, assessment, and (if needed) deployment of geoengineering

101 Victor uses the language of policy think-tanks in the global North. It presumably includes countries
included on the ‘Failed States Index’, recently re-badged as the ‘Fragile States Index’: like Pakistan,
Afghanistan, Sudan and Nigeria and their half a billion inhabitants (see for example
http://fsi.fundforpeace.org/ [last accessed 16 May 2016]). These are countries for whom (and to
whom?) things must be done.

102 See Barnett & Campbell (2010) for a critique of the widely articulated view that low-lying Pacific
Islands should be abandoned in the face of climate change and rising seas.

103 For example, since SGE doesn’t address ocean acidification that problem may need a different
geoengineering intervention as part of the ‘cocktail’ of climate interventions.
systems’ (2011:193). ... A better understanding that a taboo is a dangerous policy because it cedes defeat in this race will help realign the politics in the liberal democratic countries in favour of supporting a research program’ (p.196).

Victor’s use of terms such as ‘subjects’, ‘Triage’, ‘receivership’, and ‘countries that matter’, is revealing. This is the world imagined from the standpoint of the geo-politically powerful. There is a presumption that already powerful countries and interests in the world should manage climate and take decisions for the ‘Rest’, including developing and deploying SGE. But it is hard to imagine that SGE imposed by a club of the powerful would be deployed benevolently, in ways good for most but possibly inconvenient to the climate and temperature desires of the powerful. As Stilgoe has pointed out, history suggests that ‘centralised sociotechnical systems controlled by rich people, will tend to exacerbate the gap between rich and poor rather than close it’ (2015a:190). And it is hard to see why the majority of the world’s population, in the global South and in countries that don’t ‘matter’, would accede to this vision of SGE.

Victor seems to recognise this when he urges that any attempts to regulate SGE multilaterally should be blocked. But this then leaves him with the problem of how to make SGE acceptable. The approach he suggests is to normalise SGE ‘through experience and dialog’. ‘Meaningful norms are not crafted from thin air’, Victor argues. They must ‘make sense to pivotal players’, ‘provide a useful function’ and then ‘become socialized through practice’. He believes that the spread of human rights norms may be a model. (2011:195). Certainly, although he does not acknowledge that, it would require a framing shift away from his own miserabilist account. It would suggest arguing that “we are doing SGE for you, not for us”.

Nature and the environment are only present indirectly in Victor’s imaginary. He laments that environmental scholars ‘care too much about their subject’, and are too ‘green’ and ‘evangelical’ around ‘the need to halt planetary destruction’ (2011:x-xi). In his account, nature’s value appears to be mainly utilitarian and its going out of kilter, such as if climate ‘tips’, is of concern because of the risks and impacts on human society. Nature is to be managed. We should adapt to environmental problems where possible, or find ways of masking them (such as by SGE) where needed or if the problems become extreme (p.199). Victor acknowledges that ‘masking requires the cooperation of nature, which is harder to predict and usually less pliable’ (p.199).

Victor imagines a miserable present and an even more miserable and dystopian future, one which ‘we’ need to get used to. He concludes his book:
‘Scenarios where geoengineering systems are deployed are not far off; getting ready for them probably means starting to test and evaluate systems today. The Brave New World is here.’ (2011:200)

The reference, of course, is to Aldous Huxley’s famous techno-dystopian novel, where ten World Controllers run a benevolent dictatorship, a World State. In the novel, this dictatorship controls most of the world apart from a few inconvenient areas where the ‘savages’ are left to their own devices.

In short, for Victor, the economic and geo-political status quo and their maintenance is largely assumed (see also 2010:xvii). SGE is imagined as an elite project, an additional leg of climate policy, and part of suite of adjustments and additions to current approaches to climate change. Climate change is a serious problem for which big technologies are a central solution, and SGE may require undemocratic ‘club’ approaches to be brought into being.

Salvation: saving the world from climate risk
A fourth narrative presents SGE as essential to save the world from the risks of climate change. I take David Keith’s short book, A case for climate engineering (2013), as the strongest version of this argument and indeed of those advocating for SGE more generally. He acknowledges, in the book’s title, that this is a case for SGE, rather than claiming it to be the case. Keith is especially influential in the construction of SGE both as an idea and in practice. He has published extensively on the topic over almost three decades. He is a leading promoter of SGE research, and he has directly shaped and influenced all the major institutional reports.104 His book allows him to express his case for SGE without the constraints of reaching consensus which inevitably shape any institutional policy report – many panels have included members sceptical of the geoengineering turn. I will not repeat the extensive analysis of his views contained in earlier chapters and will focus on summarising the explicit and implicit imaginary contained in his book, and occasionally reference related literature by Keith.

Keith regards predictions of climate catastrophe as ‘rhetorical flourishes’ and holds that ‘there is no imminent existential threat’ (2013:24). However, ‘climate risks are serious’ and the rate of change is especially concerning since our infrastructure, crops and coastal cities have

104 Keith was a member of the Royal Society working group (2009), on the scientific committee of the IPCC Expert Group and the invited keynote speaker for its 2011 session in Peru (IPCC 2012:19), as well as a reviewer of the NAS/NRC report (2015). He was also a co-author of the NOVIM report (Blackstock et al 2009), ‘helped fine tune several of the [Woodrow Wilson] report’s recommendations’ (Olson 2011:vii), was on the Bipartisan Policy Centre’s task force (2011:4), on the scientific panel of the GAO report (2010), on the working group of SRMGI (2011), and was one of four witnesses to testify to Congress about geoengineering (CONG-S&T 2010:4).
evolved for the current climate (p.24-27). The chances of stopping before 500ppm or holding global temperature rise below 2 degrees are seen as ‘remote’. Keith’s imagining of how climate will unfold is entirely consistent with successive IPCC science assessments. This aspect of the Salvation imaginary is distinct from the Market imaginary outlined above which downplays the urgency of the issue.

Keith, like Victor, imagines geoengineering as one of a number of strategies to address climate change. His framework for climate change management is described in the Woodrow Wilson Report (Olson 2011:4), and replicated below as Figure 6-3. Keith does not regard SGE as benign or even desirable: ‘It’s a terrible option’ (quoted in Wagner & Weitzman 2012:n.p.). He even sees the ‘intuitive revulsion’ towards SGE as ‘healthy’ since ‘our gadget-obsessed culture is all too easily drawn to a shiny new tech fix’ (2013:xi). However Keith does see SGE as necessary to reduce climate risk and save the poor. Keith is especially exercised by ‘the ugly prospect of rich people arguing that we should reject the geoengineering Band-Aid – thus denying what may be a large benefit to the poor – in order to goad the rich into cutting emissions’ (2013:137). For him, this ‘repugnant’ argument comes from rich and educated first-worlders claiming to speak for the poor. Better, he suggests, to geoengineer as a pro-poor poverty reduction strategy, not to mention a ‘greening’ one.105 Climate change, and resultant crop losses, ‘will put millions of the poorest at risk’ (p.138). Whilst the emissions and energy use come mainly from the rich, ‘the burdens of climate change fall most strongly on the poor who will also benefit most strongly from geoengineering (if it works) when it reduces these burdens’ (2013:139).

Keith cautions against rushing to use SGE (xii) and advocates using it to offset only some, not all, warming relative to pre-industrial temperatures. He imagines ‘the wise use of geoengineering’ (2013:174), one which recognises the potential risks of the technology. The obvious question which follows is ‘who will ensure wise use?’. Keith attaches great importance to finding a suitable, and plausibly democratic, model of governance, although he does not develop one.106 Keith regards the commonly-cited risks of SGE as overstated. He

105 This is a very similar argument to that presented by advocates of genetically-modified food crops: that it was necessary to supplement the ‘green revolution’ with a ‘gene revolution’ – to increase crop yields and reduce both poverty and pesticide use – whilst labelling opponents of GMOs as ‘anti-science’ (Borlaug 2000). The actual outcomes have been more complicated and less-obviously rosy (Ehrenberg 2016; Hakim 2016).

106 In this regard the ‘Salvation’ and ‘Geo-management’ imaginaries can be seen as complementary. For Victor, realpolitik suggests a small club of states agree on SGE governance, in the apparent belief that wise (or wise-enough) use will follow if a ‘responsible’ state leads.
challenges, for example, the widespread claim that SGE would disrupt the South Asian monsoon, obviously a major negative for any SGE proponent. His choice of words is precise, including the qualifiers: ‘...all studies to date ... suggest that the appropriate use of geoengineering could reduce climate risks to Asian agriculture’ (2013:58 first emphasis in original, other emphases my own). But he mainly contrasts any risks with the far greater risks (as he sees it) of unmitigated climate change (72). Any possible dangers of hubris are outweighed by the dangers of climate change.

Figure 6-3: Keith’s view of where geoengineering fits into ‘climate management’*

For Keith, SGE is an experimental technology, and it is more engineering than science (2013:116). He emphasises that SGE is a mundane and not especially innovative technology. This is true, in one sense. If one assumes SGE to be primarily a technoscientific object, a ‘thing’ or set of things which must be made to operate reliably to spray sulphate aerosols into the stratosphere and achieve cooling effects, then “mundane” is an apt description. It builds upon pre-existing technologies and existing knowledge of physics and chemistry. However, if SGE is understood as a sociotechnical, world-shaping, project then it is not mundane at all.

For Keith, the aim of deploying SGE is to ‘shave the peaks off’ global warming and allow time for mitigation to occur and for carbon dioxide removal technologies to be developed and

* cited in Olson (2011:4)
deployed. He imagines starting with small injections, tracking the effects, and then slowly ramping the dosages up or down so there is no single shock to the system and reversibility is possible. The risks of doing this, he argues, are minimal. Keith’s goal is akin to the ‘climate stabilization’ argument proposed by Wigley in 2006 which we have met in Chapter 4. But here the aim is not to restore the Earth to a previous temperature but to manage a transition to a new climate and, ideally, get to a point where the SGE intervention can cease.

Keith argues that his interest in SGE is ‘rooted in a concern that environmentalism has lost its way’ (2013:xv). He proclaims a love of the outdoors and a suspicion of cost-benefit utilitarian claims about the value of nature.

‘The challenge is to craft an environmental ethic that recognises non-utilitarian values in the natural world without asserting that these values trump all others and without making naïve claims of a sharp distinction between nature and civilization’ (xvii).

In doing so he engages with contemporary thinking about nature, influenced by Marris’s work *Rambunctious Garden* (2011) which argues, says Keith, that ‘environmentalists should abandon the obsessive defense of pristine nature in favor of an expanded environmental ethic that embraces the messy but vibrant reality of landscapes shaped by human action’ (p.xviii). Recognising humanity’s role in shaping landscapes does not ‘drain them of value or turn them into an artifact’. Indeed their value lies in their history, ‘the co-evolution of nature, culture and technology’ (p.xvii). In short, for Keith the foundation of his case for geoengineering lies in the post-natural turn in environmental thinking.

This is accompanied by a political stance, expressed as a humanitarian desire to help the world’s poorest. At the centre of what Keith imagines SGE will bring is the idea that SGE will reduce climate risk and thereby ‘benefit the poor and politically disadvantaged’ by reducing crop losses, heat stress and flooding over the next fifty years (2013:10).

Keith is explicit about his differences with opponents of geoengineering. Local is not better than global: ‘the essence of solving global commons problems like climate is to compel local communities to cut their emissions … [against their] self interest’ (2013:146). On technology he argues that ‘most of the big environmental wins of the last half century have been technofixes’, not ‘social fixes’ (p.147). On capitalism he argues that calls for ‘a fundamental reengineering of market capitalism’ are misplaced: since it does a better job of environmental regulation than any other system (p.145). And on the global south he maintains that whilst it is possible SGE ‘will bolster the power of the strong over the weak … the opposite seems just as likely’ (p.153). The cheapness of SGE means it is ‘a levelling technology’ and ‘acts to diffuse
power away from the richest and most powerful nations to a much larger pool of weaker states’ (p.155).

Couched in the language of values, risk and rationality, and with the self-assurance to proclaim SGE as being part of a new environmentalism and also good for the poor, this too is the voice of power. It is akin to the World Bank and IMF prescriptions of what is needed for the greater good, for stability, for development. Despite all the qualifications, to be solved by further research and small-scale trial deployment, SGE is offered as salvation. The choice of cover image for the book is revealing (see Figure 6-4), since it mirrors standard Christian iconography so closely. It depicts, in grayscale tones, a shaft of sunlight piercing through dark clouds onto the peaceful sea below. It is both similar and distinct from the image adorning the cover of the influential Launder & Thompson edited volume (2010) which takes a global-based view from above the planet, with the bright rays of the Sun rising over the Earth, and with a scientific-looking chart (of rising something) superimposed.

Figure 6-4: Book cover images which encapsulate the ‘Salvation’ imaginary.

Convergences and divergences in competing imaginaries
The four narratives presented above can be understood as presenting competing imaginaries. Imaginaries are animated by particular understandings of how social order is, and should be, structured in the world. They contain and reproduce worldviews, including how the world is ordered, how power is enacted, and to what ends. They are rooted in the present even as
they envision particular futures. Sociotechnical imaginaries are particularly focussed on how these envisioned futures relate to developments in science and technology (Jasanoff 2015).

I summarise schematically, in Table 6.1, the key elements of the four competing sociotechnical imaginaries of SGE discussed above. This includes not only the general world outlook (which I shorthand as the ‘holding imaginary’) which animates each and their general stance towards the dominant global order, but also a range of elements of specific relevance to SGE: such as their understanding of the contemporary climate condition, of ‘nature’, as well as of technology. Mood too is important: hegemonic imaginaries generally project a vision of a desirable future social order associated with the technology, even if a dystopian shadow is acknowledged. This has, to date, proven especially challenging for all but the most blindly enthusiastic proponents of SGE.

None of these competing imaginaries is hegemonic although some are more apparent in the institutional literature on SGE than others. Whilst each sociotechnical imaginary is distinct, and their distinctiveness is emphasised here for heuristic purposes, they often share assumptions and perspectives. The ‘Market’, ‘Geo-management’ and ‘Salvation’ narratives all broadly imagine a continuation of the dominant global order, ‘market globalism’ (Steger 2009), outlined earlier in the Introduction to this thesis. In this sense they can be understood as three related imaginaries of power. And they all share a belief that new and large-scale technology is the most critical component when it comes to addressing climate change, even embracing explicitly the desirability of ‘technofixes’. The ‘Un-natural’ narrative, by contrast, uses this term disparagingly and is explicitly critical of the dominant global order.

Both the ‘Un-natural’ and the ‘Salvation’ narratives are alert to, and troubled by, global inequality and poverty, although they differ sharply as to the best response to this: with the former imagining ‘bottom-up’ solutions (with ‘the poor’), and the latter ‘top-down’ ones (for ‘the poor’).

‘Dangerous climate change’ is a central narrative in mainstream accounts of climate change (Liverman 2009). Three of the narratives (‘Un-natural’, ‘Geo-management’ and ‘Salvation’) take the climate prognosis to be extremely serious and something to be addressed urgently. A discourse of climate ‘crisis’ permeates all their imaginings of SGE although each understands this through different interpretative lenses: as a crisis of global injustice (Un-natural), a crisis of policy and global order (Geo-management), and, more familiarly, as a crisis of rising

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107 The shaded areas indicate elements visibly present in major institutional reports.
temperatures (Geo-management and Salvation). Only the Market narrative downplays the urgency and immediacy of the issue, although it does acknowledge the ‘long tails’ of climate risk. All four narratives embrace a view of climate as a ‘global’ object, although the ‘Un-natural’ imaginary is the only one to stress that climate is experienced differentially and lived locally, and should be responded to accordingly.

The dominant approach to climate, as found in the work of the IPCC, privileges a scientific framing of the issue and a utilitarian analysis of response (O’Lear 2016; Liverman 2009). As I have shown in the previous Chapter, this is also the approach in the main institutional literature on geoengineering. Intriguingly, although all the narratives have an adequate grasp of climate science, none of them prioritises a purely science-based framing of SGE, in the sense of suggesting that policy flows from the science. Policy is understood to be a choice, and the world of SGE that must be imagined needs to be underpinned by more recognisably social (and economic) concerns. The ‘Un-natural’ narrative, perhaps paradoxically, comes closest to an approach rooted in the scientific literature, by placing a heavy reliance in its argument against SGE on the general insight from the Earth Sciences that Earth systems are complex and interlinked, with deeply uncertain dynamics. This embrace of science is mobilised to suggest any interference with such complex natural systems should be avoided, although perhaps it is ‘post-normal science’, as discussed previously, which is being embraced.

As outlined in an earlier chapter, all public surveys report that much of the discomfort with the idea of geoengineering is because people find what it is proposed to do to the Earth to be in some sense ‘un-natural’. Nevertheless ‘Nature’ is barely discussed in the ‘Geo-management’ narrative, other than as something to be managed. The ‘Market’ narrative similarly does not reflect on this issue, apart from a few disparaging comments about environmentalists. But it does assume that nature is secondary to human interests and economic imperatives. Only the ‘Salvation’ and the ‘Un-natural’ narratives pay attention to the question of nature. The issue is, of course, central to the ‘Un-natural’ narrative where SGE is imagined as a violation of Gaia, an offence against ‘Mother Earth’/Pachamama. The ‘Salvation’ narratives takes a different approach. Keith, who I have presented as the author of the strongest version of the

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108 As the Richard Branson quotation at the head of this chapter suggests, it is possible to envisage versions of the ‘Market’ imaginary more in line with mainstream views of the climate situation as both serious and urgent.

109 Bickel & Lane are almost alone in being drawn to an EPA definition of geoengineering as ‘the intentional modification of Earth’s environment to promote habitability’ (2009:5). This definition subtly shifts the focus of geoengineering from its standard one of addressing climate change to one which explicitly prioritises human interests.
‘Salvation’ imaginary, regards himself as an environmentalist and a dedicated lover of wilderness, and is clearly troubled by the Nature problem. He lands on the position that there is no longer any true wilderness, that we live in hybrid environments, and that the question therefore becomes what elements of the non-human we choose to value and, accordingly, how we shape the world. This is post-nature thinking in the Breakthrough Institute tradition, and indeed Keith is a founder signatory of their *Ecomodernist Manifesto* (2015).

Science has its institutional politics too. In the attempt to get SGE taken seriously as a climate policy option and enable its development and trialling to proceed, two of the narratives (‘Salvation’ and ‘Geo-management’) are closely aligned politically. Indeed, whilst I have separated them here, it is possible to interpret them as two sides of a single imaginary – with the ‘Geo-management’ narrative emerging from a disciplinary focus on international relations, governance and climate policy; whilst ‘Salvation’ focusses on the science and engineering relevant to SGE and the promise of a better-than-otherwise future. Arguably the ‘Market’ narrative is also aligned, judging by the frequency of reference to SGE’s cheapness in both the ‘Geo-management’ and ‘Salvation’ narratives. In this respect, especially given that each imagines a continuity with the dominant global order, the ‘Market’, ‘Geo-management’ and ‘Salvation’ narratives can also be understood as three threads in a single ‘Power’ imaginary.

In practice, David Keith and David Victor have both been particularly influential in shaping the institutional reports (as panellists and reviewers), and other key panellists and SGE knowledge-brokers, as identified in the Introductory Chapter, appear to broadly share their sociotechnical views. And yet neither the ‘Geo-management’ nor the ‘Salvation’ narratives and their associated imaginaries have managed to become hegemonic, and generate a more stable and widely embraced vision of why SGE is needed and how it should proceed. If anything, between the Royal Society report (2009) and the NRC report (2015a) their influence has diminished. Why the imaginaries associated with the most institutionally embedded narratives have failed to become dominant is a question I will return to towards the end of this Chapter.

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110 The version of the ‘Market’ narrative I have selected as an exemplar is especially ideologically partisan. This may explain why the ‘Salvation’ imaginary is often embarrassed by the implications of embracing such strongly utilitarian principles when it comes to the problem of climate change, whilst still acknowledging the cheapness of SGE and the some of the cost-benefit modelling which flows from the ‘Market’ narrative.
Chemtrails: a shadow fifth imaginary

I will now touch briefly on the chemtrails narrative, which can be understood as a shadow imaginary lurking in the background of mainstream discourse (both supportive and oppositional) about SGE. There is no single Chemtrail story but variants can be found on a variety of websites, many of which have extremely large followings. These are heavily based in the United States but significant followings and local sites can be found in a number of European and other ‘developed’ countries.

The Chemtrail narrative typically calls on people to ‘wake up’ and ‘look up’ and recognise that government (on behalf of global elites) are engaging in a secret geoengineering program to poison people (and their land, water and air) by spraying dangerous chemicals and biological agents from aircraft at high altitudes and claiming that these are the normal contrails produced by aircraft. There are various accounts as to who the elites getting government to do this are: bankers (sometimes Jewish bankers is the suggestion), The Illuminati, the military and the powerful generally. Many poisonous chemicals are said to be involved: aluminium, arsenic, barium and much else besides. The Chemtrailers’ major concern appears to be to expose this conspiracy. Why the elites would be doing this is rarely fleshed out: perhaps to reduce population, is sometimes the suggestion, but a generalised assumption that this is what ‘they’ do pervades the websites. Figure 6-5 is a typical example of the innumerable photographs produced as evidence by Chemtrail websites. The sites take great pains to claim scientific authenticity: they produce test results of soil contamination for example although they are less clear when showing a link between these and the aircraft contrails. It is sociologically revealing that the comments sections of these websites frequently make a connection between the chemtrail conspiracy, as they see it, and other conspiracy theories (such as the JFK assassination). Noteworthy too is that in 2016 website comments have also frequently expressed admiration for Donald Trump.

No consistent position on climate change is evident. Some sites make no connection to climate change. Others see climate change as another elite ‘hoax’. Yet others suggest that the spraying was first done to change climate and is now done to cover up that ‘fact’. Increasingly, the Chemtrail sites talk about solar geoengineering rather than chemtrails.

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111 Major ones include GeoengineeringWatch, GlobalSkyWatch, Global Research (which calls itself a centre for research on globalization) amongst many, many others (Cairns 2014). There are also websites which specialise in debunking chemtrail ideas as pseudo-science, notably ContrailScience. These sites morph and change rapidly and so the most reliable source to verify the above assertions is simply “google ‘chemtrails’”.
<table>
<thead>
<tr>
<th><strong>SGE seen as ...</strong></th>
<th><strong>Un-natural</strong></th>
<th><strong>Market</strong></th>
<th><strong>incipient</strong></th>
<th><strong>‘Power’</strong></th>
<th><strong>imaginary</strong></th>
<th><strong>Salvation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Holding imaginary</strong></td>
<td>dangerous elite initiative which must be opposed.</td>
<td>opportunity for capitalist-friendly climate solution.</td>
<td>essential addition to portfolio needed to tackle climate change.</td>
<td>essential to save the world’s poorest from dangerous climate change.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capitalism / dominant order</strong></td>
<td>Global North dominates the world and resists both strong climate action and justice for the South. RADICAL (SOUTHERN) ALTERITY</td>
<td>Economically neo-liberal. Most problems solvable by removing regulatory barriers to free enterprise. MARKETS, GROWTH &amp; DEVELOPMENT</td>
<td>Contain climate catastrophe by getting ‘countries that matter’ to take realistic action. REALIST POLICIES + TECHNOLOGY</td>
<td>Avoid climate catastrophe and make the world safe for modernity and development. THERE IS NO ALTERNATIVE</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Climate</strong></td>
<td>Big capital causing climate problem; dominance of global North a problem</td>
<td>Strongly favour capitalism and assume US geo-political hegemony Rational calculation (utilitarian cost-benefit) model the key to decision</td>
<td>Existing economic and geo-political order are the assumed ‘reality’</td>
<td>Flawed but adaptable; no need for fundamental change</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nature / environment</strong></td>
<td>A major problem which has existing answers (mitigation, climate justice, equitable carbon budgets, CBDR etc)</td>
<td>A potential future risk / problem. Dominant policies (mitigation, pricing carbon) expensive and growth-reducing</td>
<td>A major problem, but an energy markets and technology problem not an environmental one</td>
<td>A major problem where mitigation is too slow and unlikely to be enough.</td>
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</tr>
<tr>
<td><strong>Science &amp; Technology</strong></td>
<td>Undemocratic and unjust if climate response decisions made in the global North.</td>
<td>Democracy may constrain action to develop SGE.</td>
<td>Club of powerful states must co-operate (not all states). Silent on justice. Democracy subservient.</td>
<td>Justice (as Development) important motivation for SGE. Silent on democracy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mood</strong></td>
<td>Need localised, humble technologies not globalised, big science technofixes. Uncertainties and dangers too great.</td>
<td>Embrace technology and technofixes.</td>
<td>Affordable, effective technologies the key answer to environmental problems. Brave New World</td>
<td>Technofixes where needed. SGE more engineering than science; resolve uncertainties in practice.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dystopian present and chaos ahead if SGE imposed on the world</strong></td>
<td>Bland, matter-of-fact and technical</td>
<td></td>
<td>Miserabilist Realism</td>
<td>Distasteful option but ‘lesser evil’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geoengineering implication</td>
<td>Risky and dangerous.</td>
<td>Actively develop and deploy if not too obviously risky.</td>
<td>Get it ready as it may be needed, even if risky.</td>
<td>Develop, incrementally deploy, monitor, further develop etc... Use as part of portfolio of action (including mitigation).</td>
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<tr>
<td>Resist imposition on global South. Ban deployment and constrain research.</td>
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</tbody>
</table>

Table 6.1 – Summary of competing narratives of solar geoengineering
The ‘Chemtrail’ narrative shares with the ‘Un-natural’ narrative a sense of being outside the corridors of power, and both are suspicious of the workings of global elites. Both narratives are also suspicious of technologies in the hands of elites. Both can be seen as expressions of an absence of power, unlike the ‘Market’, ‘Geo-management’ and ‘Salvation’ narratives. But they also differ. The ‘Un-natural’ imaginary is rooted in mainstream understandings of climate change and climate science. It is anti the dominant order rather than anti-government. It also accepts that SGE is not yet happening.

**Traces in the NRC report**

Traces of each of these narratives and their associated imaginaries can be found in the institutional literature, although combined slightly differently in each of the institutional reports. In Table 6.1 the shaded parts of the Table indicate the component parts of the

* Sourced from GeoengineeringWatch.org (2016).

111 Only the Chemtrail narrative is explicitly addressed in the institutional reports. The NRC report, for example, labels it a conspiracy theory and a myth which persists despite being repeatedly debunked. In so doing it understands ‘myth’ to be an ‘untruth’, a standard techno-scientific formulation, when myth could as easily be understood as a powerful and persistent story which captures and feeds popular imagination. The NRC report does not inquire into why this ‘myth’ might persist but it does note that it illustrates ‘the possible type of reaction from a portion of the public when and if a climate intervention effort is undertaken’ (2015a:208). One lesson it draws is that ‘the involvement of private contractors
various imaginaries which are most visible in the institutional reports, especially the most authoritative and influential reports emanating from the NRC (2015a), the Royal Society (2009) and the IPCC (various). Based on the details of the institutional reports presented in earlier chapters, the elements selected should not come as a surprise.

To avoid repetition I will illustrate my argument by examining one report, Reflecting Sunlight (NRC 2015a), in more detail. Produced by the National Research Council of the US National Academy of Sciences: ‘the nation’s pre-eminent source of high-quality, objective advice on science, engineering, and health matters’, it is the most comprehensive, authoritative and up-to-date of the institutional reports. It emanates from the centre of SGE technoscientific expertise, the United States. And it is, along with perhaps the Royal Society report, the most influential. Further, its main focus is specifically SGE and, to a lesser extent, marine cloud brightening (a separate report examines CDR). It should be noted that the composition of its panel and referees, whilst still primarily science-centred, was more varied than most other institutional reports.¹¹³

Some background information is pertinent. At the request of, and sponsored by, the US ‘intelligence community’ as well as the National Oceanic and Atmospheric Administration (NOAA), NASA and the Department of Energy, the United States National Academies established a Committee to consider ‘Geoengineering Climate: Technical Evaluation and Discussion of Impacts’. This committee was tasked to examine key examples of ‘both solar radiation management [SRM] and carbon dioxide removal [CDR] techniques’ (2015c:129). I have outlined elsewhere the committee’s rejection of the term at the centre of their brief, “geoengineering”, as implying ‘a greater level of precision and control than might be possible’. Instead they labelled the object of their study ‘climate intervention’, because “intervention”, as they put it, connotes ‘an action intended to improve a situation’ (2015a:x). They also diverged from their brief in rebadging “solar radiation management” as the less managerialist and more science-sounding ‘albedo modification’. The particular technique which is the focus of this thesis, SGE, is called ‘Stratospheric Aerosol Albedo Modification’.

rather than the military services would likely help promote international buy-in and help minimize conspiracy theories’ (2015a:209).

¹¹³ The reviewers included David Victor, David Keith and a co-author of Keith’s, Edward Parson, all of them broadly supportive of the SGE turn. But it also included Alan Robock, a scientist known to be sceptical of SGE on pragmatic, evidence-based grounds (2008), and Clive Hamilton, known to be hostile (2013a). This, in itself, reinforces the notion that no single imaginary is hegemonic, and that compromises were assumed necessary in determining the composition of the panel and the choice of reviewers.
The report presents itself in the voice of detached, objective, science, and it visualises the variables in a manner similar to the IPCC assessment reports – Figure 6-6 presents a representative sample of images used in the NRC report. These reveal how it conceives of SGE as a technoscientific intervention into climate. But it simultaneously acknowledges in the text that SGE is surrounded by ethical, political, governance and social concerns.

**Figure 6-6: Scientisation of SGE: representative sample of figures in NRC report (2015a).**

Calls for a strict separation between science and politics is frequently encountered in the policy literature and Jasanoff has shown the artificiality of this. She has argued that ‘studies of scientific advising leave in tatters the notion that it is possible, in practice, to restrict the advisory practice to technical issues or that the subjective values of scientists are irrelevant to decision-making …’ (1990:249).

Perhaps unusually then, the NRC report does not argue for a separation, indeed it makes the connection between the technoscientific and the socio-political explicit. But, having acknowledged the connection, it proceeds as if such a separation exists: that policy decisions will be made elsewhere, that the social aspects can be separately analysed on the foundation of the technoscientific analysis provided, and that the technoscientific analysis is not itself
shaped by social assumptions. It imagines a distinction between ‘facts’ and ‘values’ even as it acknowledges the difficulty in doing this.

‘Values’ are, of course, present in the report although rarely explicitly. Here I try to identify elements of the four narratives and their associated sociotechnical imaginaries outlined above, which are visible in the NRC report in some form. The tone of the report is bland and technical in the manner of the ‘Market’ narrative. But, this apart, what explicit and implicit worldviews can be found?

How is climate imagined? The starting point of the NRC report is that ‘anthropogenic climate change has the potential to cause substantial harm’ (2015a:36), that mitigation is likely to fall short of required targets, and therefore technological solutions may be needed. Taken together, this most closely resembles the standpoint of the ‘Salvation’ and, to some extent, ‘Geo-management’ narratives. In line with the dominant framing, climate change is seen as a ‘global challenge’ signalled by changes in global average temperatures, and SGE is understood as a potential means ‘to offset global mean radiative forcing of CO₂’ (2015a:7). Framing a problem as ‘global’ does, of course, summon up the suggestion that what is required is a global solution (Hulme 2014:54-55). Whilst SGE is imagined as global, the NRC does point out that any global intervention to reduce global average temperatures, would result in differential regional effects (2015a:34).

At the same time the report conveys discomfort and a sense of “why are we are going here?” when it embraces the argument that there are already existing ‘answers’, in particular mitigation (the starting point, in part, of the ‘Un-natural’ imaginary). Indeed the report’s primary recommendation is that climate change efforts ‘should continue to focus’ on mitigation and adaptation (p. 3, my emphasis). This is presented as though it were a conclusion of science when it is manifestly a policy preference. In short the NRC report gestures towards, but does not want to embrace, the starting point of the ‘Geo-management’ and ‘Salvation’ narratives, that the strategy of mitigation is not working. And it rejects, in effect, the ‘Market’ narrative and its vision of mitigation as a flawed strategy.

Competing imaginaries are visible too in a revealing exchange at the launch of the report when questions were put to a four person panel of committee members. The question posed was:

114 At the launch of the NRC report, question time saw Michael MacCracken commenting that he was surprised to find the word ‘should’ in a scientific report (NRC 2015d: around 34’ I rely on the video recording of the entire launch event). In his comments MacCracken, a long-time enthusiast for SGE (1991; 2006) and a scientific participant in the IPCC-EXP (2012), and GAO (2010) reports, was clearly unhappy that the report was not promoting a view of gradual implementation starting soon.
‘Do you think climate intervention of some sort is inevitable?’ (2015d: around 1hr 12’). The response from committee member and former NASA chief scientist, Waleed Abdalati: ‘I would say climate intervention has occurred and is part of a cause of climate change’. This echoes the Mark Lynas trope that we have encountered earlier: “nothing new here, we are already geoengineering the Earth and need to get good at it”. A fellow panellist interrupts Abdalati to say any intervention has been ‘inadvertent’: this comes from a counter-argument that because society is already intervening in ‘nature’ this doesn’t give permission to continue doing so (strains of the ‘Un-natural’ imaginary are audible here). Abdalati continues with a non-committal non-answer: ‘Whether it is inevitable in the future really remains to be seen’. Marcia McNutt, the committee chair (and also Editor-in-chief of Science and formerly director of the US Geological Survey), then interjects holding up the CDR report: ‘I hope that this one will be used. Reforestation, afforestation, better earth soil management ... those are what we should be doing... This one [holding up the albedo report] ... gosh I hope not!’ Retired Admiral David Titley, another committee member, interjects, apparently trying to find the middle ground: ‘I would say the choice is still ours’, with ‘ours’ left unelaborated. None of the substantial issues underlying this exchange are directly addressed in the report. But they are clearly present, at least in the minds of the panellists and in how they imagine SGE.

In its direct consideration of geoengineering the NRC report holds onto two main views – don’t use it, and do more research. Risk (part of the ‘Salvation’ and ‘Market’ narratives) and danger (central to the ‘Un-natural’ narrative) are at the heart of the NRC’s Recommendation 3 which ‘is opposed to climate-altering deployment [at scale] of albedo modification techniques’ (2015a:15). The words ‘at this stage’ are not included in this formulation. And yet, since ‘more research’ is called for, the potential deployment of SGE is indeed imagined. But this call for further research is itself qualified: ‘multiple-benefit research’ into the climate system as a whole should be the emphasis, rather than research specific to SGE (2015a:10-11). This is a dilution of the “prepare the technology for use even if it is risky”, of the ‘Power’ narrative. And it is certainly not the “incrementally deploy”, as part of research, approach of the ‘Salvation’ narrative. But the NRC report is also not proposing to return SGE to its prior Un-

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115 From a general ethical perspective, doing a ‘bad’ act intentionally would exacerbate rather than diminish moral responsibility.

116 Although the spirit of the NRC report is skeptical of SGE the wording chosen – ‘climate-altering deployment’ – can be interpreted as allowing experimentation outside the laboratory as long as the amounts of aerosols can be held to be small enough not to be ‘climate-altering’. This is exactly the claim made by David Keith and colleagues in their announced desire to conduct what they call a ‘stratospheric
imaginability since SGE, if it is ever used, is said to be part of a portfolio of climate policies (central to the ‘Salvation’ and ‘Power’ narratives). One can see, in the formulations adopted, the contestation between various imaginaries at work, with the result that a clumsy compromise position emerges.

The NRC report, premised on a technoscientific understanding of the object of its enquiry, and aware of the centrality of socio-political questions but not equipped to handle these, has few places to go. It can displace the troubling questions, sending them elsewhere. Or it can apply the epistemological tools it is familiar with to problems that are unfamiliar. Or it can pose challenging questions without sufficient reflexivity as to how deeply challenging these are to its own epistemology. The report does all these things. I provide an example of each. First, the NRC report asserts that ‘decisions will ultimately involve values and relative acceptability of various kinds of risks – factors that are outside the scope of science (2015a:181). This is the standard, albeit untenable, science-politics policy divide already referred to. Second, the report notes ‘the chasm between what may be technically feasible and what might constitute wise and prudent action’, and notes that ‘substantial research’ would be needed ‘before this gap could be bridged’ (p.38) … as if wisdom and prudence could be researched, or more certain technical research might make the need for prudence and wisdom superfluous! Third, at one point the report lists key questions to be answered prior to undertaking large-scale research into geoengineering. These include a question rooted in the ‘Un-natural’ narrative: ‘would society ever know enough to responsibly decide to deploy albedo modification?’ (2015a:167-8). The question is raised but then not addressed. It is a surprising question given the assumption throughout the report that this is, of course, possible. It is yet another marker of the competing imaginaries which percolate through the report. In practice the call for “more research” works to conceal, or paper over, the different normative stances on SGE within the committee itself.

Nature and the environment are not explicitly addressed in the report. There is some consideration of the potential environmental effects of SGE. But these are analysed predominantly through the lens of physics and chemistry, such as effects on stratospheric ozone, precipitation, soil moisture, photosynthesis and ocean acidity (NRC 2015a:92ff), but not on, say, ecosystems. Two conflicting undercurrents are present. There is the implication at many points in the report that major interventions into the Earth’s complex and non-linear controlled perturbation experiment’ (Dykema et al. 2014). See also the eight field experiments proposed by a 28-person panel meeting at Harvard University in March 2014 (Keith et al. 2014).
systems will have unpredictable effects and may be unwise (for example 2015a:30; 39). This is the gist of the McNutt intervention cited earlier, suggesting a preference by some for solutions thought to be more ‘natural’. There is also, given the focus on cost-benefits, risks and technology, the implication that human interests and economic imperatives are paramount (for example NRC 2015a:65 or 89). The shadow of a developmentalist imaginary contained in the ‘Salvation’ narrative can be seen in the frequent attention paid to the presumed effect of SGE on crop yields. Occasionally this is qualified by the observation that ‘increased net primary productivity on land is not necessarily a positive outcome for natural ecosystems’ (2015a:90).

Similarly, the report seems to assume the existing economic and geo-political order. It does not take the ‘Market’ approach of seeing the current order as virtuous. Implicitly it appears closer to the ‘Salvation’ narrative which can envisage no real alternative to the dominant order, or the ‘Geo-management’ narrative which is more inclined to frame concurrence with the status quo as the ‘hard-nosed’ recognition of reality. The closest the report comes to addressing this issue is when it acknowledges that mitigation, whilst technologically feasible, ‘has been difficult to achieve for political, economic, and social reasons that may persist well into the future’ (2015a:181). There is no further discussion of this ‘realist’ perspective. And, perhaps unsurprisingly for an official report, there is no discussion of the possibility that the existing dominant order may exacerbate the climate problem, or be an obstacle to its Recommendation 1 – continue aggressive mitigation. This silence is indicative. The assumed compatibility between SGE and the maintenance of the dominant global order is apparent in a number of less direct ways. It is evident firstly, in the reliance on a utilitarian cost-benefit model as a key part of the assessment process; secondly, in the positive gloss put on private sector engagement with geoengineering (its potential to stimulate innovation, investment, economically beneficial spin-offs etc.) even whilst cautioning against the ‘possibility of neglecting social, economic, and environmental risk assessments in favor of the pursuit of corporate profitability’ (2015a:173-4)\textsuperscript{117}; and thirdly, in concern about the potential for SGE to de-stabilise the existing geo-political order (assumed to be a major risk), alongside silence regarding its potential to aggravate injustice or undermine democracy.

But it is important not to overstate the third point above. On many of the key aspects of what a world brought into being by SGE might look like, the NRC report is silent. It avoids the

\textsuperscript{117} Elsewhere the report notes that SGE requires little or no major technological innovation (NRC 2015a: 178).
concern that SGE can be assumed to be inherently antithetical to democracy, by focusing its attention entirely on research governance. It regards discussion of the governance of deployment, such as how it is decided when to use it (2015a:149), as beyond its scope.

The report catalogues in some detail the many and various proposals regarding research governance (pp.151-167). With one exception this is done without endorsement or even discussion. The exception, and the only proposal discussed and strongly rejected, is Hulme’s argument that ‘if the deployment of the technology cannot conceivably be adequately governed, then the technology itself should not be researched’ (2014). In this sense the NRC report can be said both to recommend against SGE and to rule out ruling SGE out. SGE is presented as undesirable, and to be avoided, even whilst the implication is that it is imagined to be inevitable, or at least potentially necessary.

The NRC report, in short, does not present a coherent sociotechnical imaginary. It was impossible to find a common story, in itself a reflection of expert disagreement and public ambivalence, even antipathy. But there are traces of a number of sociotechnical imaginaries contained within it. This suggests that none of the competing narratives and their associated imaginaries is hegemonic in the institutional reports, that there is no dominant account of what SGE is, what it is for and how it might shape social order positively. Contesting imaginaries have produced a stalemate, and a report lacking a coherent imagination.

A sociotechnical imaginary struggling to be born
The concept of the ‘sociotechnical imaginary’ refers to ‘collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology’ (Jasanoff 2015:3). As we have seen, it is hard to discern a coherent sociotechnical imaginary in the NRC report, although the assumptions and visions of a number of competing imaginaries, or at least narratives, can be detected.

The tensions between these imaginaries are held at bay in much of the institutional literature by a dual process of scientisation and narrowing. Scientisation elevates the importance of expertise and scientific modes of enquiry, and thereby tends to both marginalise non-expert, public voices and to de-politicise. Narrowing simply withdraws critical questions from the scope of enquiry, often after acknowledging their centrality. In a sense both the narrowing and the scientisation are reflexive, with the reports’ authors frequently acknowledging both the limitations and the implications of these moves. SGE is treated as technoscientific object, whilst being acknowledged as a sociotechnical project. But to the extent it emerges in the
Sociotechnical imaginaries are central in both shaping and bringing new technologies into being. And material power, along with the normative and the ideational are critical in the emergence and stabilisation of these imaginaries. In her work on sociotechnical imaginaries Jasanoff notes that they ‘can originate in the visions of single individuals, gaining traction through blatant exercises of power or sustained acts of coalition building’ (2015:3). At the time of writing both Keith and Victor have been especially influential in efforts to normalise SGE as a component of climate policy. Not only are they both at the heart of the major institutional reports and central to some of the networks of experts within these but the imaginaries they have generated also explicitly engaged with the social dimension which is largely absent in the institutional reports. They have understood SGE as a sociotechnical project rather than simply a technoscientific one, although they often try to maintain a boundary between the technical and the social. And their imaginaries have become part of the way of thinking shared by an extensive and influential network of knowledge brokers, as discussed in the Introductory Chapter, who are favourably disposed towards progressing research on and experimenting with trial deployment of SGE. Most, but not all, are scientists. They are overwhelmingly male, and they are located in the global ‘North’. They can be found on the panels of all the key institutional reports relevant to SGE and most have numerous refereed publications and popular articles on the subject. Notwithstanding their influence they have, to date, been unable to mobilise sufficient political power to impose their vision of SGE. How, then, can one explain why none of SGE’s competing imaginaries has been able to rise to dominance for policy purposes? The question is especially pertinent to the three most associated with power and the dominant order (‘Market’, ‘Geo-management’ and ‘Salvation’), or the two (‘Geo-management’ and ‘Salvation’) which already operate from a privileged platform.

One explanation can be found in the imbalance between the utopian and the dystopian. Jasanoff has noted that dominant sociotechnical imaginaries are ‘typically grounded in positive visions of social progress’ even when they acknowledge a shadow side. In the case of SGE none of the competing narratives is able to sustain a substantially positive vision. Indeed the dystopian overwhelms even the suggestion of utopian. Buck has noted that most narratives of geoengineering are stories of failure and insurance (2010). Keith’s ‘Salvation’ narrative comes closest to a positive vision in imagining SGE as a technology to help save the poor from serious
climate change. But even he primarily presents SGE as regrettable, risky, distasteful and, at best, a necessary ‘lesser evil’.

Another explanation may lie in the strength, persistence and public resonance of the idea that SGE is un-natural and unwise. The claim of necessity finds it extremely hard to break through this centuries-old, ontological barrier between the social and the natural. Whilst the taboo against SGE may have been broken in the specialist community of climate science and climate policy, it has not been broken more broadly. Further, as I have shown in earlier chapters, there are substantial indications, especially since the 1970s and 80s, of a change in the normative stance of many of the relevant scientific experts, such as climate scientists and Earth scientists. SGE involves remaking climate and that is an exercise in Mastery. Certainly traces of the post-War ‘dream of Mastery’ persist, especially in institutions like the Lawrence Livermore Laboratory. But a significant proportion of the experts now display an attachment to ideas of ‘nature’ having inherent value, to a sense that limits/boundaries/thresholds carry normative implications for social practice, and that ideas such as ‘sustainability’ imply some need for retreat from existing consumption practices. This is what Victor has in mind when charges environmental scholars with ‘car[ing] too much about their subject’ and implies they are too caught up in ‘green evangelism’ (2011:x-xi). It helps explain the persistence of SGE as an ‘un-natural’ idea even as that narrative sits outside the circles of power considering SGE as a policy alternative. It also explains Keith’s efforts to summon concepts such as ‘post-nature’ and hybridity in order to present a vision which can cut through talk of anything being un-natural.

Yet another explanation for the failure of any imaginary to become dominant may lie in the incomplete engagement in the various pro-SGE narratives with questions of material and geopolitical power. Is a world of SGE safer (and for whom?) than a world without it? Clearly there is interest in SGE in both the US security establishment (prime sponsors of the NRC report) and amongst at least parts of the existing elite. The attraction of SGE for the powerful is that it may offer a technological intervention which can be climatically stabilising, reducing climate risk relatively cheaply and without seriously disrupting the established global economic and military order. But SGE can also, credibly, be expected to be deeply de-stabilising of the geopolitical order, as the India-Pakistan example outlined in the previous Chapter suggests. In coming to terms with these issues, much depends upon who it is imagined will make deployment decisions (raising questions of democracy, justice and governance) and what the

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118 The ‘Market’ narrative is too ideologically partisan to reflect this view in its most persuasive form.
climate and agricultural effects of intervention actually turn out to be (currently expectations in this regard are marked by significant uncertainty). The security agencies of the global superpower are also anxious about ‘rogue’ deployment which it has not authorised resulting in an SGE ‘arms race’. Whilst the focus of the ‘Geo-management’ narrative is on questions such as these, the vision it offers of a ‘club’ of powerful states ushering in a Brave New World is not only un-democratic, techno-centric and gloomy. More important, for the established power elites, it is far from clear that it would make the world safer for them.119

I have suggested that pessimism/dystopia, insufficient acknowledgement of traditional views that SGE is un-natural and unwise, and a failure to produce a convincing account that SGE would make the world safer for established elites, all help explain why no vision of SGE has become broadly accepted. Or perhaps it is simply the case that a sociotechnical imaginary must always be contested when the technology itself mainly exists theoretically and is not yet deployed. In any event, the fact remains that what SGE is, what it is for, and whether it is desirable, are all disputed today. No single imaginary is dominant. SGE is best understood as a technology and a sociotechnical imaginary struggling to be born.

119 When attached to the ‘Salvation’ narrative a ‘liberal’ version of the ‘Geo-management’ narrative might emerge – the Brave New World is needed to save the poor. When attached to the ‘Market’ narrative a more isolationist, security-focused version emerges – the global ‘North’ (plus China?) fences itself off, uses SGE and adapts to climate change, whilst leaving the Rest to their fates.
Section III – TOMORROW
Chapter 7: Future imaginings

‘Plausibly, 6 billion people would benefit [from solar geoengineering] and 1 billion would be hurt’.

Martin Bunzl (in Wood 2009)

‘… meeting [a 2°C or similar] target by means of albedo modification would require a millennial or even multimillennial deployment’.\(^{120}\) (NRC 2015a: 62).

We have seen that consideration of SGE is no longer taboo, but that it has also not become normalised as an acceptable addition to the portfolio of climate policies and technologies. The institutional reports, as I have shown in my analysis of knowledge, values and power in Chapter 5, have adopted a number of approaches which might have been expected to help normalise SGE. But they have typically withheld explicit endorsement of the technology and have not recommended its acceptance as a respectable ‘third leg’ of climate policy. Even recommendations for ‘further research’ into SGE have had caveats and pre-conditions attached, and experimental, relatively limited, deployment of SGE, as recommended by SGE’s chief proponents, has to date failed to win “official” endorsement (Stilgoe 2015a; NRC 2015a).\(^{121}\) We have seen too, in the previous Chapter, that a number of competing narratives and their associated imaginaries, swirl around SGE. None of them is hegemonic, and the futures they imagine are generally gloomy and dystopian.

How do we best understand the reluctance to endorse SGE which is apparent in the major institutional reports? Could it be, as the reports suggest, because of the presumed uncertainty and potential dangers which surround the technology? Whilst there are real concerns in this regard, it is hard to see these as orders of magnitude more extreme than earlier decisions to, say, endorse nuclear power or allow genetic modification technologies to proceed. Or perhaps it is better understood as a consequence of contingent institutional factors: the inability of SGE’s proponents to build a consensus in the ranks of climate science or a sufficiently powerful coalition of interests to force endorsement of its wishes. If so, then this still begs the question of why it has been so difficult, to date, to develop such a coalition.

\(^{120}\) The report qualifies this with ‘unless techniques to greatly accelerate CO2 removal from the atmosphere (CDR) are deployed at very large scale’.

\(^{121}\) I am thinking here of the so-called ‘controlled perturbation experiments’ which have been proposed (Dykema et al 2014).
In this Chapter I will look at SGE’s future, to help illuminate what is constraining SGE’s emergence as a ‘normal’ and deployable component of climate policy and what might facilitate its embrace. Because I examine the future, this Chapter will inevitably be more speculative, partial and free-ranging than the previous Chapters. How the climate situation unfolds and how the powerful perceive their interests will, of course, matter and will affect whether SGE is embarked upon, and if so what shape it takes, and what world it is expected to create.

I will focus on the ideational and the material. The ideational is especially important, especially given that the existing imaginaries are unpersuasive and pessimistic and none is hegemonic. As a not-yet-operational technology, SGE is already being fashioned by the many imaginaries which society projects onto it, and how these imaginaries evolve will affect whether and, if so, how it is normalised and deployed. Of course, the ideational does not exist as “pure idea” or free-floating concept, and cannot be understood only in the abstract. Rather, the ideational and the social emerge intertwined, as the term “sociotechnical” implies. Further, the sociotechnical is situated in active relationship with the wider material world, including its more-than-human dynamics. Whilst I have, thus far, emphasised that SGE is a form of worldmaking, I have tried not to ignore that it also aims to be quite literally climate-shaping, and that neither climate nor worlds are passive entities. Climates act back, and worlds are over-determined by the interests of the already powerful.

I begin my consideration of geoengineering’s future/s by examining two dimensions of this material context. Firstly, I briefly outline how climate change is expected to unfold, to the extent this is known, and with a focus on the potential implications for SGE. Even as the anthropogenic influence on the shape of climate is recognised, it is generally acknowledged that climate is an unruly and autonomous entity, and a powerful one. Secondly, I will look at the relationship between SGE and relations of power in the world. This includes the ways in which the idea of SGE facilitates the ongoing reproduction of existing relations of inequality and power, and yet also undermines it by challenging and subverting the ways in which the world is currently understood and engaged with. My argument will be that these paradoxical power effects are central to understanding SGE’s future.

When turning to the ideational I focus on, and critically discuss, two paradigms which are becoming evident in the framing and envisioning of SGE. The first can be called ‘developmentalism’, and draws on the dominant contemporary account of how the project of modernisation should be achieved. The second is the novel, and increasingly ubiquitous,
concept of the ‘Anthropocene’: that humanity is now the dominant geological force shaping the Earth. I conclude by suggesting that if SGE does materialise as an operational technology, it will do so as a sociotechnical imaginary of the Anthropocene.

The climate of power

Climate

Scientific analysis tells us, claiming a high degree of confidence, that global average temperatures are rising, and projected to rise further, and that the drivers are mainly anthropogenic. Rising greenhouse gas concentrations are heavily driven by carbon-intensive economic, energy and transport systems, and by changes in land use such as deforestation and more intensive agricultural practices (IPCC 2013a). In short, rising greenhouse gas (GHG) emissions are a function of a particular form of industrial modernity.

The Paris climate talks of December 2015 set the goal of keeping warming below 2°C compared to pre-industrial levels, whilst also including the aim to pursue efforts to bring it down to 1.5°C (UNFCCC 2015). This is generally agreed to be unachievable on the basis of existing national climate targets, known as INDCs (Clémençon 2016). How much warming is likely to occur is dependent on many factors, including the extent to which ongoing GHG emissions are curtailed and GHG concentrations kept within touching distance of 400ppm.

Most troublingly for climate policy-making, predictions of how the climate will behave are necessarily uncertain, and the ‘liveliness’ and non-linearity of the climate system means that the most reliable estimates are necessarily probabilistic, and cover a wide range of probabilities. Wagner and Weitzman, for example, calculate the global average temperature changes associated with various concentrations of CO₂e. As Figure 7-1, derived from their book Climate Shock (Wagner & Weitzman 2015:53) shows, whilst median estimates are of a temperature increase of 2.5°C above pre-industrial associated with 550ppm, the estimates also include so-called ‘fat tails’, lower, but still troubling, probabilities of much more extreme temperature rises, in this case increases of greater than 6°C.

The societal effects of increases in temperature are also difficult to predict, and become increasingly difficult the higher above the present it is. Importantly, much depends on the speed of change and the adaptability of societies to such changes. The IPCC has, at various times, attempted to estimate the likely effects of various temperature increases: using its ‘burning embers’ image to illustrate this (IPCC 2001).112 A number of other studies have

112 I put aside here that the image itself is discursively controversial (Liverman 2009).
attempted to describe what the future may hold (Lynas 2008; Christoff 2014; World Bank 2012; World Bank 2013). In all cases their conclusions are extremely disturbing. Coral reef ecosystems, for example, become largely unviable approaching 2°C. A report prepared for the World Bank, specifically examining sub-Saharan Africa, South Asia and South-East Asia, expects that between 2°C and 4°C extreme climate events could push households into poverty traps, and affect crop yields and food security adversely (World Bank 2013). Another report concludes that ‘a 4°C world would be one of unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on ecosystems and associated services’ (World Bank 2012:xiii). For Lynas, at 5°C the planet becomes unrecognizable and billions can be expected to die (2008). As all these studies imply, climate is no longer comprehensible as a backdrop, or even as a cause that produces known effects. The reality is more complex and causation is multi-directional. Climate is an active agent, and a “vibrant” and disruptive one to boot. It is both shaped by and actively shapes human activity.

![Global average temperature probabilities associated with CO2e concentrations](www.climateshock.org)

Figure 7-1: Global average temperature probabilities associated with CO2e concentrations
How the warming trends unfold will, of course, impact on SGE’s emergence (or not) as a potential climate policy and technology. Only in the most general terms can one conclude that the greater the global warming, the more attractive SGE becomes as a solution. And even this conclusion requires three major caveats. Firstly, average global temperature figures conceal as much as they reveal. Climate change is not experienced as a global average, but rather as particular lived conditions in particular societies and communities, each with varied climate sensitivity and varied ability, resources and capacity for adapting to such changes. In some cases, warmer winters may even be embraced by those living in higher latitudes (Nyang 2015).

The extent to which global average changes are comprised of vastly different experiences can be seen in the following example depicted in Figure 7-2, a familiar scientific representation of global surface temperature anomalies which represents temperature divergence from the longer-term averages (1951-80). In this case February 2016 is depicted as an exceptionally warm month in the Northern hemisphere winter, with global average temperatures 1.35 °C above the 1951-1980 thirty year average, and 1.63 °C above pre-industrial (NASA GISS http://data.giss.nasa.gov/gistemp/). It is evident that the actual temperature changes in particular communities and societies vary dramatically – a super-heated climate in the Arctic and across swathes of Russia; a large rise of up to 4 degrees in much of central Asia, Eastern

123 Of course some aspects of climate change, such as sea level rise, are more generalised effects of temperature rises.
Europe, the Middle East, and the forest-dense regions of central South America and central Africa; and even cooling in some places.

Secondly, for considerations of SGE, the rate of change is likely to be more significant, socially and politically, than the magnitude of temperature change. A slow, albeit steady, rise in temperatures – as has occurred over the past decades – fails to prompt the necessary sense of urgency which seems to be a pre-requisite for SGE to be embraced. Gradual temperature increases are less perceptible to humans, and are often adapted to as the “new normal”.

There are still human casualties of course, not to mention casualties across ecosystems and among other species. But without an ‘event’ we are left with what Rob Nixon has called, in another context, ‘slow violence’: ‘violence that occurs gradually and out of sight, a violence of delayed destruction that is dispersed across time and space, an attritional violence that is typically not viewed as violence at all’ (2011:2). Only major climate events, such as major extreme weather events, impacting significant numbers of people and capable of being visually communicated, are likely to prompt calls for the deployment of SGE. Typhoon Haiyan, which struck the Philippines in 2013 and claimed an estimated 6,300 lives with over 1,000 missing, is perhaps an example although, since more remote areas of the country bore the brunt of this extreme weather event, it lacked global tele-visibility (Lagmay et al 2015). The Japanese tsunami of 2011 is perhaps a better example of what I have in mind as a trigger event, since it prompted a major u-turn in that country’s nuclear energy policy, although it is, of course, not a climate change example.

Thirdly, and following on from the above, any such climate event will lead to significant calls for SGE only to the extent that it impacts people, places and societies that ‘matter’, as seen by those with the power and ability to embark on SGE.124 Above all this means as seen by the United States government and/or its key allies. To this extent, Victor’s ‘hard-nosed realist’ approach, as discussed in the previous chapter, is surely relevant. In short, SGE is unlikely to be embarked upon to save the polar bear or the sparsely-populated Arctic circle. And many consecutive days of temperatures close to 50°C in India, as has occurred in 2016, will carry considerably less weight than a similar event in California would when it comes to thinking about SGE as a response.

124 Even power and ability need to be supplement by the political will to embrace SGE and this, in turn, requires a coherent narrative, an imaginary of SGE which has social purchase. I turn to this point later in this Chapter.
In short, climate developments matter, and a warming climate makes the deployment of SGE more likely. But much depends on whether such developments occur and are interpreted as major climatic events, and whether these impact heavily on the inhabitants of countries with the geo-political power to embark on SGE. The power of climate and the climate of power are entwined, and this is nowhere more evident than in considerations around SGE.

**A technology of the powerful**

SGE is a proposed technology which explicitly and intentionally aims to re-shape global climate. It may reverse or slow down global warming, but in doing so it does not restore the climate of the past. Rather, it inaugurates novel climate/s. It is a global intervention with regionally varied effects on the Earth as a ‘lively’ entity, on its human and more-than-human occupants, and on the societies and biomes they constitute and inhabit. SGE is manifestly a powerful technology.

Less commonly acknowledged is that it is also a technology of the powerful. By this I mean it is a proposed technology which is inherently more attractive to those states, classes and institutions which are currently most powerful in the contemporary world, those with the geo-political and economic might to be able to impose SGE on the world, than it is to those less powerful.\(^\text{125}\) I base my assertion that SGE is a technology of the powerful on five claims, each evidenced in earlier chapters.

First, SGE enables, or at the very least is compatible with, the continuation of existing, and otherwise environmentally unsustainable, patterns of extraction, production, consumption and trade. All the competing narratives outlined in the previous Chapter acknowledge this, even as they adopt different normative stances regarding the desirability of this compatibility.\(^\text{126}\) Hamilton has called it a ‘conservative technology’ (2013a:97).

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\(^{125}\) That some states have more power in the global arena than others is well-established. So too that there is an unequal distribution (and reproduction) of wealth in the world and within particular societies (Piketty 2013); and that these imbalances have political effects ranging from the actions and interests of those intent on maintaining this state of affairs, to those opposing or subverting it. I am not arguing that existing elites must inevitably embrace SGE: there may be many practical reasons not to do so. Rather I am simply claiming that SGE has an inbuilt bias towards the currently most powerful, towards the political and economic status quo.

\(^{126}\) Compatibility with the existing economic system is variously held to be undesirable (the Un-natural narrative), desirable (Market), necessary (Geo-management), or inevitable-absent-alternatives (Salvation).
Second, SGE assumes the maintenance, or at least stability, of existing structures/regimes of global power. This is because embarking on SGE is a long-term commitment (that could range from decades to centuries or even millennia) that cannot be terminated quickly or easily, and therefore requires stable and predictable governance over periods exceeding the life of any existing government or global institution and most socio-economic orders in human history to date.

Third, and relatedly, SGE would appear to be inimical to democracy, a major source of (potential) influence for the less powerful. This is not only because democracy implies the possibility of reversibility, accountability and recall, and typically operates on timescales incompatible with SGE. It is also because SGE imposes climatic effects on everyone, and yet it is impossible to conceive of circumstances in which its deployment might be democratically agreed by everyone. This is acknowledged in the ‘Geo-management’ imaginary with its vision that a single global power or ‘club’ of powers might deploy SGE. A technology that is not accepted, can only be imposed, and this is necessarily an exercise of coercive power.

Fourth, deploying and maintaining SGE implies even greater concentration of political power than is currently the case. Whatever decision-making practices surround it, SGE ultimately requires a single metaphorical hand on the ‘global thermostat’. As Clive Hamilton has quipped: SGE is ‘the dictator’s technology of choice’ (2013a:96). When it came to making choices of temperature/precipitation settings (SGE is a crude technology) it would be naïve to expect decisions to be made by the few in the interests of the many and against the interests of the few. Indeed, deployed SGE entails a concentration of power which even existing elites may baulk at.\textsuperscript{127} Even the manifestly undesirable alternative of an SGE ‘arms race’, with different elites/powers (think Russia, China and the United States) making competing interventions into the Earth’s climate implies greater centralisation of powers than currently exists (see Urpeleinian 2012 for a game-theoretic analysis). In a world of rising nationalism, unilateral and competitive deployment of SGE bodes ill for democracy and the planet. As Dalby has argued, in the context of urging a rethink of geo-politics and security analysis, ‘the atmosphere then becomes not only a volume to be secured, but also one to be competed for directly’ (2013b:45).

\textsuperscript{127} Importantly, the rich are most insulated, personally, against extreme climate change and most likely to have other options including ‘exit’ (Hirschman 1970) to higher latitudes and climate-controlled habitations/environments.
Fifth, SGE is a ‘big’ technology in that it only makes sense at scale and by a state with the confidence it can maintain such large interventions well into the future. Although not especially expensive SGE does require the resources to inject sulphates, and keep injecting them, 20 km up into the stratosphere. And it does require maintaining and developing sophisticated systems of climate satellite surveillance able to monitor the effects of SGE, and adjust it accordingly. In reality, these avenues are not open to the less powerful nations of the world, and certainly not to their citizens. A ‘technology of humility’ (Jasanoff 2003) this is not.

In short power in all its dimensions should be understood as intrinsic to SGE, rather than extrinsic. SGE presents as both a powerful technology and a technology of the powerful. ‘Hubris’ – with its suggestion of pride, arrogance, overconfidence and defiance of the gods – is the term which connects these two aspects, and indeed SGE is frequently charged with being a manifestation of hubris.

... and yet subversive
And yet, in some respects, SGE is also undermining of the status quo, politically, ontologically and epistemologically. Politically, as we have seen, the concentrations of power required to deploy and maintain SGE are substantial. Indeed, suggesting that SGE is incommensurate with democracy is, arguably, to understate the problem. It is not only that agreeing to deploy SGE implies a rejection of the international institution of multilateralism, which is based on state consent. It is also that there is no conceivable alternative democratic order, no demos, that could decide on what ‘settings’ to maintain, or how deployment should continue. Further, since SGE once embarked upon is not easily ceased responsibly, any decision regarding continuation is both highly constrained and impossible to bring into effect over the timescales normally associated with democratic practice. SGE appears entirely incompatible with inclusive multilateralism between states (admittedly not a novel situation) and democratic practice within states – specifically the state or states deploying SGE. Further, if multiple countries or actors competitively embarked on SGE then even worse climate outcomes can be expected, unless the dominant actor/s were able to prevent or intervene to disrupt such competition.\(^{128}\) Victor’s suggestion, as outlined in Chapter 6, is more radical and subversive than he perhaps intends: that dealing effectively with climate change means inaugurating a Brave New World of autocratic and technocratic rule.

\[^{128}\] This explains a focus in the NRC report (2015a/b) on what instrumentation, satellites and surveillance systems would be needed to detect whether anyone else (beyond the USA) was deploying SGE.
As we have seen in Chapter 5, engaging with and thinking about climate change and SGE is disruptive of, or at least sits uneasily with, dominant epistemologies, assumptions about the role of science, and narratives of risk. Uncertainty, indeterminacy, contested values and constantly changing climate dynamics are ubiquitous. The mode of analysis and practice that gives attention to such dynamics has been called ‘post-normal science’ (Funtowicz & Ravetz 1993; but see also Wesselink & Hoppe 2011). The types of policy problems which emerge when thinking about climate and SGE have been labelled as ‘wicked’, and even ‘super-wicked’ problems (APSC 2007). Ideas like these are not unfamiliar in the field of climate policy, but they do have ramifications. They challenge the existing ‘practices of objectivity’ (Jasanoff 2011) in climate science and policy. In essence they convert climate from a problem with calculable risk and requiring solutions from experts, to a condition that summons up a multiplicity of interventions and adaptations. In the process the notion of climate as a ‘global’ problem is challenged and undermined, even as the inevitably messy global intervention of SGE is introduced.

Ontologically, as we have seen in previous Chapters, SGE is especially challenging to existing verities about both the role and place of humans, and the human relationship to ‘nature’ and the more-than-human world. Discontent about SGE along these lines emerges repeatedly in public engagement exercises around geoengineering. They are also evident in widely expressed concerns about whether it is right for humans to ‘play God’, and whether SGE is a manifestation of human hubris. Any interrogation of such questions also throws into sharp relief the extent to which all the discussions of SGE as a potential climate policy and technology are rooted in modern, largely Western, ‘naturalist’ (Descola 2013 [2005]) cosmologies and marginalise or ignore other ways of ordering the world (but see Wong 2015).

Clingerman (2014) has provided a perceptive account, written from the perspective of theological anthropology, of the complex and contradictory implicit accounts of what it means to be human, held respectively by proponents and opponents of geoengineering. Both appear to conceive of the human as ‘in between’ the natural and the artificial. Opponents of

\[129\] Wicked problems are not really ‘problems’ as such since that would imply ‘solutions’. They are better thought of as ‘conditions’ (and constantly evolving ones) requiring ‘engagement’.

\[130\] Contrast this with a number of implicit assumptions apparent amongst proponents of SGE: not only the notion of their (the geoengineers) practical ability to re-shape the climate in planned ways, but also a normative sense of their entitlement to do so, and that ‘nature’ as an autonomous entity has ended or is ending. As we saw in the previous Chapter, what I call the three related Power narratives (‘Market’, ‘Geo-management’ and ‘Salvation’) all make these assumptions, although Keith’s ‘Salvation’ narrative is alone in explicitly embracing the ‘post-natural’, neo-environmental turn.
geoengineering see humans as stewards who must maintain the separation, whilst understanding ‘... that human knowledge is fragmentary, our abilities are situational, and thus our responsibility is inevitably provisional and must be marked by humility’. Here humans are ‘strangely un/natural beings’ (p.11, italics in original) not qualified to rule the skies. This is, of course, a deeply rooted, even conservative, tradition. It is a stance which can be found in the ‘Un-natural’ imaginary described in the previous Chapter.

Proponents of geoengineering, Clingerman argues, interpret the ‘in betweenness’ of humans as a reflexive engagement with the world, rendering ‘... the distinction between artifice and nature indistinct in an effort to undertake a restoration of the planet’ (p.11). Environmental failures are addressed through radical humanization, ‘... not by redefining the human self in terms of being “natural,” but by rendering the climate a domesticated participant, as it were, in such human betweenness’ (p.12).

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We see, therefore, that a Janus-like quality is apparent in SGE’s re-emergence. On the one hand it is a response emanating from the centres of global power, rooted in standard practices and epistemologies of science, and purporting to be a solution to the climate change problem. In this sense SGE is part of a hegemonic, or at least preponderant, tale about tackling climate, in the name of modernity, using big technology. And yet it is simultaneously a subversive story which undermines a great deal in the dominant accounts of modernity, of science and of the human-nature binary. This explains in large part, why the most common sociotechnical imaginary of SGE (the ‘Power’ imaginary associated with the mainstream knowledge-brokers of SGE and with its three variant narratives ‘Market’, Geo-management’ and ‘Salvation’) has, to date, failed to gain traction as the sociotechnical imaginary of SGE: a subversive story is wrapped within a hegemonic tale, to use Ewick and Silbey’s resonant phrasing (1995). The oppositional ‘Un-natural’ imaginary, ironically, is less subversive and resonates more closely, in many respects with the dominant accounts of the human-nature binary in particular, and the notion of humans as ‘in between’ the natural and the artificial.

If a dominant sociotechnical imaginary of SGE is to emerge, one which facilitates its development and deployment, then it will need to engage with these tensions. Thinking speculatively, one can anticipate SGE’s proponents engaging with a number of discursive
strategies if they are to generate a more compelling sociotechnical imaginary of SGE. These include:

- de-naturalising ‘nature’ and naturalising a changed role for humanity, one which normalises human intervention at scale;
- addressing ‘hubris’ either by recasting it as wisdom in new circumstances, or by reconceiving the project as one of ‘tinkering’ and adjusting under conditions of uncertainty;
- displacing concerns about democracy and legitimacy from questions of process and structure (who speaks and what deliberative processes of decision-making might be fair) to assertions about global outcomes – from focussing on how multiple voices can be democratically heard, to emphasising how the deployment of SGE will be for the benefit of the poorest and most vulnerable;
- developing a normative account of why the intervention by some into the climate of others/all might be compatible with, or outweigh, long-standing rules recognising the sanctity of state sovereignty;
- making the overall vision a more positive-sounding one, in which utopian imaginings outweigh dystopian anxieties, or at least one in which the affective sense of loss (of the assumed natural order) which SGE evokes, is accompanied by a sense of gain and optimism for the future.

**Attaching to more ‘optimistic’ imaginaries**

All of these discursive moves are likely to hold together in a more compelling way if they can be attached to existing imaginaries which have already gained widespread social traction, and/or if they can be presented as part of something entirely novel, a momentous turning point which makes SGE both ‘obvious’ and desirable. My argument is that a ‘successful’ sociotechnical imaginary of SGE is likely to marshall existing discourses of developmentalism/human rights as well as the paradigm of the ‘Anthropocene’, with its assertion that humanity has entered a new and unprecedented epoch. Indeed, signs of such a trajectory are already apparent, in nascent form, in some of the accounts of SGE: including

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131 SGE’s opponents would, of course, need to challenge each of these strategies and develop the counter-narrative which already exists in bare-bones form in the ‘Un-natural’ imaginary.

132 As outlined in Chapter 6 Keith has tried to address this by recasting SGE as fundamentally about engineering rather than science, a problem-solving approach where the technology is tweaked in response to climate feedback (2013:116). Presenting SGE as a ‘mundane’ technology, rather than a world-making technology, does similar discursive work.
Keith’s book *A case for climate engineering* (2013) discussed in the previous Chapter. It is to these concepts I now turn.

**Development**

There are indications of an incipient embrace of developmentalism by geoengineering’s proponents (see Buck 2012 for a discussion of this). The thrust of the argument is that the poor will be hardest hit by climate change and that SGE, by reducing the risk of catastrophic events, can be expected to help the poorest nations and people to survive and get on with the primary objective – developing. The argument is frequently expressed in the language of human rights intervention and foreign aid, with SGE seen as analogous to a humanitarian intervention and an aid to those who are unable to fend for themselves or whose governments are unable to fend for them. This type of approach is not unique to geoengineering. Stilgoe has drawn attention to the frequency with which new technologies, such as nano-technology or genetic modification technology, are presented as innovations that will lead to great benefits for poor countries (2015a:34).

This developmentalist turn – as I will label it – is rarely visible in the institutional literature. But it can be found in a number policy-influential texts and in some of the academic literature. A 2008 paper presented to a Council on Foreign Relations workshop imagines geoengineering pursued unilaterally by wealthy nations to reverse or avert sea-level rises threatening to “… impose disaster on hundreds of millions of people” (Ricke *et al.* 2008:1). Geoengineering here is imagined as altruism or foreign aid. Keith too, as described in the previous Chapter, has argued that rejecting the geoengineering ‘Band-Aid’ might deny ‘a large benefit to the poor’ (2013:137). In particular crop losses from climate change would put millions at risk (2013:138). This last assertion is frequently contested.

Indeed, among the most contested issues in debates around SGE are those which relate to modelling the expected effects of SGE on food production in the tropics and on precipitation. For example, Pongratz, writing with Ken Caldeira and others, present modeling showing increased crop yields under SGE (Pongratz *et al.* 2012). By contrast, Svoboda and Irvine (2014) explore the question of compensation for potential ‘victims’ of SGE, relying on the widespread expectation, derived from other modeling, that there would be reduced intensity of the hydrological cycle, meaning less rainfall. Horton has rejected these assumptions and claimed that modeling shows no region would be worse off, whilst apparently conceding that some

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133 The socially-innovative dimension of SGE makes it especially ripe for such an approach since, as I have noted in the Introductory Chapter, it is hard to treat SGE as technologically innovative.
countries in some regions would be (2014). Reynolds is concerned by Svoboda and Irvine’s failure to emphasise that ‘aggressive mitigation … would hinder economic development, including in poor countries’, as well as their failure ‘to emphasize that SRM [SGE] appears to hold the potential to greatly reduce climate change risks to the environment and people, particularly to the world’s poor’ (2014b:184). Here, the oft-stated development call for continued extraction and burning of fossil fuels as the cheapest way to meet the burgeoning energy and development needs of poor countries meets SGE’s potential to mask some of the climate effects of such a choice.

Some opponents of SGE have been alert to the developmentalist turn. The ETC Group have expressed their fear of SGE being normalised by being presented as ‘foreign aid’ (2013b). Their stance came in response to a modelling exercise which concluded that injecting sulphur aerosols into the stratosphere in the Northern hemisphere would lead to drought in the Sahel, but injecting them in the Southern hemisphere would lead to increased rainfall there (Haywood et al. 2013).

David Keith, as we have seen, is particularly exercised by what he sees as ‘rich people’ rejecting ‘the geoengineering Band-Aid’. For him geoengineering is a necessary component of a pro-poor poverty reduction strategy. His use of the ‘band-aid’ metaphor is, in itself, interesting. It is in the genre of geoengineering as medical intervention, only with the treatment imagined as much more benign, even trivial, than the standard ‘chemotherapy for the planet’ metaphor. The capitalization of ‘Band-Aid’ presumably references the initiatives of Bob Geldof and other music celebrities in the field of so-called humanitarian intervention and development. These initiatives have been widely critiqued, most mildly as exacerbating the very problems they presumed to address (Müller 2013; Rieff 2005).

But, to interpret Keith generously, perhaps the more substantial point he wishes to make is that the answer to world poverty is development, that climate change threatens that trajectory, and that SGE enables the development project to continue and may help prevent any reversal of achievements to date. In a similar vein, one of the few occasions where David Victor, in his discussions of climate policy and SGE, refers to morality is where he suggests that ‘rich industrialized countries have a moral obligation to adopt policies that impose the least deadweight cost on the world economy’ (2011:184). This is essentially the standard and hegemonic “development comes through economic growth” paradigm.

A variation on the incipient developmentalist turn in geoengineering puts more emphasis on humanitarian intervention. In a paper, co-authored by two people from the Red Cross/Red
Crescent Climate Centre together with a prominent and policy-influential proponent of geoengineering, Jason Blackstock, it is suggested that geoengineering technologies can be seen as a humanitarian response to climate disaster. The authors regard it as analogous to the “responsibility to protect” (R2P) doctrine, whereby the “international community” is said to have a responsibility to step in when a state, as they put it, is unable or unwilling to protect its own citizens from physical harm. They link this ‘duty to intervene’ argument to questions of liability and compensation which might arise given that ‘vulnerable populations … are also likely to be those most detrimentally impacted by any negative side effects of geoengineering experiments’ (Suarez, van Aalst & Blackstock 2010:3-4). Their paper does not exactly promote SGE. But they do ask whether ‘the international community ha[s] a “responsibility” to explore and develop’ geoengineering, since it ‘might provide a means for avoiding some of the worst climate-induced suffering’ of vulnerable populations (Suarez, van Aalst & Blackstock 2010:3, emphasis in original).

The R2P doctrine endorses the notion that outside intervention is required to protect citizens from genocide, war crimes, ethnic cleansing and crimes against humanity, when their own governments do not, or are complicit. As Orford has argued, the concept can be best understood as ‘offering a normative grounding to the practices of international executive action that were initiated in the era of decolonization and that have been gradually expanding ever since’ (Orford 2011:10). The suggestion by Suarez et al. is that similar authority should exist for protecting citizens from the effects of climate change. Left unexplored is why their own governments cannot act, or why the intervention should be into the climate system rather than the state/s most responsible for climate change. For our purposes, the point is that proponents of using something like an R2P principle for SGE are apparently searching for a normative basis to legitimate intervention without consent, on humanitarian grounds.

There are clear echoes here of the more generalised securitisation of climate policy, with its association with ‘executive action’, which has been apparent for a number of years (Dalby 2013a; Marzec 2015). Buck notes the potential to ‘shift climate change from being an economic or scientific problem to being a humanitarian disaster, and geoengineering could become one critical response’ (2012:264). She contrasts the humanitarian vision with the vision which sees geoengineering as enabling capitalism to continue with ‘business-as-usual’: a

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134 Whether the R2P doctrine is a norm of international law is itself controversial and not explored here.
135 Not surprisingly, given their Red Cross affiliations, they use medical metaphors to ponder how to obtain the ‘informed consent’ of seven billion subjects ‘before they participate in clinical trials of a geoengineering intervention?’ (Suarez, van Aalst & Blackstock 2010:3-4).
key component of a number of the complementary narratives which constitute the ‘Power’ imaginary discussed in the previous Chapter. Throughout, the virtue and desirability of the development project is assumed, even though this is far from universally recognised.

Indeed, there is an extensive literature challenging as simplistic the notion that the pursuit of economic growth is the key mechanism through which improvements in living conditions and well-being can be achieved (Easterly 2006). And there is extensive evidence of a symbiotic relationship between the dominant political-economic order of ‘market globalism’ in an unequal world, and discourses and practices of both development and institutionalised human rights, on the other (Pahuja 2011). Development can be understood as a product of the dominant political-economic order in the post-colonial era (Pahuja 2011; Escobar 1995). Rist defines ‘development’ as ‘a set of practices requiring the transformation and destruction of the natural environment and of social relations with the aim of increasing the production of commodities, goods and services’ (1997:13). And human rights discourses in their current institutionalisation, as Moyn has shown, are often mobilised as a putative component of a modern, liberal-democratic, Western international order (Moyn 2010), even if they are not universally endorsed. On this reading both ‘development’ and, to a lesser extent, ‘human rights’ have been incorporated institutionally and ideationally into the dominant international order and its practices of governance. They are universalising discourses privileging a globalising worldview.136 Whilst Buck juxtaposes the humanitarian and business-as-usual visions of geoengineering, one could instead stress the connectedness of the two visions: that geoengineering framed as a humanitarian necessity and attached to ‘development’ is precisely what may enable business-as-usual, legitimise unilateral intervention and assist in normalising SGE. Indeed, in many ways, the developmental turn in SGE is a deeply conservative one, in the strict meaning of that word.

The significance of the developmentalist turn in geoengineering lies in the work it performs in helping to re-imagine SGE as a progressive and desirable social project, as utopian even. In essence it works to reconstitute SGE as virtuous and not merely as realistic, and it provides a seemingly “ethical”, foundation for pre-emptive intervention into the climate system. In particular the pro-poor ‘development’ aspect provides the virtuous reason, and the humanitarian angle provides a justification for a trans-boundary intervention (in practice by

136 Buck, in a paper entitled ‘What can geoengineering do for us?’, imagines a ‘best-case’ version of SGE which ‘may provoke an infrastructural opportunity to move towards global democracy and participation …’ (2010:2).
the most powerful). It attempts to reframe SGE in universal terms, as something which will need to be undertaken in the interests of the world’s poorest and to protect them from climate change. The developmentalist turn is an acknowledgement that SGE is not simply a technique or technoscientific project, and a step towards imagining it as a desirable technosocial entity inserted into a larger project of global ordering, of worldmaking.

**Anthropocene**
The developmentalist turn provides both a “halo effect” and the re-assurance that geoengineering can buttress the universalising project which is market globalism. However, it does little to address the ontological instabilities that SGE invariably throws up. For this one must pay attention to the ‘Anthropocenic turn’ which is becoming visible in the discussion of SGE.

The Anthropocene idea, literally ‘The Epoch of Humans’, has clearly captured the zeitgeist. The popularisation of the term is closely associated with a number of climate and Earth systems scientists, most notably Paul Crutzen (2002). Today, reflections on it can be found in every discipline imaginable, across the sciences, the humanities and the social sciences (for an excellent overview see Davies 2016). The idea of the Anthropocene is founded on the proposition that the Earth is no longer in the Holocene, still officially our current geological epoch which commenced some 12,000 years ago, and that a new geological epoch has commenced where humans (as a species) are now the major driver of changes to the physical Earth systems.

There is no agreement on when the epoch began although those closest to the stratigraphic debates appear to be converging on a proposal of somewhere around 1950 (Zalasiewicz et al. 2015), concurrent with the beginning of the so-called ‘Great Acceleration’ (Steffen et al. 2015; McNeill & Engelke 2014). Whilst the Anthropocene carries the suggestion of being a scientific concept, it currently lacks the formal imprimatur of science, at least in the sense of being formally recognised by stratigraphers as a new geological epoch. Nor is it likely to be recognised any time soon (Walker et al. 2015).

Paul Crutzen, who is associated with lifting the taboo on solar geoengineering, is also closely associated with the emergence of the term Anthropocene (2002; Crutzen & Stoermer 2000).

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137 Alternative datings vary dramatically and include the rise of agriculture thousands of years ago, and the beginnings of the industrial revolution in Europe. As Davies has noted, the earlier datings tend to focus on human capacity to shape environments, whilst the later ones emphasize the ecological consequences of that capacity (2016:45-48).
His short 2002 article in *Nature*, ‘The Geology of Mankind’, concludes by touching on the implications as Crutzen saw them:

‘A daunting task lies ahead for scientists and engineers to guide society towards environmentally sustainable management during the era of the Anthropocene. This will require appropriate human behaviour at all scales, and may well involve internationally accepted, large-scale geo-engineering projects, for instance to ‘optimize’ climate’ (2002).

This founding statement is an especially managerialist and expertise-elevating interpretation of the Anthropocene. It is one still commonly encountered. For our purposes, it is important to note that for Crutzen it was apparent that geoengineering and the Anthropocene must be thought about together.

As I have argued elsewhere, the Anthropocene is typically understood to be both an *is* and an *ought*: a description of a new reality, and also a prescription as to what this implies. The concept is typically attached to one of a number of distinct normative perspectives and sensibilities (Baskin 2015). There are proponents of a ‘great Anthropocene’, embracing the Promethean and the technocratic, and enthusiastic about the opportunity to shape a better world. One can also find the more modest ‘good Anthropocene’, in which the knowledge of human culpability imposes a duty on humanity to steer the Earth in a balanced direction. And then there is a shame-inducing ‘salutary Anthropocene’, which observes with horror the environmental devastation which accompanies the epoch. As Andrew Revkin, a journalist and one of the members of the ICS’s ‘Working Group on the “Anthropocene”’, colloquially put it: ‘You can look at it and go “Oh my God”, or you can look at it and go “Wow, what an amazing time to be alive!”’. I kind of choose the latter overall’ (2014).138

Most accounts of the Anthropocene imply some sort of boundary-breaking and ontological re-ordering of long-standing assumptions about the relationship between the human and the more-than-human, between ‘nature’ and ‘culture’, and between the short timescales of modernity and the long ones of the Earth, as well as suggestions that new understandings of agency are required. Some lament the ‘end of nature’ (McKibben 1989). In the scientific and

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138 Revkin produces the New York Times’ ‘Dot Earth’ blog. He is also one of the members of the Working Group on the ‘Anthropocene’, itself a sub-group of the ‘Sub-Commission on Quaternary Stratigraphy’, which is in turn part of the International Commission on Stratigraphy (ICS). The ICS, part of the International Union of Geological Sciences, will decide if the Anthropocene is accepted by the sciences as a new geological epoch. Its 2016 Congress had been expected to consider recognition of the Anthropocene but chose not to on the basis that the Anthropocene Working Group was “at least a few years away from submitting a proposal” (IGC 2016).
popular literature acknowledgement of this new ontology is often expressed crudely. According to Crutzen and Schwägerl:

‘The long-held barriers between nature and culture are breaking down. It’s no longer us against “Nature”. Instead, it’s we who decide what nature is and what it will be. ... In this new era, nature is us’ (2011:n.p.).

This is now 'The Age of Man' according to National Geographic magazine (March 2011). According to Mark Lynas in The God Species, ‘Nature no longer runs the Earth. We do’ (2011:8). One is left asking, as Szerszynski puts it, whether the Anthropocene is ‘the apotheosis or the end of human exceptionalism? Is this the age of the humanisation of planet or of the planetisation of the human?’ (2013a:2). In most accounts of the Anthropocene it is evidently the former. The relevance of all this for SGE, with its combination of Earth-shaping and world-making, is largely self-evident and therefore only requires brief elaboration.

As I have argued elsewhere (Baskin 2015), almost all versions of the Anthropocene concept, especially in the scientific and policy literature, share four attributes, and each of these can be understood in ways which contribute to a narrative that makes SGE necessary, legitimate and understood as a ‘normal’ part of climate management. Firstly, the concept universalizes, normalises and naturalises a certain portion of humanity as the ‘human’ of the Anthropocene. Humanity, considered as an entity, summons up a need for global, universal responses.139 If our species is responsible, as undifferentiated species, then it makes sense to gloss over or ignore the relationship between our environmental predicament and the dominant order, as it is in institutional considerations of geoengineering.

Secondly, the Anthropocene emphasizes the extent to which nature’s autonomy and independence have been diminished if not lost. It thereby reshapes the way the relationship between the social and the Earth is thought. It is sometimes argued that it dissolves, or recognizes as dissolved, the boundary between nature and society. Certainly there are intimations of this. But, more exactly, it acknowledges that the nature-culture boundary is a constructed one. It does not so much dissolve the boundary as relocate it, whilst retaining the traditional hierarchy. It reinserts the human into nature only to re-elevate humanity above it. Seen in this way it can be understood as a colonising move, and the concept does so explicitly (humanity has become more powerful than nature) as part of a wider claim to be a novel and universal truth. Geoengineering too can be understood as a type of boundary claim, a

139 Similar universalising, normalising and naturalising moves are also evident in contemporary human rights and developmentalist discourses.
colonising move. It entails humanity moving from existence within climate to assertion over climate. The Anthropocene concept offers to make a virtue of the boundary claim, or at least deems it to have already happened, which is a simple acknowledgement of the ‘facts on the ground’ revealing anthropogenic impacts. In this worldview, at the risk of extending the colonial metaphor, SGE may even have something akin to a “civilising mission”, the ideology which rationalised the colonial project. The newly claimed territories must be reworked to behave as its new masters expect.

Thirdly, the Anthropocene argument typically suggests that humanity and its planet have entered a new epoch (some time around 1950). This exceptional state, where humanity is the dominant geological force, is both unprecedented and the “new normal”. Exceptionality becomes a permanent attribute: an epoch. Of course the Anthropocene concept, in its scientific incarnation, is mainly about environmental or Earth systems entering a new and exceptional state. But with nature and society so entwined then exceptionality in the political, undemocratic, Schmittian sense is implied. This underpinning of the Anthropocene idea is helpful for proponents of SGE. It is widely acknowledged that one of the biggest obstacles to operationalizing SGE, as discussed above, is that it is ungovernable democratically, or at least is inimical to democratic governance.¹⁴⁰

Fourthly, at least some degree of Earth systems management and technological intervention is implied, and often explicitly called for in the Anthropocene argument. Crutzen’s understanding, cited above, assumes this. Lynas puts it more directly:

‘The Age of Humans does not have to be an era of hardship and misery for other species; we can nurture and protect as well as dominate and conquer. But in any case, the first responsibility of a conquering army is always to govern’ (2011:11–13).

The Anthropocene idea presumes, or at the very least makes legitimate, major interventions into the workings of the earth in order to improve and save it for “humanity”. The facticity of the Anthropocene claim (its description) is thoroughly entwined with its normative aspect (its prescription, explicit or implicit, of what to do). Certainly this normative aspect can be couched in more or less hubristic terms.¹⁴¹ But the general effect is to locate SGE as a not especially distinctive intervention.

¹⁴⁰ I refer here to both a decision to deploy SGE and to the systems required for maintaining regular aerosol injections over a very long period.
¹⁴¹ Of course, many proponents of the Anthropocene concept may not embrace SGE, although they are more likely to argue “not now”. For Steffen, writing with Crutzen, and for the Stockholm Resilience Institute, the Anthropocene concept implies the need for planetary ‘stewardship’ (Steffen et al. 2007;
In short, I am arguing that the Anthropocene is not simply a neutral idea capable of being mobilised badly or well, although it is of course capable of being understood in more or less Promethean ways. Discursively, the concept does political and ideational “work”. It can contribute to normalising SGE. It describes and acknowledges a new ordering of things thereby undermining pre-existing ontological assumptions on which so much resistance to SGE relies. The effect is to naturalise, scientise and inaugurate a novel human condition. It acts to globalise and universalise, fitting comfortably with mainstream understandings of climate change as a global problem. And it works to legitimate climate interventions, even exceptional ones since these are no longer regarded as “abnormal”.

There are many critical accounts sceptical of the Anthropocene concept itself (for example Malm & Hornborg 2014; Baskin 2015; Dibley 2012; Crist 2013; Moore 2014). And there are also critical but sympathetic accounts, exploring the issues that the Anthropocene idea aims to encapsulate. Some of these have an older intellectual provenance. This is especially the case in relation to re-thinking the idea of ‘nature’ (see for example Haraway 1991; Merchant 1980; Descola 2006; Latour 2004; Castree 2005, 2014) or acknowledging, as Swyngedouw does, that ‘nature is always already social’ (2011:259). Many leading thinkers recognise in the Anthropocene a concept that unsettles the philosophical, epistemological and ontological grounds on which both the natural sciences and the social sciences have traditionally stood. Lövbrand et al. explore modes of engagement with what they see as ‘the post-natural, the post-social and the post-political ontology of the Anthropocene’ (2015: 212). For Latour, the Anthropocene is an acknowledgement that history has become ‘geostory’ in which ‘all the former props and passive agents have become active’ (2013:73-4). With specific reference to geoengineering, Yusoff sees a new geo-ontology emerging which reshapes our understanding of geopolitics (Yusoff 2013). And Clark sees in geoengineering an opportunity ‘to imagine a new kind of geologic politics in which identity, citizenship, and governance are construed ... in relation to a dynamic and stratified earth’ (2013:2831).

The argument here is not that the embrace of the Anthropocene implies an embrace of SGE, although it often does. My point is simply that the Anthropocene concept lends itself to being mobilised to “resolve” the many ontological instabilities which accompany SGE, instabilities which account for the distaste and sense of ‘un-naturalness’ which have made SGE difficult to
‘normalise’. The Anthropocene concept, especially in its more scientific versions, and those which understand it as ‘great’ or ‘good’, provides fertile ground for the idea of SGE to flourish.

**A sociotechnical imaginary of the Anthropocene**

This Chapter has sought to illuminate what is constraining SGE’s emergence as a ‘normal’ and deployable component of climate policy and to ask what might facilitate its embrace. In drawing the discussion together, three key factors will be critical.

The first relates to how climate change unfolds. I have argued that physical changes to climate are unlikely, by themselves, to trigger the deployment of SGE. This view is contrary to the implicit expectations of most institutional accounts of the technology. Whilst a crossing of the so-called guardrail of 2°C (or even 3°C and beyond) may well prompt further calls for SGE and help build a coalition of advocates, this is unlikely to be sufficient to enable deployment. The only exception to this expectation might be the occurrence of a major climatic ‘event’ or rapid succession of events, unfolding in the heartlands of the global North (and the US in particular), and entailing both *many* fatalities and extensive televisual coverage.142 This is currently unlikely, given the substantial and relatively resilient infrastructure in place. But, of course, as temperatures rise the likelihood of such events increases.

The second factor relates to the balance of social relations power and the balance of power within existing elites. I have noted, both as a matter of fact but also inherently, the extent to which SGE inclines towards being an elite and undemocratic project, and how it is both a powerful technology and a technology of the powerful. At the same time, the technology itself is perhaps too powerful and too irreversible even for elite adoption. Whilst it offers a solution to climate change which is compatible with the continuation of business-as-usual (of current practices of extraction, production, consumption and exchange), it is a ‘solution’ which must, of necessity, be imposed rather than democratically agreed. Any attempt at imposition would, one must expect, trigger resistance from those not driving the process, whether citizens, other countries, or even less influential fractions of the ‘Northern’ elite itself.

This is closely connected to the third factor, which is how the technology is imagined and the social and political appeal, or disdain, this generates. Currently none of the existing imaginaries of SGE is hegemonic or sufficiently persuasive to be readily and widely embraced.

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142 I am speaking here of something truly substantial, a climatic equivalent to the September 11 attacks in the USA: an event *far* larger in magnitude than, say, Hurricane Sandy, which struck the N-E coast of the United States in 2012 resulting in around 200 deaths, about half of which were in the Caribbean.
Further, the distaste provoked by the three more mainstream component narratives (which together can be understood as constituting the ‘Power’ imaginary), including the sense that it is somehow ‘un-natural’ is, for proponents of SGE, a large part of the problem. Only a re-imagined SGE is likely to provide a foundation for the technology’s acceptance and deployment. This takes us into the realm of the ideational and I have critically explored above the ways in which ‘development’ and the ‘Anthropocene’ might form part of such a re-imagining. Both are commanding concepts. Whilst “development” offers virtue and the claim of altruistic intervention, the “Anthropocene” naturalises a new ordering of the world in which SGE might be understood as natural, inevitable and unavoidable. The Anthropocene idea helps make geoengineering imaginable and legitimate. It offers the possibility for SGE to become part of a positive vision of the future. It offers to address the ontological instabilities which any climate-making project throws up. And its technocratic and Earth management implications help normalise SGE as an answer to the question “how are we to stop imminent, dangerous global warming?”

All three factors – climate change, social relations of power and imaginaries – are inter-related and emerge together. As Szerszynski has noted, new technologies are shaped by and themselves shape social practices and relations. How they are imagined is critical, particularly in the case of SGE, a technology which does not yet exist. In imagining a technology, a world and a climate are imagined too (2016).

SGE is currently a highly-contested, nascent, technology for addressing climate change. I have argued that it will only become an operating technology insofar as the three factors mentioned co-emerge. At the level of imaginaries I suggest that SGE will only become normalised insofar as it is reborn as a sociotechnical imaginary of the Anthropocene, when its attachments to the particular science and politics of climate change are loosened, and re-attached to a positive vision of a good and modern “Anthropocenic”, to coin a term, world. This will not remove the risks of the technology, but it will reframe them as so many technical hurdles for human ingenuity to overcome.

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For critics of geoengineering, this may be a cautionary tale about embracing the Anthropocene concept.
Chapter 8: Conclusion

‘Technologies take on a special kind of social meaning when they are new. As they emerge in various social contexts, modern technologies become the focus of intense political, economic, cultural, and even emotional investment.... It is almost inevitably a field onto which a broad array of hopes and fears is projected and envisioned as a potential solution to, or possible problem for, the world at large. Technological development is one of the primary sites through which we can chart the desires and concerns of a given social context and the preoccupations of particular moments in history.’ (Sturken & Thomas 2004:1)

Solar geoengineering (SGE) aims to reverse or limit the rise in global temperatures by injecting aerosols into the stratosphere to reflect sunlight and reduce incoming solar radiation. Since the mid-2000s it has emerged (or, more accurately, re-emerged) as a new proposal to tackle the troubling effects of climate change. It is held by its proponents to be a potential and much-needed way to supplement the existing climate strategies of mitigation and adaptation. For some SGE is seen as an alternative to mitigation. By engineering the climate system it is hoped to avoid the worst effects of climate change.

SGE is a controversial technology. As I have shown, and as even its proponents concede, SGE provokes widespread distaste and hostility, even revulsion. It is no longer ‘officially’ taboo, but it is also not yet ‘officially’ accepted. SGE is a technology of reflection in two senses. By modifying the Earth’s albedo it aims literally to reflect more sunlight away from the earth’s surface. It also, as I have shown, regularly prompts reflection on the danger of hubris and on the boundaries of what it is appropriate for humans to do. SGE is an in-between technology, again in two senses. It is not yet a deployed technology nor has it really been trialled (although parts of it have been), but it is far more developed than being simply an idea. It can also be understood to stand in-between the human and nature, albeit in different ways as I discuss in Chapter 7. SGE is also a ‘troubling’ technology in many respects. It troubles because of the many risks which appear to be attached to it (from ozone depletion to monsoon disruption). It troubles because it aims only to mask the warming effects of rising greenhouse gas concentrations, not tackle the concentrations themselves. It troubles the existing verities of climate policy which focus on mitigation and adaptation, and make the arguably heroic assumption that existing approaches (if ramped up) could constrain temperature increases to 2°C. And it troubles many of the premises of mainstream Western environmentalism which desperately wants to tackle climate change but is also inclined towards the protection of and non-interference in ‘nature’, and commonly imagines that SGE can only bring trouble. All these features of SGE make apparent that in thinking about SGE the material and the
ideational, how the world (and climate) is and how it ought to be, are entwined. I have been alert to this insight throughout.

In the remainder of this conclusion I will cover two things. Firstly, I summarise the overall arguments being made and address my three specific research questions: how does SGE today differ from previous incarnations of the idea, what is constraining SGE from being normalised and embraced as part of a wider strategy for tackling climate change, and what is at stake in SGE’s re-emergence? Secondly, I reflect on two implications of my argument: the challenges SGE poses for environmentalism, and what the Paris climate agreement (and the election of Donald Trump) mean for SGE.

The argument
In this thesis I examine SGE in depth, focussing especially on the accounts provided by ‘official’ institutions and leading knowledge-brokers (generally proponents). Since what SGE is and what it is imagined to be changes over time, I have structured the thesis into three periodised sections. ‘Yesterday’ focusses on earlier efforts to promote geoengineering prior to its re-emergence in the mid-2000s. This section provides a basis for reflecting on what’s different between geoengineering past and present. The ‘Today’ section takes an in-depth look at geoengineering, and especially SGE, since its re-emergence. I unpack the rationales and framings of contemporary SGE, the relations of power, knowledge systems and values which accompany its re-emergence, and the competing imaginaries which animate both proponents and opponents of SGE. This allows me to explore what is at stake in SGE’s re-emergence and to develop some initial insights into what is constraining SGE’s normalisation. The final ‘Tomorrow’ section is inevitably more speculative and looks at how SGE might unfold and how changes to climate, changing relations of power, and the embrace of discursive turns towards both the Anthropocene and developmentalism might facilitate SGE’s normalisation.

Throughout this thesis I show how particular assumptions and conceptions about society, about climate, and about ‘nature’ are intimately tied up with SGE’s re-emergence. SGE’s re-emergence, in turn, is challenging and re-shaping some of these assumptions. Social values are shaping (and constraining) the technology, and the technology is challenging and compelling reflection on existing social values. I understand SGE as a sociotechnical project rather than, as is typically the case, a putative technology for tackling climate change which it is conceded may have social and ethical implications. Social and power relations, I argue, are intrinsic to SGE. They are not additional, extrinsic, complications. Unusually, and distinct from nuclear technology, biotechnology and other technologies which raise comparable existential
questions, SGE is being assessed prior to its becoming operational, rather than alongside or following its deployment.

What’s different?

One of my thesis questions is: **In what ways does geoengineering’s re-emergence today differ from earlier iterations and imagined interventions?**

During the period of Mastery, which I describe in Chapter 2, no clear distinction is made between ‘weather’ and ‘climate’ and there is little or no sense of an emerging warming trajectory. Geoengineering is embraced because it is possible, not because of any climate or weather problem needing to be addressed. For almost three decades after the end of World War Two, both the imagining of geoengineering (and terraforming), and the very real interventions to manipulate major weather systems, form part of Cold War efforts by the two major powers to control space, the atmosphere and the world.

As I show in Chapter 3, from the 1970s, in both East and West, there was pushback from both scientists and from wider publics against many of the assumptions and the hubris of the Mastery era. There was growing resistance to the idea that active domination and control of nature was desirable or even possible, and increasing acknowledgement of ecological degradation and even ‘limits’. This ‘environmental turn’ helped push consideration of geoengineering into abeyance, to the extent that it was thought about (which was rare). There was no imagined problem needing a geoengineering solution. On the few occasions the idea arises it comes to be regarded as, in effect, ‘taboo’.

Through the 1970s and 1980s there is growing awareness and understanding among scientists of the global warming implications of rising CO₂ emissions. By the late 1980s and early 1990s climate change starts to be understood more widely, and presented as a global ‘problem’ requiring a global ‘solution’... in particular the cutting of CO₂ emissions. There was now an acknowledged problem and also a ready solution, mitigation, although recognition of urgency was not yet widespread. This, together with the persistence of ‘greener’ values consistent with the 1970s environmental turn, and a degree of optimism in the West engendered by the end of the Cold War, helps explain why nothing came of the attempts by some in the United States to revive official support for SGE in the early 1990s and again in 2001. This failure can also be attributed, as I show in Chapter 3, to solar geoengineering lacking credible advocates: SGE’s champions at the time were all associated with the now passé Mastery imaginary. Only in the mid-2000s, with the climate condition deteriorating and mitigation efforts manifestly underwhelming, do credible scientific proponents for lifting the taboo on SGE emerge.
In comparing geoengineering’s post-War past to its post-2005 present there is clearly an evolving understanding of climate, and a widely-felt attitudinal shift, not least amongst climate scientists, away from the idea that human mastery over and subjugation of nature is desirable (let alone possible). Further, since the early 1990s, a growing perception of climate as an urgent and major global problem becomes evident. When considering geoengineering’s past we see, therefore, shifts and developments geo-politically, ideationally and in thinking about climate specifically.

But between geoengineering’s past and its contemporary re-emergence there are also deep continuities in the assumptions made. To deploy SGE, to make it an operational technology, is to assume that the climate system can be ‘managed’ or ‘engineered’. It is to assume that the power to shape climate in intended directions is achievable. It is to assume the dominant Western standpoint: a binary human-nature relationship in which the human is dominant and entitled to determine the shape, meaning and direction of everything else. SGE’s proponents assume an imperial identity, at least implicitly, when they take on the mantle of the ‘we’ who must ‘do something’ about climate. These assumptions hold even when they are tempered, when, for example, ‘unknowns’ are recognised, or the inability to determine precise outcomes is acknowledged. Arguably the more ‘responsible’ and cautious proponents of SGE, when they worry about governance are, in effect, seeking a higher authority to give them the managerial role.

In short, SGE’s re-emergence, if it is to become a deployed technology, must still rely upon many of the core assumptions and hubris of the earlier Mastery phase of geoengineering. But these assumptions are no longer regarded as self-evident, as they once were. Since the environmental turn of the 1970s they have been contested and opposed at least as much, if not more, than they are accepted. In geoengineering’s earlier Mastery phase these assumptions were actively embraced by both powerful institutions and powerful scientists, and attached to optimistic visions of ‘progress’, self-confidence and faith in both science and scientists. But such visions are now contested, not least within the epistemic community of Earth and climate scientists. Today, whilst advocates of SGE are tied to Mastery-like assumptions regarding what can be done, it is no longer taken as self-evident that these actions ought to be done. The result is that SGE is hard to convey optimistically or be attached to utopian visions, visions which the advocates themselves may no longer fully believe. As a result contemporary proponents of SGE are driven towards a dystopian, pessimistic stance. SGE must be pursued as a ‘lesser evil’, a ‘bad idea whose time has come’, a development ‘unfortunately necessary’ to avert ‘climate catastrophe’.
What’s constraining SGE? What's holding SGE back? Why are the arguments of its proponents not getting policy traction? As another of my thesis questions asks: **What is currently restraining the normalisation of SGE as a legitimate third leg of climate policy, alongside mitigation and adaptation?** I have shown throughout that SGE is now part of climate policy discussion. It is respectable to talk about it but it has not yet been officially embraced. It has not been ‘normalised’, by which I mean it is not yet regarded as a valid addition to mitigation and adaptation as a climate policy option. Nor is it currently treated as a ‘normal’ technology needing development, as for example carbon capture and storage (CCS) is. SGE is partly accepted as an idea but not yet as a practice. Indeed it has many vocal opponents, some arguing that its embrace is premature since there are too many unknown risks, and others arguing for the turn to geoengineering itself to be resisted.

Five inter-related dynamics are working to constrain SGE’s normalisation. None of these, on its own, would necessarily be fatal. But together they provide a powerful resistant dynamic.

Firstly, as I discuss at length in this thesis, there are obvious uncertainties and perceived risks regarding the likely socio-economic, geo-political, ecosystem and physical Earth effects surrounding SGE. Much depends on the amount of warming any SGE initiative intends to mask and therefore the ‘dose’ of sulphate aerosols applied, as well as on the location where the injection takes place (with the southern hemisphere tropics typically suggested as ideal). ‘More research’ may result in better modelling and sharper, more fine-grained, projections and probabilities regarding the physical effects of SGE (precipitation patterns, ozone depletion and so on).

But it is unlikely to produce sufficiently reliable understandings of the likely socio-economic, ecosystem and geo-physical effects. Reading the social and geo-political effects is not possible. And reading environmental effects off the models is also a deeply flawed exercise. It amounts, as discussed in Chapter 5, to ‘climate reductionism’ the mode of analysis in which ‘climate is first extracted from the matrix of interdependencies that shape

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144 “More research is needed” is a regularly repeated trope in the institutional reports on SGE. In practice it is hard to disentangle researching SGE from ‘doing’ or deploying it and calls for ‘more research’ can easily mask experimental deployment. There is widespread agreement that effective governance should precede research. But what if SGE is essentially ungovernable other than autocratically, as Hulme has argued (2014), plausibly in my view? Why research something when, if the research generates a working technology, it cannot conceivably be governed democratically? Not surprisingly, engaging with where (field or laboratory) and how to legimately and ethically progress research into SGE, when there is insufficient agreement as to whether SGE is a legitimate intervention into the climate, means that the research governance questions rarely end up being about research governance. Instead they become a proxy battleground for the ‘whether’ question, and mask the fact that the ‘whether to solar geoengineer’ question remains unresolved.
human life within the physical world’, and then elevated to the role of ‘dominant predictor variable’ (Hulme 2011:247). It may be possible to reduce some of the uncertainty surrounding SGE’s effects, but not most of it. Much is unknown and unknowable this side of experimentation and deployment. Absent a high appetite for risk SGE is not easily normalised.

A second constraint relates to affect and dystopia. As I have shown repeatedly, it has proven difficult to locate advocacy for SGE within an optimistic narrative. One attempt to do so, the ‘Salvation’ narrative discussed in Chapter 6, is only indirectly optimistic since any optimism is achieved by attaching SGE to altruism, virtue and the claim that it is in the interests of the world’s poorest. In any event, as I also show, it is only one narrative among a number, and none of them is hegemonic. Another attempt, as expressed in the ‘Market’ narrative emphasises SGE’s cheapness and thereby attaches itself to the utilitarian utopia of the unconstrained market. But this approach has found little support for reasons which I outline in Chapter 6, including that its advocates commonly regard the dangers of climate change as exaggerated. A second constraint, therefore, is the failure to attach SGE to a positive vision.

Contrast this with the normalised policies of Mitigation and Adaptation: despite being defensive responses to climate change both can and have been characterised as having multiple social and economic co-benefits, and as encouraging innovative approaches and technologies. Without a positive vision of this sort normalisation becomes more difficult. Among comparable technologies only nuclear weaponry was normalised in the context of a dystopian vision, and normalisation was as a technology which made a credible threat to a Cold War enemy rather than as a technology that should be used.

The slow pace of climate change is a third constraint. This observation may appear counter-intuitive since the acceleration of global warming itself is often understood to be a factor facilitating SGE’s normalisation. Indeed the ‘climate crisis’, combined with the inadequacy of mitigation, was a central motivation in the calls for lifting the taboo. But, as I have argued in Chapter 7, the situation is more complex. Climate changes are unfolding rapidly when viewed from the perspective of Earth sciences and the relative climate stability which has characterised the Holocene. But, from the perspective of individuals and their societies the changes are slow, or sporadic and highly uneven. They allow time both for some adaptation and for regarding the present as the ‘new normal’. Extreme changes that might appear to justify deploying SGE can already be observed, such as numerous consecutive days on the Indian sub-continent in 2016 with temperatures well in excess of 40°C, or reports that Arctic air temperatures in November 2016 were 20°C above normal (Vidal 2016:n.p.). But broader considerations, I argue, mean that unless such changes are obviously visible, extreme and
recurrent, occur in summer (a warming winter is frequently welcomed), and in a country with both the technological capability and the geo-political authority to deploy SGE, then the technology will not be deployed. Climate changes in New York will count for more than those in New Delhi. The pace of climate change is a constraint therefore but it could, of course, transition rapidly to becoming an enabler of SGE.

What could also change rapidly, but is currently a fourth constraint, is an absence of sufficiently powerful champions, in the sense of individuals, institutions, organised interests or governments having the power to normalise SGE or make it happen without consent. At the time of writing this is evident in a number of domains – in the epistemic community, in the global South, in the relative absence of vested economic interests, and in key governments (in particular the USA). As I have shown throughout the ‘Today’ section there are many opponents of SGE within the climate and Earth sciences, and they typically cite both factual considerations and value differences. Indeed, it could be said that there is, generally speaking, a disconnect between the dominant norms of the epistemic community of climate science and those of SGE’s key proponents and knowledge-brokers. The former are more inclined than the latter to acknowledge the role of market globalism in driving ecological destruction and climate damage. And they are less inclined to embrace the hubris implicit in the call for SGE. This ‘values disconnect’ impacts on the ability of the ‘official’ scientific assessments, whose panels typically include a spectrum of views, to arrive at a consensus position favourable to taking SGE forward. It results in stalemate and this is manifest in a refusal to endorse SGE, and a deferral of decision-making by calling for ‘more research’.

SGE as climate policy also appears to lack advocates from the global South. Indeed all SGE’s key knowledge brokers would appear to be male and pale inhabitants of the global North. This is significant given the claims of some advocates from the global North that SGE should be deployed mainly to protect the world’s poorest. Also absent is any evidence of interest in SGE by those who would ‘benefit’ immediately from its deployment; low-lying island states threatened with inundation. Finally, there is currently no significant or even nascent industry with sufficient power or vested interests to champion SGE. The nexus of patents, markets and private sector players that does exist is too small to have significant influence on policy. Whilst a number of countries have research and development programs, funding is relatively limited.

145 In the thesis I address the geo-political reasons why unilateral deployment by countries other than the USA, and possibly China, is unlikely, absent a turn to competitive SGE which would not deliver desirable climate results for anyone.
Enthusiasm for SGE amongst leading governments seems restricted at present to Russia. This may change with the election of Donald Trump.

Finally, SGE is compatible with the interests of the dominant global economic order, but not comfortably so. This paradoxical relationship to the currently dominant order is discussed in Chapter 7 and will be elaborated upon further in the next section when I consider ‘what is at stake’. But in brief, whilst SGE appears to have the potential to cause minimal disruption to the existing economic order in the quest to address climate change, its compatibility with the status quo is not straightforward. This explains both the current lack of economically powerful champions for SGE, as well as the interest in some forms of geoengineering shown by a number of the global economic elite, such as Bill Gates or Richard Branson.

These five factors, when taken together, constrain the normalisation of SGE. The technology seems to be currently be in a situation of stalemate. Opponents are not able to ban it or return it to the status of taboo. Proponents are not able to enforce, through persuasion or coercion, its normalisation and adoption as a third leg of climate policy.

What’s at stake?
Since SGE is proving difficult to normalise, and highly contested, there is clearly a great deal at stake. I have explored what assumptions, interests and imagined futures travel with SGE as it re-emerges. I have unpacked the interplay of values, knowledge and relations of power that constitute it. In doing so I have shown that what is at stake is intimately wrapped up with how SGE is understood. I have shown that SGE entails far more than climate-tweaking using a mundane technology as some leading proponents imply. I have shown too that SGE is not simply, as most institutional assessments assume, a technology or technoscientific object, albeit with some acknowledged uncertainties and with additional social and ethical concerns attached: concerns and uncertainties which can be resolved, it is suggested, through ‘further research’. Rather, it is a sociotechnical project and the social, the ethical and the uncertain are intrinsic to it.

SGE is simultaneously a developing technology, an emergent climate policy, an idea-information, and a claim on how the future ought to be. This is why understanding the competing sociotechnical imaginaries of SGE, and how they might evolve – the ‘Power’ imaginary (with its uncomfortably allied ‘Market’, Geo-management’ and ‘Salvation’ strands) and oppositional imaginaries (such as the ‘Un-natural imaginary) – is helpful in revealing what is at stake. As I outline in the Introductory Chapter, geoengineering acts as a screen onto which competing visions of the world are projected. Projected visions of the technology both shape it and enable it to (or prevent it from) coming into being. The world/s which are
imagined (socially, environmentally, geo-politically, ontologically) are as important to the technology’s emergence as ‘nuts and bolts’ considerations about the technique of SGE.

My thesis question asks: **what is at stake in SGE’s re-emergence, since the mid-2000s, as an object of mainstream climate policy consideration?** Competing values are crucial here, including assumptions about who and what is important, and about what values and orderings should be retained and what not. Central, too, are the constellations of interests and relations of power in the world, the hierarchies and structures of the social, economic and geo-political order. Important too is the epistemic community of climate science/policy, and the knowledge practices, value assumptions and power relations that shape the understanding of SGE. In trying to understand the interplay of knowledge, values and the relations of power which are at stake in the emergence of SGE, I broke down my core thesis question into three more specific subsidiary questions, which I shorthand as Knowledge, Values and Power:

- **which knowledge systems and epistemologies, and which ‘epistemic communities’, have been engaged with in the process of SGEs re-emergence, and which have been relegated to a subsidiary role?**
- **what ontological orderings and values are contested in the process of SGE’s re-emergence?**
- **what material and geopolitical interests are served or might benefit from the adoption of SGE as a component of climate policy?**

**Knowledge**

In analysing the epistemological challenges and knowledge claims at the heart of SGE I have shown that the ways in which SGE is approached, analytically, are inadequate to the issues being addressed. Approaches which emphasise measurement and modelling (a standard practice in climate science) and which, like much of the IPCC as a whole, elevate cost-benefit ways of seeing and valuing the world, seem ill-suited to understanding and evaluating SGE. Adopting such approaches assists in normalising SGE as another leg of climate policy, but the fact that normalisation is proving elusive is further evidence that they are a poor methodological fit.

The knowledge hierarchies surrounding SGE elevate the physical sciences and relegate the social sciences. They also elevate expertise in general and diminish public knowledge and what Jasanoff has called ‘civic epistemologies’ (2005). All this may be appropriate if SGE is “merely” a technology or a technoscientific object. But if it is understood as a sociotechnical project, a re-making of climate and an inauguration of new world/s, then such knowledge hierarchies exclude and also conceal more than they reveal. Further, calls for “more research” before
proceeding to deploy SGE presume more research in the same epistemological vein as that which has already been undertaken. In short, the ways in which expert knowledge is mobilised is not up to the task of deciding what actions to take when values are contested and in a context of deep uncertainty and the distinct possibility that much about SGE is not only unknown but perhaps unknowable.

**Values**
In one sense, SGE shines a light on the unfolding of the project of Modernity. Embarking on SGE entails humans and human societies entering into a new relationship with the Earth. Whilst many in both the global North and South would agree that a new relationship with the Earth is precisely what is needed, they rarely have in mind the relationship which SGE ushers in. A great deal is at stake, therefore, because to embrace SGE is to embrace, or at least accept, an intensification of human pre-eminence in shaping the world. It is to re-embrace the practices of Mastery. It is to accept that there are no in-principle limits to technological intervention in the Earth system, that there is nothing that cannot be managed or ‘fixed’. It is, in effect, to ratify rather than resist the ‘End of Nature’, to use McKibben’s term (1989).

There are some, indeed, who welcome this direction, and perhaps it amounts to little more than the end of innocence: not for nothing is Lyans’ book titled *The God Species* (2011). But there are many (arguably many more) who do not. Embracing, or even normalising, SGE involves choosing a particular path with the many consequences and path dependencies that are likely to ensue. In particular, it makes different, more humble, futures difficult to imagine and even harder to realise.

SGE aims to create a new average climate. It cannot return the world to climates past. It can only manufacture a *new* and cooler global climate, one that would be much cooler in some places than in others, and much drier or stormier or different to the present in some places than in others. We cannot easily predict the effects in one locale or one community or ecosystem. Creating new local weather systems, the level at which they are experienced by actual communities of people, means breaking patterns of relationship to the cycles of the natural world which shape cultures, values and material practices, and creating new ones. This is especially the case with the half of humankind still directly and extensively interacting with the land, with agriculture and with the natural world. It entails an intensification of what Rob Nixon has called ‘slow violence’, which I have discussed in this thesis.

At stake is not only which values should prevail. It is also about what other ways of being in the world, what ontologies, are erased when climate change is cast as a global problem requiring a global, universal, technological response. The worlds envisaged in the imaginaries I
analyse in Chapter 6 are very different. Even so these are all imaginaries originating from and, with the partial exception of the ‘Un-natural’ imaginary, largely situated in Western traditions of understanding modernity. SGE aims to make particular climates. In the process it remakes worlds, in the sense of re-shaping both actual the environments and how the world is commonly imagined to be. I have argued throughout that this is the source of much of the discomfort with SGE amongst both publics and experts.

In terms of values, my argument is that a great deal is at stake: not only the implications of the path taken if SGE is embarked upon, but also the alternatives foreclosed. Much more is at stake than is suggested when ‘official’ accounts acknowledge that SGE raises ethical concerns, concerns typically narrowed down, as I have shown, to the so-called problem of ‘moral hazard’ – that SGE might slow down mitigation efforts.

**Power**

Whilst SGE, should it become an operating technology, may cool the climate it would do so variably. At best it would produce fewer ‘losers’ than ‘winners’: Bunzl has suggested six billion winners and 1 billion losers (cited in Wood 2009) although it is unclear how this calculation is arrived at. The suggestion, made by some, that without SGE things would have been even worse and the ‘losers’ and losses even larger in the aggregate, is hardly likely to be compelling to those negatively affected. What possible evidence would be provided for it? And what possible real-world experience suggests such evidence would persuade the ‘losers’? Clearly, SGE is likely to be geo-politically destabilising. Examples of possible geo-political effects are identified in this thesis and include potential conflicts between nuclear-armed neighbours India and Pakistan, associated with the actual (but impossible to predict) weather effects which may materialise in one part of the sub-continent rather than another. It is highly plausible that SGE, therefore, would provoke geo-political conflict. Such situations typically favour the already most powerful states.

I make no claim of originality when arguing that it is hard to see democracy and SGE as being compatible (see for example Szerszynski *et al* 2013). By its nature the technology would seem to require autocratic governance, if only to set the desired temperature and determine the aerosol dosage. At best, ‘club’ governance, as proposed by Victor, might enable concurrence by a slightly larger group of states with the geoengineering actions of the most powerful states, namely the USA and China. Within the currently most globally powerful state, the USA, it is hard to see how the desire of Florida for more cooling and the Pacific Northwest for less, could be resolved both prudently and democratically, not to mention responsibly in respect to other states and societies. What is at stake with SGE therefore, when taking the democracy and the
geo-political concerns together, is the intensification of existing concentrations of state power at best, or the emergence of new undemocratic authority, perhaps alongside the argument for ‘exceptionality’. The ‘Geo-management’ narrative I outline in Chapter 6, acknowledges this implication in part when it explicitly imagines a ‘Brave New World’.

I have explored, especially in Chapters 5 and 7, the paradoxical relationship between SGE and the dominant order of market globalism. In many respects, as the ‘Market’ narrative emphasises, the deployment of SGE is manifestly compatible with the continuation of ‘business as usual’. By masking the immediate warming effects of climate change it enables the pace of mitigation to be slowed down and the costs and disruptions associated with transitioning to a low-carbon economy to be reduced or deferred. In this sense, as I have argued throughout, SGE can be understood as a *doubly-masking* technology since it has the capacity also to mask the socio-economic drivers of climate change. It has the potential to mask the pursuit, endorsed by most governments and businesses and the major economic multilateral institutions, of unlimited growth in extraction, production, trade and output. It masks, in short, some of the central drivers of contemporary capitalism (and, historically, of Promethean communism too).

And yet, since SGE appears to require an ultra-centralised entity to deliver it, it doesn’t fit neatly with environmental approaches which emphasise less centralised technical and procedural innovations and ones that work with the grain of existing institutions and arrangements (what Hajer 1996 labels ‘eco-modernisation’). And whilst one can envisage some corporations benefitting from SGE, this too does not mesh comfortably with notions of smaller government, de-regulation and marketised solutions to environmental problems (of the sort found in the AEI 2013 and CCC 2009 reports). Whilst SGE has the character of a technical solution to an ecological problem it seems also to imply the disruption of existing institutions. One can add here the observation that since the richest and most powerful inhabitants of the Earth have the greatest capacity (by moving, cocooning and air conditioning) to put up with even extreme climate changes, they may be the least interested in the disruptions entailed by SGE. SGE would appear, therefore, to be “hyper-compatible” with the

146 I am thinking of institutions such as the International Monetary Fund, the World Trade Organisation, the World Bank and International Finance Corporation, and the BRICS-governed, Shanghai-based New Development Bank. Whilst all acknowledge a need for ‘sustainable development’, they all privilege growth as an objective. The World Bank has acknowledged more recently that there may be some ecological limits to growth, but they resolve this by retaining their goal of growth but making it ‘green’ (2012b).
dominant order. Its compatibility is accompanied by disruptive characteristics. This can make SGE unattractive to those elements of the dominant order for whom disruption is threatening and the predictability and continuity of existing structures and investment horizons is important.

In short, what is at stake is the possibility of dangerous levels of geo-political instability, the almost certain reduction in democratic accountability which would accompany the deployment of SGE, and the perpetuation of the assumption that concerns about global warming must always be secondary to the desire for economic growth.

* * * *

In the most general sense what is at stake are the values we choose to embrace, the ways of knowing both the world and our ecological condition that we choose to guide us (and relatedly the role that we assign to science and technology), whether we look at the future with hubris or humility (and thereby the policies and practices we choose to adopt), the value we place on democratic striving and inclusive, less unequal, societies, the priority we give to the pursuit of GDP growth, and our normative account of the proper relationship between the human and the more-than-human on this planet.

* * * *

As discussed in the Introduction, I have mobilised Jasanoff’s concept of ‘co-production’ because of its insight that, in thinking about science and technology, the ways in which we know the world are inseparable from the ways we choose to live in it. In the case of SGE it helps maintain a focus on the two-way relationship between the material and the ideational, and how their coming together shapes the emergence (or non-emergence) of new technologies. Because SGE has not (yet) emerged or been normalised, what SGE is imagined to be, to be for and for whom, remains highly contested. Jasanoff’s related concept of ‘sociotechnical imaginaries’ helps our understanding of the work that imaginaries do in bringing new technologies into being. She defines sociotechnical imaginaries as:

‘Collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology’ (Jasanoff & Kim 2015:4).

I have shown how a number of competing imaginaries exist in relation to SGE. I have sometimes referred to these as ‘narratives’ to keep the term ‘sociotechnical imaginaries’
unsettled given the fact that none is (yet) ‘institutionally stabilized’, ‘shared understandings’ are not in (yet) in evidence and all the competing imaginaries struggle to present ‘desirable futures’. These are not fatal flaws in using the concept since it is precisely contestation over whether and how to stabilise SGE institutionally and ideationally which is in play, including how to make the technology’s desirable features more evident than its dystopian ones.

The sociotechnical imaginaries concept is usually applied to analyse technologies that have already emerged (see Jasanoff & Kim 2015). In this thesis, unusually, it is mobilised to help understand a technology which has not yet emerged. When used with the idea of ‘co-production’ it helps connect and cohere my three thesis questions. What is at stake is connected to the constraints on SGE being normalised and, over time, some narratives become less, whilst others become more, available for mobilisation into a dominant imaginary. The concepts also help to reveal that understanding SGE in a limited, physical and technical, sense is clearly inadequate. They help make sense of the fact that in choosing the unprecedented path of intentionally shaping the global climate (and thereby the locally-experienced weather), a societal trajectory is embarked upon, and a world is also made.

The interplay of relations of power, of knowledge and of values are critical in understanding SGE. They also explain why SGE has proven so difficult to normalise as an acceptable component of climate policy, and why a simple return to an earlier imaginary of ‘Mastery’ is not easily available. In the process I have shown that SGE is a technology which is both \textit{climate-shaping and world-making}. I have shown that whether SGE emerges – from idea to experiment to deployed technology – rests heavily on both how the current world and climate is understood, how relations of power within epistemic communities and within and between states evolves, and what future world it is imagined an engineered climate will inaugurate. For SGE to happen it will need to be normalised either by being presented and accepted as optimistic and discursively coherent, or by being coercively imposed. Or both.

\textbf{Some implications}

Having drawn together my arguments in response to the formal questions posed in this thesis it remains to reflect briefly on the future of SGE. I will briefly address two questions. What does SGE and the geoengineering turn mean for environmentalism? And what is the prognosis for SGE in the wake of the Paris climate agreement (and the election of Donald Trump)?
The troubled nature of environmentalism

I have stressed throughout this thesis that it is SGE’s ‘un-naturalness’ and hubris that most disturbs when publics are surveyed about SGE, when advocacy groups opposing SGE make their case, and even when many scientists consider the issue. I have shown in Chapter 3 the implications of the environmental turn of the 1970s and highlighted its role in delaying geoengineering’s re-emergence. But what, conversely, are the implications for environmentalism from the contemporary geoengineering push?

On the one hand, public attachment to ‘nature’ and rejection of ‘un-natural’ climate interventions sits comfortably with long-standing conservationist and preservationist traditions in environmentalism. On the other hand, ‘natural’ is today often dismissed by contemporary environmentalists as a value-laden and un-scientific concept, and an inadequate foundation for environmentalism. It sits uneasily with the scientific discourses that have been embraced by contemporary environmentalism (unlike in the 1970s), and which constitute the dominant register and discipline in which climate change is discussed.

But, as a result, the more visceral ‘un-natural’ and hubristic anxieties about SGE have little place to go. I argue that they emerge indirectly, even amongst proponents, in claims that SGE is needed for the environment or in the truncated ethical language of ‘moral hazard’. It is evident when the major institutional assessments of SGE assert the importance of values and ethics. It is manifest when David Keith, in his book *A case for climate engineering* (2013), takes great pains to stress his personal love of the outdoors and connection to nature. It can be seen in the more sceptically-inclined climate scientist and vulcanologist Alan Robock’s listing of 26 risks and five benefits of SGE (2015a). These include ‘beautiful red and yellow sunsets’ as one of the benefits, and among the risks includes, in addition to expected ones such as ozone depletion and ocean acidification and irreversibility, that there would be ‘whiter skies’, ‘no more Milky Way’ and ‘do we have the right to do this?’ (2015:n.p.).

There is no doubt, as I discuss in Chapter 7, that ‘nature’ is a slippery concept. As Raymond Williams famously argued, the word ‘nature’ is perhaps the most complex in the English language, and contains, ‘often unnoticed, an extraordinary amount of human history’ (1980: 64). And as I have argued elsewhere (Baskin 2015), many issues are enmeshed in the term,

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147 Boucher et al (2014) are not alone in acknowledging that the idea that geoengineering is ‘unnatural’, even that it should be unimaginable or taboo, repeatedly arises in the growing number of studies of public perceptions and responses to geoengineering. This is less a reflection of the respondents ‘green-ness’ or embrace of the natural world, but more a sense, often inchoate, that geoengineering somehow breaches the ‘natural’ order, the sense of how things should be between humans and ‘nature’.
from the empirical ‘nature’ in the world ‘out there’, to the concept of ‘Nature’ with its history, politics and complexity, to the associated Nature-Culture binary which frames much of western thinking and scientific practice (cf. Merchant 1980; Cronon 1995; Latour 2004). It is today widely acknowledged that humans and their societies exist in, not above or alongside, ‘nature’, and that the popular understanding of what is, and is not, natural shifts over time and is valued variously. This suggests that ‘nature’ and a sense of SGE being ‘un-natural’ may be a weak conceptual foundation on which to rest opposition to SGE. More broadly SGE may provide pause for environmentalists and environmentalism more generally, to re-think a number of their existing standpoints. It is hard to proclaim ‘the End of Nature’ (McKibben 1989) and then to oppose interventions that engage with that reality in post-natural ways. This is the standpoint adopted by Lynas (2011) when he argues that ‘we’ are already engineering the Earth when we drive our cars, with the implication that embracing geoengineering is nothing really new. The response to Lynas that geoengineering is different because it is undertaken intentionally, is manifestly a weak one: each new decision to drive or to build a car plant is intentional and taken in a context where the ecological effects are now known.

A great deal of thought is going into re-thinking environmentalism. Some aim to acknowledge the human shaping of ‘nature’ and urge that we treat the wilds as a ‘rambunctious garden’ and recognise it is no longer an untamed ‘other’ (Marris 2011). Some suggest the need for a new environmental theory of the post-natural world, rooted in an acknowledgement that nature has ended (Vogel 2015) even as environmental problems persist. Others, including some of SGE’s advocates and sympathisers, have hoisted the banner of the Breakthrough Institute’s version of eco-modernism (see Eco-modernist Manifesto 2015) which not only acknowledges nature’s end but calls for its active modernisation.

Against such approaches the argument can be made the attachment to ‘nature’ should not be lightly abandoned, not least because it attaches to popular discourse. It can be argued that artifice and wildness are only two extremes of a long and complex continuum, and that acknowledging that nature is damaged does not mean it has ended, nor that it has it lost its exteriority, agency and otherness (Worthy 2013). Perhaps nature has not ended, it was ‘always already social’, but rather humans have ended, in the sense that they have become more alert to the ways in which they are entwined with nature, and are rediscovering truths that other cultures and times have long appreciated. My point here is only that the idea of SGE, and its potential deployment and effects, can help illuminate the re-thinking of
environmentalism that is currently underway, and that there are implications in embracing post-nature perspectives too rapidly.

The Paris agreement (and Donald Trump)
Finally, what are the implications of the Paris climate agreement of December 2015 for geoengineering and SGE, and vice versa? The short answer is that the Paris targets make geoengineering and SGE more likely, if there is serious intent to meet the targets. I will turn to the longer answer shortly. As I outlined in the Introductory Chapter, the Paris agreement committed future state signatories to two main goals: holding warming to 2°C above pre-industrial, and even aiming for 1.5°C; and committing to zero net emissions in the second half of the century (UNFCCC 2015). There is little prospect the temperature targets can be met without immediate mitigation efforts which are dramatically stronger than existing commitments ... other than by deploying SGE. And the goal of reaching zero emissions relies on what the agreement repeatedly refers to as ‘anthropogenic emission removals’, in effect by utilising some form of geoengineering of the carbon-dioxide removal (CDR) variety, sometimes known as ‘negative emission technologies’.

SGE is not mentioned in the Paris agreement. And no specific CDR technologies are endorsed. But only one of the IPCC pathways (RCP 2.6) comes close to being aligned to the goals contained in the Paris agreement. The assumption appears to be that meeting a zero emissions target requires the massive expansion and uptake of a form of geoengineering known as Biomass Energy with Carbon Capture and Storage (BECCS). This is a technology that involves growing very large quantities of biomass, burning it to produce energy and sequestering the associated CO$_2$ underground or in the deep oceans. It would require plantations and infrastructure to be developed (most effectively in the tropics of the global South) across a land area almost the size of Australia: or put another way, an estimated one-third of the world’s arable land would need planting for BECCS use by 2100 (Williamson 2016). This is before considering the many challenges of sequestration. If attempted it would be at least as controversial as SGE and a great deal more expensive. It is also not yet proven as a technology. In short, the ambitious and admirable targets set in Paris can equally and plausibly be seen as faith-based policymaking. Kruger et al have called it an example of ‘magical thinking’ (Kruger et al 2016), the belief that ‘thinking about something amounts to doing it, even when the instrumental means to bring it about are absent’ (Rayner 2016:1).

It is, of course, true that the zero emissions target is some decades away and perhaps some revolutionary new negative emission technology may emerge. But the temperature target, the so-called ‘guardrail’ of 2°C, is closer to hand. SGE offers the possibility of meeting the
temperature target and, in the process, buying time to develop suitable negative emissions technologies, and to do this cheaply enough to allow resources to be channelled towards this goal. Perversely, rising CO₂ concentrations are good for biomass growth, and since SGE masks rather than tackles these concentrations, it may even be argued that it has the co-benefit of facilitating BECCS. In short, the Paris agreement normalises CDR-style geoengineering. And the temperature targets make SGE’s normalisation more likely, not imminently but perhaps dependent on the perceived viability of various negative emissions technologies.

The election of Donald Trump as US President reinforces this dynamic. His stated policies make achieving the necessary global emissions reductions less likely, and therefore increase the likelihood that the 2°C threshold will be crossed. A number of Trump’s key policy advisors share his climate denialism/inactivism and are also SGE enthusiasts. This is true of both David Schnare and Newt Gingrich both of whose views are discussed in Chapter 4. Both adhere to some variant of the ‘Market’ narrative in favour of SGE which I outlined in Chapter 6. Both are hostile to global warming ‘alarmism’, sceptical of the need for mitigation and champions of increased fossil fuel use. They are enthusiastic about SGE as a “just in case” solution which doesn’t restrain capitalism if the warnings about climate turn out to be true. Trump’s nominee to head up the US Environmental Protection Agency (EPA), Myron Ebell, appears to hold similar views (Ebell 2016; 2009). The chances of stumbling into SGE’s deployment appear to be growing.

To conclude …

One of my thesis questions focussed on what is constraining SGE from being normalised as a component of climate policy. One could flip this question and ask what is it in the practice of climate policy and climate science that gives rise to ideas such as SGE? Is it possible that the currently dominant approach to climate policy, combined with the climate prognosis, is now only able to generate dystopian ideas like SGE or ‘magical thinking’? The limitations of understanding climate change mainly through the lens of science become apparent when looking at SGE. Perhaps SGE might impel us to rethink how climate change is understood and approached more generally.

Certainly it can be argued that from the 1980s understanding climate became increasingly detached from the social conditions of existence. Average weather (climate) was privileged over lived weather and experienced seasons. Heavy reliance on surveillance from above for our data, the privileging of calculative expertise, the casting of climate as a ‘global’ problem, all have arguably contributed to this detachment. Further, as Fleming and Jankovic have noted, when the ‘social’ is then re-attached it is typically in the form of something determined by
climate change: ‘[it] “impacts” the economy, “affects” countries, “harms” national security, “hurts” the world’s poor, and potentially “leads” to global conflict’ (2011:3). Another effect has been, as Crist points out, that the attention given to climate change has had the effect of displacing other ecological concerns and de-emphasising, unintentionally, their connectedness (2007). In parallel, the sense of the numinous when thinking about climate and weather (and indeed about ‘nature’) has been eroded. And yet the numinous, the sense of being in the presence of something awe-inspiring and ‘other’, not necessarily in a religious sense, has long been a critical component in common understandings of climate (and ‘nature’). Would a science of climate that was both more down to Earth and more connected to the numinous, produce an idea like SGE? Such questions and their implicit critique are not novel. But reflecting on SGE perhaps brings them to the fore anew.

Absent a radical turn in thinking about climate and the environment, my expectation is that SGE will be deployed coercively, in a few decades time, in response to calls to ‘do something’ about unruly weather. Its deployment will likely be ‘too much, too late’: by which I mean that the climate condition will be significantly more disrupted than currently and require a higher dosage of sulphate aerosols than is prudent. This, in turn, is likely to have effects we simply cannot anticipate and usher in both a new climate (which may take centuries to stabilise around a new equilibrium), and with it, new World/s.

I acknowledge that this is a dystopian vision. But, as Eagleton has argued, it is possible to have hope without optimism (2015). And my hope is that better alternatives than SGE may emerge, that resistance is possible, and that more humble ways of being in the world are possible too.
Epilogue

As I was finalising this thesis for submission an opinion piece was published by two leading proponents of solar geoengineering, both based at Harvard, and with the apposite title ‘Toward a More Reflective Planet’. It is an argument for literally making the planet reflect more sunlight using SGE: ‘we need to turn down the heat – and fast’ (Keith & Wagner 2016:2). This thesis also argues for a ‘more reflective planet’ but in a diametrically opposed sense. For me SGE imposes an ethical obligation and provides a lens through which to reflect on our planet and our Earthly condition. My objective has been to critically interpret SGE, exploring what is at stake in its emergence, what is constraining its normalisation, and reflecting upon and unmasking, where necessary, the masking, reflective technology which is SGE.

In 2010, as a part-time doctoral student, I commenced the research which has culminated in this thesis. My first step, with the hope that this would clarify and sharpen my research questions, was to read everything I could find of direct relevance to geoengineering. From early in the process I was struck by how all the assessments of geoengineering, and most of the associated papers and reports, especially those emanating from scientific bodies, concluded by calling for more research being needed. I also soon observed a pattern in the responses I received when explaining solar geoengineering (SGE) to non-specialists in the most professional and neutral ways I could muster. I was sometimes asked ‘could it work?’, never asked ‘how could SGE be made to work?’, but invariably asked, often with an accompanying grimace, ‘who imagines doing such a thing?’. As I have shown in this thesis such distaste, and resistance to the idea itself, is widespread.

These two observations, taken together, also reveal a widespread expert—non-expert divide in how this important matter of public concern is understood. But fortunately the divide is not an absolute one. I conclude by repeating a comment cited early on in this thesis. It is from Gavin Schmidt, a climatologist and Director of the NASA Goddard Institute for Space Studies in New York:

“Think of the climate as a small boat on a rather choppy ocean. Under normal circumstances the boat will rock to and fro, and there is a finite risk that the boat could be overturned by a rogue wave. But now one of the passengers has decided to stand up and is deliberately rocking the boat ever more violently. Someone suggests that this is likely to increase the chances of the boat capsizing. Another passenger then proposes that with his knowledge of chaotic dynamics he can counterbalance the first passenger and indeed, counter the natural rocking caused by the waves. But to do so he needs a huge array of sensors and enormous computational resources to be ready to react efficiently but still wouldn’t be able to guarantee absolute stability, and indeed, since the system is untested it might make things
worse. So is the answer to a known and increasing human influence on climate an ever more elaborate system to control the climate? Or should the person rocking the boat just sit down?” (cited in Fleming 2010: 234-5).
Appendix 1: The science & technology of solar geoengineering

In this Appendix I outline the essentials of the Earth’s energy balance, and then describe the Sulphate Aerosol Injection (SAI) technique more fully, avoiding technical language where possible. Finally I summarise what we know about the likely effects of the SAI technique of solar geoengineering, which I abbreviate as SGE, and how we know it.

The Earth’s energy balance
As illustrated in Figure A1-1, when incoming short-wave solar radiation (essentially sunlight) reaches Earth it is absorbed or reflected back. Some is absorbed in the atmosphere (including the dangerous ultra-violet radiation absorbed by the ozone layer, the relevance of which will become apparent). At a global scale average incoming solar radiation is 342 W/m². About 30% is reflected back into space and this depends on the albedo (the reflective properties) of the surface it hits. In practice this is mainly reflected away by clouds (those which are whiter have more albedo), but about ⅙th is reflected by the Earth’s surface (such as polar ice), and a further ⅙th by particles in the atmosphere (such as desert dust and air pollution). Net incoming solar radiation is 240 W/m². This energy is converted into heat and warms the Earth.

The Earth gives off this heat, and loses energy by emitting infra-red (long-wave) radiation. When the net outgoing infra-red radiation is the same as the net incoming solar radiation, then the Earth is in energy balance and average temperatures are relatively stable. But much depends on the chemical composition of the atmosphere. The build-up of greenhouse gases (GHGs) – including CO₂, methane and others – in the atmosphere has an insulating effect and causes more of the outgoing long-wave (infra-red) radiation to be absorbed and re-radiated not only upwards into space but also downwards back to the Earth’s surface. In practice this leads to global warming and also associated effects, such as gradual ocean acidification.

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148 More accurately, short-wave electromagnetic radiation comprises visible light, ‘near infrared’ radiation and a small amount of ultra-violet radiation. On reaching the top of the Earth’s atmosphere the Sun shines at a strength of 1366 Watts per m². This is roughly what is experienced in the tropics when the sun is directly overhead. However, because half the planet is dark at any one moment and because high latitudes receive less direct short-wave radiation, the average is about a quarter of this.

149 White surfaces (such as snow and ice) reflect more, and darker surfaces (such as oceans and forests) less.

150 Without an atmosphere the Earth’s surface temperature would be approximately 33°C cooler than its current 15°C average.
In short, when the Earth’s energy balance is disturbed it attempts to restore the equilibrium by warming or cooling in response. Global warming, therefore, can be a result of either increased solar radiation (in practice largely constant) or increased greenhouse effect. Mainstream climate policy (mitigation) aims to limit or reduce the concentrations of key GHGs in the atmosphere which are reducing the amount of heat escaping into space. Solar Radiation Management (SRM) techniques, by contrast, aim to manage incoming solar radiation.

The NRC report into geoengineering draws on standard mechanistic metaphors to explain the process.

“The climate system can be compared to a heating system with two knobs, either of which can be used to set the global mean temperature. The first knob is the concentration of greenhouse gases such as CO₂ in the atmosphere that affects the infrared side of the energy balance ... The other knob is the reflectance of the planet, which controls the amount of sunlight that the Earth absorbs.” (2015:33)

Humans, of course, have no control over the quantities and wave-lengths of energy emitted by the sun. So proposed SRM techniques include ideas to increase albedo, and thereby ensure a larger proportion of incoming solar radiation is reflected back into space before being converted to heat. Techniques under consideration include cloud whitening or marine cloud-
making at vast scales, and, more modestly, whitening the roofs of houses and other built infrastructure. Unlike SAI, these techniques operate at or close to the Earth’s surface.

Another approach is to limit the amount of solar radiation which reaches the Earth by deflecting it in outer space (placing reflective mirrors in space is one such idea) or in the higher reaches of the atmosphere. The latter is where the SAI technique comes in. In essence SGE using aerosol injection relies on the volcano analog, and aims to mimic the cooling effects observed following major volcanic eruptions such as Tambora or Mt. Pinatubo.

**The Sulphate Aerosol Injection (SAI) technique of solar geoengineering**

SGE is not yet an operating technology. In concept it involves injecting very fine sulphuric acid aerosols into the stratosphere, ideally at tropical latitudes and at an altitude of around 20kms (Robock 2014b). These aerosols then scatter some of the incoming sunlight back into space. In the stratosphere air does not circulate much vertically, but it does circulate extensively horizontally (think of the jet-stream). Injected in the tropics, stratospheric circulation rapidly mixes the air across latitudes.

Gravity will, of course, bring these particles back to Earth. The rate will depend largely on how fine the injected particles are and whether they coalesce into larger particles. In all events, for this type of geoengineering to work an ongoing injection of sulphate aerosols is required to maintain the reflective shield and therefore the cooling effect.

It is important to note that, as Keith puts it, “climate forcings from greenhouse gases and [solar] geoengineering are intrinsically different.” (2013. p. 56). SAI effectively masks the warming effects only. It does not remove the underlying cause of warming, the build-up of GHGs in the atmosphere. Indeed, if GHG concentrations continue to increase alongside SAI, then an increasing dosage of sulphate aerosols is needed to compensate for this. And SAI does

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151 An aerosol is a suspension of fine particles in air, in this case the optimum size is probably a few tenths of a micron in diameter (a thousandth of a raindrop) (Keith: 64-5). Because of the ozone and other effects of sulphates, alternative particles have been proposed, including black carbon and titania. But research suggests these carry no benefits and may even have worse effects than sulphates (Jones et al 2016). The stratosphere is at different altitudes depending on latitude (it starts at about 8 kilometers above the Earth’s surface at the poles, rising to as much as 18kms above parts of the Equator).

152 Drawing on experience of volcanic eruptions Robock states that “[t]he removal of particles from the stratosphere typically is an exponential process. The e-folding time is about one year, which means that a year after the formation of volcanic sulphate particles from tropical injection, the concentration is about ⅓ of the original amount, and after another year, the concentration is about ⅓ of that” (Robock. 2013.: 164-5).
nothing to alter ocean acidification, for example, which is a chemical effect of rising CO2 concentrations.

Keith calculates that to counterbalance half of the current carbon dioxide forcing – that is, to offset about 120 billion tons of carbon – “... would require injecting only one million tons of sulphur into the stratosphere each year” (2013: 67). There is a great deal of uncertainty about these numbers and they rely upon laboratory and theoretical chemistry and on assumptions regarding how the chemistry might work in practice. Would the aerosol particles remain fine or coalesce into big droplets and thereby be less effective? What other chemical reactions might be triggered? SAI is expected to reduce stratospheric ozone, no small matter, but it is unclear by how much, as this in turn depends on how effective the Montreal protocol has been at reducing chlorine loading in the stratosphere by the time any deployment commences.

Known unknowns linked especially to the chemistry and physics have prompted calls for limited small-scale field experiments to be conducted (Keith, Duren & MacMartin. 2015). In Russia there have been a few small-scale, field trials of sulphate spraying aimed at testing dispersal and albedo effect (Izrael et al. 2009), but these occurred at ground level and not in the stratosphere and their usefulness is unclear. Proposals related to small-scale field testing of SGE have been put forward but, at the time of writing, not yet approved nor funded (Dykema et al. 2014; Economist 13 Dec, 2104).

The UK’s SPICE project sought to assess from an engineering perspective whether a tethered balloon with a hose attached would be capable of spraying sulphuric acid directly into the stratosphere. This poses significant engineering challenges. SPICE aimed to develop a working, scaled-down, prototype which would distribute (water) aerosols (Stilgoe 2015). But the project was suspended by the scientists following public controversy (The Guardian 16 May 2012). A number of other proposals have been made regarding how aerosols would be delivered into the stratosphere. Some have imagined massive towers built on mountaintops, or artillery-type shells being fired (Robock 2014a: 166) – see Figure A1-2. Keith imagines a small fleet of aircraft able to deliver one million tons per annum to around 23km altitude, at a cost of about $1 per kilogram – or $1 billion per annum (Keith. 2013: 95).
In short, whilst getting all the components of any SGE project to work may be challenging, there is nothing especially technologically innovative about SGE in relation to the hardware, materials and delivery methods under consideration.

**Assessing the effects of geoengineering**

A great deal of uncertainty surrounds the likely effects of SGE on the climate, the broader environment, and on human society. These will be explored in some detail throughout this thesis. For now it is important to note three difficulties. Firstly, what is being compared? Obviously the larger the number of unknowns there are, the greater the uncertainties about the predictions. Comparing the anticipated effects of SGE to the present situation, is likely to be more reliable than comparing these to the anticipated effects of a warmer world. But the latter is the more salient comparison.

* From Robock (2014a: 166).
The second difficulty is how do we know the likely effects? There are two main methods used. One relies on existing climate model, ideally ones that have been suitably adapted. The other involves extrapolation from the observed effects of major volcanic eruptions – the so-called volcanic analogue.

Significant effort has gone into developing, adapting and supplementing existing climate modelling efforts.\textsuperscript{153} Climate modelling has its own problems: there are major data gaps; the workings of the complex, dynamic system that is climate can never be fully understood; all models are highly dependent on their underlying assumptions; prediction is impossible and only a best estimate of the probability of a particular outcome, with a higher or lower degree of confidence, can be hazarded. Further, what is being modelled is essentially the physical aspects of the climate system, and with emphasis on temperature and precipitation variations.

And yet we know that the climate is part of a range of coupled Earth systems, including social systems, themselves embedded in the human—non-human interaction which constitutes the environment.

This not to argue that the models and climate simulations can say nothing about SGE, only that they have significant limits. Indeed, the NRC report, for example, acknowledges that ‘models provide an incomplete and imperfect picture of the world’ (2015: 30), and that there are particular weaknesses in current modelling of both clouds and aerosols (2015: 8). Keith who favours incremental deployment of SGE and advocates learning by doing, acknowledges that one can never really know how SRM by SAI will work by running computer models (2013: 82).

The volcanic analogue is widely used, especially data relating to the Pinatubo eruption in the Phillippines in 1991 and, less commonly, historical accounts. They generally show very strong climate perturbations. But it can be argued that SGE is different from such analogues for reasons including the spatial evenness of particle distribution, and the relative cleanness of the stratosphere into which particles would be injected, compared to the lower atmosphere through which volcanic eruptions must pass (NRC 2015a: Appendix D).

The third difficulty flows from the modelling emphasis. In the main the effects examined are physical effects on temperature and precipitation. To the extent that effects on, say, crop production are modelled, this is typically read from the physical modelling.

\textsuperscript{153} The GEOMIP initiative attempts to pull together and increase the sophistication of various modelling efforts. Housed at Rutgers University, their website is \url{http://climate.envsci.rutgers.edu/GeoMIP/}. 
Given all these provisos, what are the likely effects of SGE? To counterbalance the physics bias in the literature I will begin with an historical account, alluded to in the Prologue. The Tambora eruption of 1815 was one of the most powerful eruptions in recorded history with four times as much energy as the Krakatoa eruption of 1883. Mount Tambora was reduced in height by one-and-a-half kilometres, and the explosion could be heard a thousand kilometres away. 140 billion tonnes of pyroclastic magma were ejected, including an estimated 60 million tonnes of sulphur, much of it reaching into the stratosphere over 40 kms above. For at least two days it was pitch dark for hundreds of kilometres around. Tens of thousands died in the immediate aftermath of the eruption. But worse was to come. According to Wood, the eruption ‘spawned the most devastating, sustained period of extreme weather seen on our planet in perhaps thousands of years’ (2014: 8). Global temperatures plummeted and there were major crop failures as far away as Canada and the United States. In North America, 1816 was known as ‘The Year without a Summer’; in Germany ‘The Year of the Beggar’. In India the monsoon failed for three consecutive years leading to famine and new strains of cholera. Famine devastated Yunnan and much of China. Food prices soared globally and food riots broke out. It changed the balance of power across vast swathes of the world. Globally, according to Wood, the death toll ‘…was likely in the millions – or tens of millions if we include the worldwide cholera epidemic its eruption almost certainly triggered’ (p.233). Proponents of SGE would argue that a more limited, controlled injection of aerosols would likely have far less extreme effects. More recent, and far smaller eruptions, indicate many similar climatic effects on precipitation, albeit on a smaller scale.

What does the modelling show? According to the authoritative NRC report ‘decreasing the amount of sunlight absorbed by Earth can offset most of the global mean warming caused by elevated greenhouse gas levels’ (NRC 2015a: 37 citing Kravitz et al. 2013a). The NRC makes only very general statements about the likely effects of doing SGE: that ‘consequences of concern’ include ‘some ozone depletion’ and ‘reduction in global precipitation’ and that ‘benefits and risks will not be uniformly distributed around the globe’ (2015: 7; see also Kravitz et al 2014; and Moreno-Cruz et al 2012). The various models also disagree in many respects. For example, whilst the models agree that precipitation and evaporation over the Amazon basin would decline, they produce very divergent results regarding the precipitation response over Africa (NRC 2015a: 44).

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154 My account of the Tambora eruption relies upon a fascinating study by Gillen D’Arcy Wood (2014) and on Oppenheimer (2003).
An even more recent summary of expected climatic impacts is provided by Jones et al, reviewing the scientific literature, and points to ‘weakening of the hydrological cycle’, changes in ozone concentrations, and ‘stratospheric dynamical changes ... as the result of tropical heating in the sulfate layer and by changes to wave propagation from the troposphere’ (2016: 2843-4).

There is generally very little reliable information regarding the likely effects of SGE on ecosystems or biodiversity, as well as on social systems. What studies exist largely derive their conclusions from the physical models. The NRC report notes there may be increased ozone depletion, and implicitly a rise in skin cancer: but ‘current understanding indicates the changes would be small’ (2015: 95). ‘Changes to precipitation, surface temperature, and soil moisture ... may have an impact on ecosystems’: but ‘current understanding indicates the changes would be much smaller than those experienced if [SGE] were not employed’ (95). Reduced sunlight intensity, combined of course with high levels of CO2, might enhance photosynthesis, but might also affect solar power and solar heating negatively. Rain and snowfalls would be more acidic, but probably by only a ‘small fraction of the acidity increases associated with industrial pollution today’ (95).

In short there is very little scientific understanding of the likely effects of the deployment of SGE, at the level of lived experience, although there are grounds for being able to anticipate the broad physical trajectory of changes. There is some evidence of grounds for concern based on actual observations of the agricultural and social effects of major eruptions which have happened in the past, although it is unclear the extent to which the analogue applies.
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