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A small-scale experiment with global implications?

An exploration of how involved scientists, advisory committee members and critical stakeholders depict the solar geoengineering project SCoPEx.

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Abstract (English)

Stratospheric aerosol injection (SAI) is a speculative technology which has the goal of lowering global mean temperature by introducing reflecting aerosols into the stratosphere. Like other solar geoengineering technologies, the idea of deploying (or even researching) SAI has stirred up significant controversy. That controversy especially emerges every time researchers publicly announce that they plan to do an outdoor experiment of SAI. Such moments of controversy are a good entry point for Science and Technology Studies (STS) researchers, because within it, stakeholders debate the meaning of scientific evidence and make explicit their takes on SAI outdoor experimentation and SAI in general. In this thesis, I examine one of the most recent planned outdoor experiments of SAI –SCoPEx– and demonstrate how involved scientists, Advisory Committee (AC) members and critical stakeholders depict issues surrounding SCoPEx and SAI outdoor experimentation in general. Contextualizing the case with STS-literature on controversial technologies, postcolonial issues, and public engagement, I analyze data material from websites, documents, and interviews to map out what meanings the different actors attribute to SCoPEx. My research shows that while the depictions of the AC and the SCoPEx-scientists mostly align with each other, critical stakeholders almost always tend to argue in opposite directions of the AC and SCoPEx-scientists. While critical stakeholders argue that SCoPEx cannot be treated separately from questions around the deployment of SAI, SCoPEx-scientists make repeated efforts to disassociate themselves and their work from the deployment of SAI. I show how there is a severe discrepancy between how the governance and public engagement process of SCoPEx is depicted by the AC and how it is depicted by the critical stakeholders. I conclude that SCoPEx is an intriguing case which exemplifies some central issues that matter within SAI outdoor experimentation and public engagement processes. Examining the data material available leads me to the conclusion that the public engagement process initiated by SCoPEx and its AC is riddled with inconsistencies and needs to be engaged with critically.

Abstract (Deutsch)

Stratospheric aerosol injection (SAI) ist eine spekulative Technologie, die darauf abzielt, die globale Durchschnittstemperatur durch die Verbreitung reflektierender Aerosole in der Stratosphäre zu senken. Wie andere Formen des solaren Geongineerings hat auch die Idee, SAI einzusetzen (oder auch nur zu erforschen), erhebliche Kontroversen ausgelöst. Diese Kontroversen werden vor allem immer dann laut, wenn Forscher*innen öffentlich ankündigen, dass sie ein SAI-Experiment im Freien planen. Solche Kontroversen sind gute Ansatzpunkte für Forscher*innen im Bereich der Wissenschafts- und Technikforschung (STS), da die Beteiligten darin über die Bedeutung wissenschaftlicher Beweisführung diskutieren und ihre Ansichten zu SAI-Experimenten im Freien und SAI im Allgemeinen explizit machen. In dieser Arbeit untersuche ich eines der jüngsten geplanten SAI-Experimente im Freien - SCoPEx - und zeige auf, wie beteiligte Wissenschaftler*innen, Mitglieder des Advisory Committees (AC) und kritische Interessensgruppen die Themen rund um SCoPEx und SAI im Allgemeinen darstellen. Ich kontextualisiere den Fall mit STS-Literatur zu kontroversen Technologien, postkolonialen Themen und Partizipation und analysiere Webseiten, Dokumente und Interviews um aufzuzeigen, welche Bedeutungen die verschiedenen Akteur*innen SCoPEx zuschreiben. Meine Untersuchung zeigt, dass die Darstellungen des AC und der SCoPEx-Wissenschaftler*innen meist übereinstimmen, während die kritischen Akteur*innen fast immer in die entgegengesetzte Richtung argumentieren. Während kritische Akteur*innen argumentieren, dass SCoPEx nicht getrennt von Fragen rund um den Einsatz von SAI behandelt werden kann, bemühen sich SCoPEx-Wissenschaftler*innen wiederholt, sich und ihre Arbeit vom Einsatz von SAI zu trennen. Ich zeige, dass es eine große Diskrepanz zwischen der Darstellung des Prozesses der Governance und des Partizipationsprozesses von SCoPEx durch das AC und der Darstellung durch die kritischen Interessengruppen gibt. Ich komme zu dem Schluss, dass SCoPEx ein faszinierender Fall ist, der zentrale Fragen aufwirft, die bei SAI-Experimenten im Freien und bei Partizipationsprozessen von Bedeutung sind. Die Untersuchung des verfügbaren Datenmaterials zeigt, dass der von SCoPEx und seinem AC initiierte Partizipationsprozess einige Ungereimtheiten aufweist und deshalb kritisch betrachtet werden sollte.

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List of abbreviations

AC.....*Advisory Committee*
AC-members .....*Advisory Committee members*
CDR..... *carbon dioxide removal*
CS .....*critical stakeholder*
GHG ..... greenhouse gas
HOME.....*Hands Off Mother Earth*
IPCC .....*Intergovernmental Panel on Climate Change*
NGO ..... *non-governmental organization*
RRI..... *Responsible Research and Innovation*
SAI ..... *stratospheric aerosol injection*
SATAN .....*Stratospheric Aerosol Transport and Nucleation*
SCoPEx..... *Stratospheric Controlled Perturbation Experiment*
SPICE.....*Stratospheric Particle Injection for Climate Engineering*
SRM .....*solar radiation management*
SSC.....*Swedish Space Corporation*
STS .....*Science and Technology Studies*
UN..... *United Nations*
UNEP .....*United Nations Environment Programme*

Deliberate climate change as a solution to climate change is not just insane but it is as Einstein said repeating the mindset that got you into the crisis in the first place. And what is that mindset? A mechanistic worldview, the idea of mastery and control and engineering solutions for everything living … The sunshine is the primary source of energy for life on earth … Blocking the sun … it is totally unpredictable what it is going to do. … Therefore, it is of course a crime against the earth, it's a crime against life.

Vandana Shiva (ETC Group, 2021, sec. 1:25:00-1:26:51)

We conclude that a prima facie moral obligation exists to investigate the potential of SRM [solar radiation management] to help the developing world … Yet such research has yet to be performed, and without an adequate evidence base, the *a priori* dismissal of SRM as one potential tool of climate policy is at best imprudent, and at worst immoral.

Joshua Horton and David Keith (2016, p. 84)

1.Introduction

Frederika Mathilde Louisa Saskia is the queen of the Netherlands and she is worried about the future of her country. She lives in a world in which climate change has already taken its toll on humanity. Flooded cities which have been abandoned and look like a scene in a post-apocalyptic movie are a normality just as much as earthsuits – whole-body suits which use a system of cooling pipes to cool down and protect human bodies from the unbearable heat during the hottest hours of the day.

The queen is worried. In fact, she is worried to such an extent that she is flying a plane to Texas to meet oil-industry billionaire T.R. Schmidt, who has a rather spectacular plan which involves several huge things. Concretely, it involves a huge pile of sulfur, a huge gun-like apparatus which is pointed towards the sky (The Biggest Gun in the World!) and huge bullets. T.R. Schmidt plans to combine these things by filling up the bullets with sulfur and using The Biggest Gun in the World to shoot them high up into the stratosphere. Once they have reached a certain height, the bullets use their built-in combustion engine to turn the sulfur into sulfur dioxide – a gas known for its great reflective capabilities. With enough bullets fired, so the plan goes, the stratosphere will eventually have enough sulfur dioxide in it so that a significant portion of sunlight which would otherwise reach the Earth's surface is reflected back to outer space. A reflection which lowers global temperatures – a development urgently needed to stop sea level rise and with it hopefully the worries of the Dutch queen.

This is how the plot of Neal Stephenson's recent science-fiction novel *Termination Shock* (2021) starts out. While T.R. Schmidt and Frederika Mathilde Louisa Saskia are not real people, the idea to introduce reflecting aerosols into the stratosphere to reduce global temperatures and thus the impacts of climate change very much is. It has been debated under the term *solar geoengineering* –or more precisely: *stratospheric aerosol injection* (SAI)– and with the continually worsening situation around climate change it is more relevant than ever.

1.1. Climate change

We would not be discussing the option of deliberately altering the climate if there was no such thing as climate change. Rising sea levels, species going extinct, an increase in extreme weather events and the destruction of natural habitats – these are no dystopian scenarios of fiction, but they are very real consequences of human-induced climate change of which scientists have been warning for decades now. But not only did scientists warn about a looming disaster, they also have been urging policy-makers to take one central measure against it: Greenhouse gas emissions –especially those of the so-called industrialized countries– need to be limited and respectively decreased (IPCC, 1990, p. xxvi). This measure is known as *mitigation* and stems from the scientific consensus that greenhouse gas (and especially carbon dioxide) emissions are the leading cause for human induced climate change (IPCC, 2021).

Mitigation is a well-known political goal today that has gained traction in endeavors against climate change such as the Paris Agreement (United Nations, 2015). But even "halting all greenhouse gas emissions would still not prevent the climate impacts that are already occurring" (European Commission, 2021, p. 1). Which is why the second big term in climate change policy is *adaptation*. Simply put, the term *adaptation* serves to emphasize that humans need to not only attempt to lessen climate change through mitigation, but also take measures to *adapt* to living in a world in which the climate gets hotter and hotter. Adaptation is about making changes to the social, political, and infrastructural organization of society. "[It] can range from building flood defences, setting up early warning systems for cyclones, switching to drought-resistant crops, to redesigning communication systems, business operations and government policies" (United Nations Climate Change, n.d., para. 3).

Even though mitigation has been established as a central political goal, global greenhouse gas emissions continue to rise, as the summary for policymakers of the latest report of the IPCC states: "Total net anthropogenic GHG [greenhouse gas] emissions have continued to rise during the period 2010–2019" (2022, p. 10). Although the emissions have risen less in the last decade than they have risen in the decade before (IPCC, 2022), the increase in greenhouse gas emissions is still ongoing. In 2018, a special report by the IPCC on the 1,5°C goal estimated that "Global warming is *likely* to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate." (2018, p. 4). While the IPCC uses rather cautionary language in this report, the Hamburg Climate Future Outlook —which was published five years later— puts it more bluntly: "Meeting the 1.5°C Paris Agreement temperature goal is not plausible" (Engels et al., 2023, sec. Key Findings). This aligns with the assessment of the *Climate Action Tracker* which

claims that not a single country in the world is currently taking enough measures to meet the 1,5°C goal as defined in the Paris Agreement[1] (Climate Action Tracker, 2023).

If the 1.5°C target is not met, scientists have predicted manyfold consequences such as sea level rise, an increase of temperature extremes or species extinction among many others; most of these consequences intensify even more if the global warming rises by 2°C (IPCC, 2018). Against this background it is quite concerning that with the recent policies in place, median global warming is projected to be even higher than 2°C by the end of 2100. As one of the more recent reports of the IPCC estimates:

> Without a strengthening of policies beyond those that are implemented by the end of 2020, GHG emissions are projected to rise beyond 2025, leading to a median global warming of 3.2 [2.2 to 3.5] °C by 2100 (IPCC, 2022, p. 17)

Missing the 1,5°C target by such a large margin is likely to worsen the consequences of climate change even more (Arnell et al., 2019). This surely is an alarming scenario, but alarming scenarios like this have been around for quite some time now, as has been knowledge about measures like mitigation and adaptation to steer against the development towards these scenarios. If measures towards reaching emission reduction goals do not become more drastic, we are heading towards a climate catastrophe (United Nations Environment Programme, 2022).

1.2. Solar Geoengineering

So, what if the current trends continue and we will not be able to reduce our greenhouse gas emissions in the extent needed to avert a climate catastrophe? This scenario is the point at which *geoengineering* enters the equation. Some scholars have argued that in addition to mitigation and adaptation, geoengineering constitutes a third climate policy option (Lin, 2013). As will be shown later (1.4), there are different kinds of geoengineering, but the most relevant one for this thesis is *solar geoengineering*.

Solar geoengineering is an umbrella-term for "a set of speculative technologies" which share the purpose of "reflecting a small amount of solar energy back into space before that energy warms the planet" (Jinnah & Nicholson, 2019, p. 385). Such technologies include (but are not limited to): reflective materials in unpopulated parts of the earth like deserts; the brightening of earth surfaces (such as painting structures in cities white) or apparatuses in space that deflect sunlight (Shepherd, 2009). The "most studied and best understood" (National Academies of Sciences, Engineering, and Medicine, 2021, p. 34)

[1] As of May 2023.

–albeit possibly also the most controversially discussed– solar geoengineering technique is *stratospheric aerosol injection* (SAI). Like the digression into Neal Stephenson's novel already hinted at, the basic idea behind this approach is to release reflecting aerosols into the stratosphere which reflect sunlight back into space.

Although some of these ideas may sound like science-fiction at first, the idea of solar geoengineering has been around for more than 50 years (Caldeira & Bala, 2017). However, the idea did not receive wide interest until the year 2006, in which noble-price laureate Paul Crutzen published an essay on the matter. In this essay, Crutzen writes that "research on the feasibility and environmental consequences of climate engineering … should not be tabooed" (2006, p. 214). Since the publication of this essay, geoengineering "has developed from a fringe topic into a broad, international and interdisciplinary research endeavour" (Boettcher & Schäfer, 2017, p. 266).

Solar geoengineering is a controversial idea. In 2010, a well-known attempt of researchers to conduct an outdoor experiment of SAI has been met with significant resistance and had to be cancelled eventually.[2] The reasons for the cancellation of said experiment are manyfold and have been described in detail elsewhere (Stilgoe, 2015), but it is noteworthy that resistance against this outdoor experiment and others like it is not about the direct environmental consequences of said experiments. Instead, critics of outdoor SAI experiments have argued that such experiments are decisive moments in the development of SAI technology which would potentially put us on a *slippery slope*[3] towards the deployment of SAI (Low et. al, 2022) or send the wrong signals to decision-makers who might take SAI as an excuse to not cut greenhouse gas emissions as quickly as necessary (2.2.1).

Advocates of SAI on the other hand have depicted SAI outdoor experimentation as an important action to address societal challenges connected to climate change. A good example for this framing can be found in a paper by Horton and Keith who have argued that "taking principles of global distributive justice seriously entails *a moral obligation to conduct research on solar geoengineering* [emphasis added]" (2016, p. 80). Solely reducing emissions of CO2 and other greenhouse gases, they argue, would not account for "the short term, during which millions of the world's most vulnerable people will suffer harms from climate change that simply cannot be mitigated by emissions cuts" (Horton & Keith, 2016, p. 90).

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[2] This attempt of SAI outdoor experimentation will be covered later on in more detail (2.1.2).
[3] I will come back to this term and explain it on more detail (5.1.2).

What do these different takes on SAI outdoor experiments tell us? They tell us that the discussion about whether to research SAI with outdoor experiments (or not) is not merely a discussion about the involved technicalities. Instead, outdoor experimentation of SAI is connected to complex and value-laden questions on a large scale: What is the right way to deal with climate change? Who gets to decide on whether solar geoengineering should be employed or not? Should we even conduct research on solar geoengineering or should we refrain from it altogether? These and many other questions repeatedly arise in the discussion of planned SAI experiments and as such, they make something explicit which researchers from the field of Science and Technology Studies (STS) have repeatedly shown in the past: namely that processes which are oftentimes attributed to science (and science only!) actually have a sociopolitical dimension to them which deserves thorough scrutiny (3). It is against this background that this thesis takes a recent planned SAI outdoor experiment as its primary subject of investigation and uses it as an opportunity to supply an STS-inspired reflection about the manyfold sociopolitical implications which are connected to SAI-research.

1.3. Empirical context and scope of this thesis

Even though recent attempts of SAI outdoor experimentation have been met with significant resistance and/or critique from civil society (2.1), endeavors of scientists to carry out SAI outdoor experiments continue. Most recently, scientists from the Keutsch Group at Harvard University (Keutsch Group at Harvard, n.d.) have attempted to conduct a small-scale SAI outdoor experiment in Kiruna, Sweden. The experiment goes by the name of *The Stratospheric Controlled Perturbation Experiment* (SCoPEx) and within it, scientists plan to launch a balloon into the stratosphere. Attached to that balloon would be an equipment gondola that can release reflecting materials such as sulphates or calcium carbonate while at the same time measuring how these materials behave within the stratosphere (Keutsch Group at Harvard, n.d.). Presumably in anticipation of the project stirring up some controversy, the research team established a dedicated Advisory Committee for the project which operates independently from the research team and advises the involved researchers on the research and governance of SCoPEx (SCoPEx Advisory Committee, n.d.).

In late 2020, the SCoPEx-team announced that they plan to perform a test-flight of their balloon and equipment gondola in June 2021 (Keutsch Group at Harvard, 2020). This announcement was met with a public outcry of various non-governmental organizations (NGOs), which culminated in an open letter which called for a cancellation of the test-flight (Henriksen et al., 2021). About one month later, the SCoPEx Advisory Committee announced their decision to advice the SCoPEx-team to suspend (not cancel!) the

experiment, but continue the public engagement process which is part of the governance of SCoPEx. Up until today[4], it is still unclear whether the experiment will take place or not.

Even though SCoPEx and the events around it are not fully concluded at the time of writing, just investigating and analyzing the turn of events until this point in time already constitutes an enriching research endeavor. SCoPEx is an attempt of outdoor SAI experimentation and as such it represents "a condensation point for controversy" (Stilgoe, 2016, p. 852) just like other, similar SAI-experiments before it. Within the controversy around SCoPEx, stakeholders make explicit their takes on the broader topic of SAI and SAI outdoor experimentation. By collecting, analyzing, and comprehensively mapping out these different framings within this case I want to contribute to a better understanding of the issues which are connected to SCoPEx, SAI and SAI outdoor experimentation in general. Such a better understanding is vital, since it seems likely that SAI and questions around its outdoor experimentation will be increasingly debated in the future as the climate crisis intensifies (Gunderson et al., 2018).

There are three stakeholder groups which I deem most relevant in the case of SCoPEx: Scientists who work within SCoPEx; SCoPEx Advisory Committee members and critical stakeholders who have publicly voiced their opposition of SCoPEx. With this thesis, I want to supply a thorough insight into how these three actor groups depict and position SCoPEx and the issues connected to it in often differing ways. I do this based on an extensive amount of empirical material; I gathered and analyzed data material which was available on the official websites of the SCoPEx-project, the webpage of the SCoPEx Advisory Committee and the various webpages and blog entries which are connected to critical stakeholders. This involved not only the text on the webpages themselves, but also documents which were available from these websites (especially from the webpage of the SCoPEx Advisory Committee). For varying reasons (4.3), I expanded upon this main body of data with one semi-structured interview with a critical stakeholder and transcripts of publicly available interviews with scientists who are part of SCoPEx. All this data was imported into MAXQDA® and coded thematically.

This thesis is structured as follows: After finishing this introduction with a short discussion of the terminology around solar geoengineering (1.4), I introduce the reader to the world of solar geoengineering by giving an overview of some of the most relevant strands of the academic debate about it; concretely I will go into recent attempts of SAI experimentation (2.1), the relation between solar geoengineering and mitigation (2.2),

[4] May 2023.

different positions on the meaning of solar geoengineering research (2.3) and postcolonial aspects connected to solar geoengineering (2.4). Having done that, I outline the concepts which have informed my thinking while engaging with the case at hand: STS-literature about controversial technologies (3.1), postcolonial STS (3.2) and literature on public engagement (3.3). Moving on to the empirical part of this thesis, I assemble the case of SCoPEx by supplying more basic information about SCoPEx (4.1) and outlining my research questions (4.2) and methods (4.3). In what can be considered the centerpiece of this thesis, I detail the results of my empirical investigation by exploring how SCoPEx is related to SAI in general (5.1), how the SCoPEx Advisory Committee and its work is depicted (5.2), how postcolonial dimensions matter within SCoPEx (5.3) and how the public engagement process of SCoPEx is perceived by the different stakeholders (5.4). In the discussion (6), I summarize and interpret key findings of this thesis and relate them to literature covered in the State of the Art (2) and the Sensitizing Concepts (3). In the conclusion (7), I wrap this research up by spelling out limitations of my work and identifying avenues for further research.

1.4. A short note on used terminology

Before we dive into the literature about solar geoengineering, some clarifications of the terminology being used around it are in order. On a very basic level, technologies subsumed under the umbrella term of *geoengineering* or *climate engineering* have the goal to modify the climate of the earth. These terms encompass a variety of technologies which are united in the fact that they have the goal to deliberately manipulate the climate on a large scale. A common way of categorizing the technologies subsumed under the term *geoengineering* is to divide them into *carbon dioxide removal* (CDR) and *solar geoengineering* technologies. The most prominent solar geoengineering technology in terms of how much attention it receives in academic and public discussion is *stratospheric aerosol injection* (SAI). The research project which takes center stage in this thesis —SCoPEx— is a planned experiment that aims to further the knowledge about SAI. Other ideas of how to practice solar geoengineering are to deploy space-based solar shields (Roy, 2022), marine cloud brightening (Cooper et al., 2014) or cirrus cloud thinning (Muri et al., 2014).[5]

[5] There are even more ideas like genetically modifying crops to increase their albedo (C. E. Doughty et al., 2011) but as with the technologies mentioned above, I am not going to go into more detail as they do not really matter for my thesis. For a comprehensive table that lists more solar geoengineering technologies, consult the Annex of the recent UNEP-Report (United Nations Environment Programme, 2023, p. 32f).

Like it is often the case in controversies, the terminology that is being used to describe the phenomenon at hand is also contested. There are many terms for solar geoengineering: Solar radiation management (Wolff, 2020), albedo enhancement (Robock, 2016), albedo modification (Cziczo et al., 2019) or albedo hacking (Pierrehumbert, 2019). The terms *Solar geoengineering* and *solar radiation management* have been criticized in particular because "regardless of which term is used, they both give the false impression of a comforting level of precision in knowing the outcome – something that is wholly inappropriate in the face of the substantial uncertainties surrounding it." (Pierrehumbert, 2019, p. 217). Personally, I do think that *albedo modification* is the best term for describing the phenomenon at hand. Although it is a rather clunky term (as Pierrehumbert (2019) also acknowledges), it does not carry implicit assumptions about the technology like *solar radiation management* or *solar geoengineering* do. Having said that, I will still mainly be using the term *solar geoengineering* in this thesis, simply because it is the term that is being used the most by the stakeholders within the empirical case that I studied. I will supply plenty of quotes in which stakeholders use the term *solar geoengineering* and I do not want to unnecessarily confuse the reader by drawing on another term for the same thing when I write about these quotes.

A further problem with the terminology in the case of solar geoengineering is an often-missing delineation between the different technologies and solar geoengineering more generally. Very often, people write *solar geoengineering* but what they mean is *stratospheric aerosol injection*. This missing terminological delineation is not a big surprise, because in the discourse solar geoengineering is mainly debated using the example of stratospheric aerosol injection. I always paid close attention to whether a statement is about solar geoengineering or SAI, but in many cases, it was not possible to tell. If I could clearly tell that a statement was about SAI, then I made sure to also use SAI and not solar geoengineering in my own text. The same applies to cases in which a statement was about *geoengineering* in general (without the solar): Here I was also cautious to not misinterpret this as a statement about solar geoengineering only. So, if you stumble upon other terms than *solar geoengineering* or *SAI* within this thesis, it is because these terms have been used in the source material.

2.State of the Art

No matter how you look at it: solar geoengineering is a controversial technology. By closely examining the empirical case of the SCoPEx-project, this thesis will show in detail how the future of solar geoengineering and potential consequences of its deployment around the world are fiercely contested. This controversiality of the technology also carries over into the academic discussion of it and thus this section mainly serves the purpose of giving the reader a good idea about the core themes within the academic debate. Without knowing about these discussions in the academic setting, it is hard to make sense of SCoPEx and the debate around it.

Having already introduced the reader to some hallmarks of the academic discussion around solar geoengineering and SAI (1.2), I continue the introduction to the debate about SAI in this section by giving an overview of recent attempts to conduct SAI experiments. I briefly go into three SAI-related attempts to release sulfur dioxide into the stratosphere (2.1.1), followed by a little more detailed description of a particularly relevant SAI-experiment in the past – the SPICE project (2.1.2). After that, I explore how the relation between solar geoengineering and the reduction of greenhouse gases has been discussed by summarizing the academic debate about the moral hazard argument (2.2.1) and showing how there is unequivocal agreement about how solar geoengineering cannot be the Plan A (2.2.2) but why it is still considered by some as a possible Plan B (2.2.3). Next, I dig into how the meaning of solar geoengineering research is interpreted differently by outlining takes which frame solar geoengineering research as necessary (2.3.1) or dangerous (2.3.2), followed by an overview of different understandings about field-experiments and climate modelling within solar geoengineering research (2.3.3). I will end the State of the Art by showing how postcolonial dimensions are brought up within the academic debate (2.4).

2.1. Recent attempts of SAI experimentation

2.1.1. Three successful (?) SAI-related sulfur dioxide releases

It does not make sense to write an elaborate piece about SCoPEx without at least shortly going into recent attempts of SAI experimentation. When I started writing this thesis, the only known SAI experiment in the public domain that was actually carried out took place in Russia in 2009. According to Low et al. this experiment is frowned upon by most western solar geoengineering researchers, as the leading scientist of the project —Yuri Izrael— was a controversial person who was known to question anthropogenic climate change and "lobbied Putin to consider solar geoengineering" (2022, p. 6). What is especially remarkable about this experiment is the lack of international reactions to it:

> The experiment received comparatively little attention at the international level despite the results being published in a paper … The most interesting factor about this experiment is that despite being the only experiment … that was fully carried out and which self-identified as SRM [solar radiation management], it gained the least attention from opponents of experimentation. (J. Doughty, 2018, p. 101f)

The case of the experiment in Russia is interesting for a number of reasons, one being that it raises the question of how to deal with individual actors who conduct tests of a global technology such as SAI without a proper governance structure in place. A question that has become more relevant than ever in the last few months[6], in which two instances became public where actors have (attempted to) release sulfur dioxide into the stratosphere with the intention of contributing to the development of SAI. Although each case would deserve a thesis on its own, I can only mention them briefly here.

The first one is Make Sunsets (2023), a start-up founded by two businessmen from the tech-industry – Luke Iseman and Andrew Song. In January 2023, it became public that they launched two small balloons containing sulfur dioxide into the atmosphere in Mexico (Garrison, 2023). Since the balloons were not monitored in any way, Iseman "said he does not know what happened to the balloons" (Garrison, 2023, para. 3). These events led the Mexican Government to announce that they would not tolerate future solar geoengineering experiments on their territory and that they plan to ban such actions in the future (Secretaría de Medio Ambiente y Recursos Naturales, 2023).

The second, nonetheless peculiar event is an experiment with the acronym SATAN (Stratospheric Aerosol Transport and Nucleation), which was carried out by independent

[6] At the point of writing – May 2023.

researcher Andrew Lockley who was previously affiliated with University College London (Temple, 2023). Through a leak by one of his colleagues it became public that Lockley launched a balloon in England that released 400 grams of sulfur dioxide into the stratosphere.[7] Unlike in the case of Make Sunsets, it has been confirmed that the material has been released into the stratosphere, which may make it "the first time that a measured gas payload was verifiably released in the stratosphere as part of a geoengineering-related effort." (Temple, 2023, para. 11). Both Make Sunsets and SATAN have been criticized for their lack of governance and overall process by more established SAI researchers like David Keith (Garrison, 2023; Temple 2023).

2.1.2. An unavoidable comparison[8] — SCoPEx and the SPICE-project

Putting more recent developments aside, the analytically most purposeful example for comparison within this thesis is the *Stratospheric Particle Injection for Climate Engineering* (SPICE) project. SPICE was an SAI related research project that started in 2010 in the United Kingdom. Going into how this early research project on SAI proceeded is important context information and immensely useful for understanding how SCoPEx was set up and debated. Although the two projects vary from each other significantly in terms of governance and technical details, their important commonality is that they both intended to conduct an outdoor experiment connected to SAI under the close watch of the international public while trying to pay attention to issues of governance. This is why in this section I want to briefly go into some basic information about SPICE, followed by a few observations that STS-scholars have made about this empirical case.[9]

SPICE aimed to investigate the effectiveness of solar radiation management (SPICE, 2023a). The project was subdivided in three different parts: (1) Evaluating different kind

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[7] Besides the obviously questionable choice of the acronym SATAN, another part which makes the event and Andrew Lockley so curious is his excessive use of devilish terms in his response to the leak which was published in *MIT Technology Review*: "Leakers be damned! … I've tried to follow the straight and narrow path and wait for the judgment day of peer review, but it appears a colleague has been led astray by diabolical temptation. There's a special place in hell for those who leak their colleagues' work, tormented by ever burning sulfur … But I have taken a vow of silence, and can only confirm that our craft ascended to the heavens, as intended. I only hope that this test plays a small part in offering mankind salvation from the hellish inferno of climate change." (Temple, 2023, paras. 7-8)

[8] This phrase was inspired by the contribution of Low et al., who write that "Comparison between SCoPEx and … SPICE … is unavoidable" (2022, p. 6)

[9] As SCoPEx will be described in great detail later on, this section will not bother with describing it. It will only focus on SPICE instead. The basic properties of SCoPEx and the actors involved therein are explained in section 4.1 and further details about the project are spelled out throughout the entire thesis.

of particles in terms of how well they would be suited for use within SAI (SPICE, 2023d), (2) Finding the best method that could be used to deliver particles into the stratosphere (SPICE, 2023c) and finally (3) using climate modelling to determine what would happen if the particles and the delivery method from (1) and (2) would be used to conduct SAI (SPICE, 2023b). It is especially the second part of the research project that caught the attention of the public. Within this part the scientists wanted to test a technology that "involves a fibre-reinforced hose, held up by a helium balloon. Reflective droplets would be pumped up the hose, and sprayed out 20 kilometres above the earth's surface." (Kuo, 2011, para. 9). To test this technology, the scientists planned to carry out an outdoor experiment on a smaller scale, using a smaller balloon and only a one-kilometer-long hose to spray water into the atmosphere (Kuo, 2011). Before the experiment could take place, significant resistance from various organizations emerged, calling for cancellation of the project (ETC Group, 2011). In 2012, the scientists working on SPICE announced that they have decided to cancel the outdoor experiment (Cressey, 2012).

What can we learn from this empirical case? Jack Stilgoe is an STS-scholar who was involved as a social scientist in SPICE and he has written an entire book about responsible innovation and geoengineering (Stilgoe, 2015). He observes that the experiment "became a condensation point for controversy" (Stilgoe, 2016, p. 852), which is something that the scientists working in SPICE did not anticipate:

> The initial assumption within the SPICE team was that the public would be interested, in a positive sense, or that the experiment could be a spur for a necessary debate on the ethics of geoengineering. (Stilgoe, 2016, p. 862)

> The reaction to it took the scientists involved by surprise. *Though originally intended as a technical test, it became a social experiment* [emphasis added]. (Stilgoe, 2015, p. 13)

This notion of *geoengineering as a social experiment* is vital. It helps to make sense of both SPICE and SCoPEx. Stilgoe writes that geoengineering is "blurring lines that separate research from deployment and scientific knowledge from technological artefacts." (Stilgoe, 2016, p. 851). If one also considers the unintended (and maybe also unwanted) self-involvement of activists into the discussion about the governance of SPICE, the case of SAI-experiments is reminiscent of classic STS-studies that have shined light on cases in which the sociopolitical dimensions of technologies animate publics to interfere in the knowledge production process (Epstein, 1995).

Another interesting dimension of SPICE that Stilgoe has drawn attention to is the fact that SPICE took a rather unusual approach to SAI research by focusing on the empirical study of cost and feasibility of SAI. David Keith (who is involved in SCoPEx) has criticized

the SPICE-project for this, arguing that "All the problems with SRM are about who controls it and what the environmental risks are, not how much it costs. Its already cheap." (The Economist, 2013, as cited in Stilgoe, 2016, p. 861). As will be shown later in this thesis, Keith has repeatedly argued that the deployment of SAI is technically and economically feasible (5.1.1). According to Stilgoe, the scientists working in SPICE at the time did not share this basic assumption:

> Things previously considered stable, such as the cost and feasibility of stratospheric geoengineering, were treated as empirical questions … The new possibilities of surprise generated by SPICE challenged the deterministic story of geoengineering. (Stilgoe, 2016, p. 862)

This example nicely shows how basic assumptions about the speculative technology SAI are constitutive of how a research project is set up and structured. Even though the research projects SPICE and SCoPEx might seem very alike at first glance, there are important differences in their setup that one needs to keep in mind.[10]

2.2. Solar geoengineering[11] and the reduction of greenhouse gas emissions

Having gone into recent examples of SAI-experiments now, I want to dive a little deeper by engaging with one of the most dominant issues (if not *the* most dominant issue) in the public and academic debate about solar geoengineering; namely its relation to the cuts of greenhouse gas emissions.[12]

2.2.1. The moral hazard argument

> Substantial emissions reductions, unlike geoengineering, are costly, rely more on social-structural than technical changes, and are at odds with the current social order. Because of this, geoengineering will increasingly be considered a core response to climate change. (Gunderson et al., 2018, p. 1)

The relation of solar geoengineering and mitigation is mostly discussed along a speculative future (Boettcher & Schäfer, 2017) that is labeled with different names in the debate: mitigation deterrence (McLaren, 2016), mitigation obstruction (Reynolds,

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[10] I will come back to this in the discussion (6.1).
[11] I deliberately do not only focus on SAI in this section, because the debate is seldomly about SAI specifically, but more about solar geoengineering in general. However, please keep in mind the terminological issues which are connected to the term (1.4).
[12] *Reduction of greenhouse* gases will be mostly referred to as *mitigation* in this section, some context on this has been provided in the introduction (1.1**Error! Reference source not found.**).

2022), trade-off premise (Baatz, 2016), mitigation inhibition (Keith, 2021) or most prominently the *moral hazard*[13] of solar geoengineering (Keith, 2000; McLaren, 2016). Although the terms each put a slightly different focus on the phenomenon at hand, they essentially all describe the same scenario: The prospect of having a technology-based solution available that can protect humankind from the consequences of climate change might serve as an excuse for policymakers and other stakeholders to continue business as usual — thus undermining the goal of reducing greenhouse gas emissions. The basic assumption of the moral hazard scenario is that (even the prospect of) having solar geoengineering available will make the already difficult task of reducing greenhouse gas emissions even more difficult. Drawing on the metaphor of insurance, Lin describes the problem like this:

> Just as insurance can encourage insureds to assume greater risks, the prospect of geoengineering the Earth response to climate change might exacerbate the very behaviors contributing to climate change. (Lin, 2013, p. 673)

Interestingly, some actors have argued diametral to the direction that the moral hazard argument takes. For example, Millard-Ball (2012) argues on the basis of a game theoretic model that the existence of geoengineering might increase the motivation for nation states to carry out mitigation efforts. The basic rationale behind his argument is that the application of geoengineering by an individual nation state could be also perceived as a threat by other countries and motivate them to collectively increase their efforts to reduce greenhouse gas emissions to prevent geoengineering by that one individual nation state. However, Millard-Ball's argument has been challenged by other scholars who argue that an increase of mitigation efforts as a response to the threat of geoengineering by individual countries seems unrealistic given the current world order and the history of taking measures against climate change (Baatz, 2016).

Despite the omnipresence of the moral hazard argument within the discourse, it is anything but clear whether the existence of solar geoengineering would have a noticeable impact on the willingness of actors to reduce greenhouse gas emissions. In a paper from

[13] "The concept of moral hazard originates in the field of economics, and refers to a lack of incentive to take action to guard against risk when one is protected from its consequences by insurance." (Boettcher & Schäfer, 2017, p. 270). The use of the term *moral hazard* in the context of solar geoengineering has been criticized by various scholars for different reasons –the many terms that exist to describe this phenomenon already hint at this– but I am not going to go into the terminological discussions about it and will mostly refer to the phenomenon with the name that is used within the contributions that I am looking at in more detail. For an extensive discussion and critique of the term *moral hazard*, please refer to Hale (2012).

2009, Shepherd points out this lack of empirical evidence and calls for more research on the matter:

> there is little empirical evidence to support or refute the moral hazard argument in relation to geoengineering, (although there has been little research in this area), and it is possible that geoengineering actions could galvanise people into demanding more effective mitigation action. Clarifying the existence or extent of any moral hazard associated with geoengineering should be part of the social science research agenda. (Shepherd, 2009, p. 39)

More than a dozen years later, however, it seems like the relation between the two strategies of dealing with climate change still remains uncertain and contested – (Baatz, 2016; Millard-Ball, 2012; Reynolds, 2022). The problematics with current knowledge about moral hazard in the context of solar geoengineering become even more apparent when it comes to questions of how to respond to the supposed relation between solar geoengineering and mitigation efforts. As Reynolds writes in a more recent publication: "Despite a decade of serious discussion about solar geoengineering, there have been no proposals to limit mitigation obstruction that would, in my assessment, be effective and feasible." (Reynolds, 2022, p. 286)

Why do the uncertainties around the moral hazard argument remain until today? McLaren has argued that scholarship investigating moral hazard issues pays "predominant attention to universal effects" (2016, p. 598) even though it is an issue that can only be investigated purposefully if it is investigated in a context-sensitive way: "mechanisms and outcomes might be different in different contexts and for different actors." (McLaren, 2016, p. 598). But still, even if such a context-sensitive approach is taken, it is very hard, if not impossible, to empirically investigate in a meaningful way whether SRM impacts the motivation of actors to pursue mitigation efforts (McLaren, 2016, p. 599). This leads McLaren to argue that future scholarship should refrain from trying to prove or disprove the moral hazard argument:

> The idea of an all-or-nothing moral hazard … that either should prevent SRM research or can be safely ignored is therefore unhelpful. The next decade of research will need to turn from trying to prove or disprove the phenomenon of moral hazard, to much more nuanced efforts to understand when, where, and how it might appear; the extent of the likely negative impacts on climate policy and its goals, including that of climate justice; and the effectiveness of different mechanisms to limit or even reverse those impacts. (McLaren, 2016, p. 600)

Regardless of whether the academic discussion of the moral hazard argument develops like McLaren envisions it or whether it does not: At this point in time, it seems like the

discussion will remain a controversial one. However, not all aspects of the discussion around solar geoengineering are that controversial. There are also aspects in which one can even speak of something like a consensus. The next section deals with such an aspect.

2.2.2. Solar geoengineering cannot be the "Plan A"…

Like should have become clear in the previous section, the moral hazard argument is one important factor that is brought up in discussions about whether solar geoengineering should be employed or not. To boil this discussion about moral hazard down to one central premise: solar geoengineering cannot be a Plan A because it might have a negative effect on more established forms of tackling climate change – first and foremost mitigation.

Even though the discussion about the (non-)existence of the moral hazard is full of disagreements, it already foreshadows one of the very few broad agreements that can be identified within the academic discourse: Most of the contributions seem to agree that solar geoengineering cannot and should not be a complete substitute for mitigation efforts.[14] This is not only the case for scholars who are rather critical about solar geoengineering in general, but it also applies to contributions which generally advocate for furthering the research and development of the technology.[15] Most actors involved in the debate about solar geoengineering seem to agree that more mitigation is needed. As Reynolds puts it: "Both sceptics and proponents of solar geoengineering research, as well as those who are and are not concerned about mitigation obstruction [moral hazard], desire greater mitigation." (2022, p. 290).

There are several reasons for mitigation being agreed upon so widely as the primary measure that needs to be taken against climate change. Firstly, this needs to be seen as a historical development: As has been shown earlier (1.1), the emissions of greenhouse gases have been identified as the leading cause for human induced climate change by scientists and as such the reduction of greenhouse gases is rightly seen as the approach that gets to the root of the problem. Since decades, scientists and climate activists have been urging policy makers again and again to make the reduction of greenhouse gases a central goal in their policies. By now, mitigation is widely established and accepted as a political goal and is part of various international treaties such as the Kyoto Protocol or the Paris Agreement. Like Hourdequin writes: "there is now a broad, international

[14] Even Crutzen already made that point in his influential paper (2006) and this attitude has since then been reiterated countless times. Just to give a few examples of contributions in which this argument appears in one form or the other: Baatz (2016), Jinnah et al. (2019), Pasztor (2021), Schneider (2019) and Shepherd (2009).
[15] Such as Lawrence & Crutzen (2017) or Nature (2021).

consensus regarding the need for emissions reduction through reduced reliance on fossil fuels, and the moral imperative in support of mitigation is clear" (2018, p. 464).

But it is not only important to reflect on what makes mitigation the Plan A of nation states, but also on what hinders solar geoengineering as being taken up as a substitute for this Plan A. To a considerable degree, this is surely owed to the fact that solar geoengineering is connected to significant challenges in terms of global governance. Like Schneider writes: "high-risk and global-impact schemes such as SAI are inherently very difficult to govern democratically, and under real-world political conditions is [*sic*] likely to unfold in a way that benefits the interests of powerful states." (2019, p. 34). Schneider's plea to view deployment of solar geoengineering in the context of global power relations is further emphasized by Robock when he asks a couple of questions that might become relevant in case solar geoengineering were deployed:

> how would the world agree on the optimal climate? What if Russia wants it a couple of degrees warmer, and India a couple of degrees cooler? Should global climate be reset to preindustrial temperature or kept constant at today's reading? (Robock, 2008, p. 17)

Questions like these illustrate that solar geoengineering governance is far from trivial and some scholars have even argued against this background "that democratic and fair global governance of solar geoengineering is unattainable" (Biermann, 2021, para. 3). But again, this take on the governance of solar geoengineering has not remained unchallenged: other scholars argue that inclusive governance of solar geoengineering is possible (Táíwò & Talati[16], 2021).

Another of the recurring arguments against solar geoengineering as a Plan A is that it just tackles the symptoms of climate change while not addressing its root causes (Pierrehumbert & Mann, 2021; Schneider, 2019; Wibeck et al., 2015). In addition, just using solar geoengineering without at the same time reducing mitigation is depicted as a problem because the employment of solar geoengineering is connected to a range of different risks and side-effects. Perhaps the gravest risk that is brought up in relation to the deployment of solar geoengineering is the so-called *termination shock*, a term that is widely used in the academic discussion (Baatz, 2016; McCusker et al., 2014; Pierrehumbert, 2019). Because "SRM only masks the warming effects of GHGs [greenhouse gases] and is not designed to reduce their concentrations in the atmosphere" (Parker & Irvine, 2018, p. 456), the hypothetical deployment of solar geoengineering without having reduced greenhouse gas emissions to zero would over

[16] Talati is a member of the SCoPEx Advisory Committee.

time lead to higher and higher concentrations of greenhouse gases within the earth's atmosphere.[17]

It is well established within the literature that under these circumstances, if solar geoengineering would be maintained as an infrastructure for decades and then suddenly be interrupted for any reason —for example by natural disasters or geopolitical conflicts— global mean temperatures would rise drastically in a very short period of time (Aswathy et al., 2015; McCusker et al., 2014). To avoid such a scenario, solar geoengineering would have to become an infrastructure that needs to constantly be maintained to keep mean temperatures at a level that does not entail catastrophic consequences. Some scholars argue that this would lead to a "millennial commitment" (Pierrehumbert, 2019, p. 217), which means that humans would be forced to maintain and uphold this infrastructure essentially forever. Other scholars relativize the risk of termination shock and argue that it would not be so difficult to protect solar geoengineering infrastructure from being suddenly interrupted (Parker & Irvine, 2018).

Other concerns that have been articulated about the consequences of deployment of solar geoengineering are that solar geoengineering might cause a decrease in precipitation (Schmidt et al., 2012; Tilmes et al., 2013) and that it would not "alleviate any of the other harms of anthropogenic emissions — particularly the ocean acidification caused by CO2" (Winsberg, 2021, p. 1117). It is also uncertain what effects deploying solar geoengineering would have on crop production (Winsberg, 2021).

So, to sum up: Within the literature, mitigation and solar radiation management are mostly depicted as non-interchangeable and mitigation is still seen as the number one measure to tackle climate change. At most, solar geoengineering is imagined to be a global climate policy action among others. Due to major risks and uncertainties connected to solar geoengineering (such as the termination shock), not even people who advocate for more research on the technology and actively contribute to its development frame solar geoengineering as a technology that can or should compete with mitigation. Instead, people who are known to be proponents of research on the technology (and others) often frame solar geoengineering as a Plan B, as a last way out in case that mitigation as a primary measure should fail. The next section deals with this framing in more detail.

[17] Strictly speaking, greenhouse gas emissions would not have to be zero, but they would have to be very low so that they can be completely compensated by using carbon dioxide removal (CDR) technologies. But the future of CDR is just as uncertain as the future of solar geoengineering. Pierrehumbert for example writes that "CDR may never be economically feasible" (2019, p. 220).

2.2.3. … but will it have to be the "Plan B"?

Given the current trends in how the world is doing in reducing its greenhouse gas emissions[18] – isn't it unwise to exclusively rely on mitigation measures to work against the consequences of climate change? What should we do if we fail to meet the goal of the Paris Agreement to keep human-induced warming of the climate below 1,5°C – or even worse, below 2°C or even 3°C above pre-industrial levels? Questions like these are often the starting point of contributions that draw upon what will be called the Plan B framing of solar geoengineering in the following.

As already established in the previous section, solar geoengineering is nowadays almost never imagined as a total substitute for mitigation (Gunderson et al., 2018), but rather as an additional technology that only is to be employed in a worst-case scenario. This is also what Plan B means here – the employment of solar geoengineering in addition to mitigation efforts but only if it will not be feasible to tackle the global temperature rise and its repercussions with mitigation and other forms of adaptation alone.

Especially in earlier research, the framing of solar geoengineering as a Plan B has often been connected to the similar framing of solar geoengineering as a technology that can help in dealing with climate related emergencies (Markusson et al., 2014).[19] What the Plan B framing and the emergency framing have in common is that they emphasize the different temporality of solar geoengineering that distinguishes it from other forms of tackling the consequences of climate change: "it could manage climate change risks in the short term, which mitigation and adaptation could not" (Reynolds, 2022, p. 286). The fact that solar geoengineering might be able to provide short-term alleviations is definitely one of the main factors why it is still so often discussed and considered as a Plan B up to this day, even though the uncertainties about negative side effects of its application remain.

Time also matters apart from the fact that solar geoengineering theoretically could be implemented and take effect very quickly. Some have argued for solar geoengineering as a Plan B in the sense that it could be used to buy more time to deal with climate change through mitigation (National Academies of Sciences, Engineering, and Medicine, 2021; Wigley, 2006). Although this argument has only been put forward by a few scholars and

[18] As spelled out in more detail earlier (1.1**Error! Reference source not found.**), greenhouse gas emissions have been continuing to rise within the last decade (IPCC, 2022).
[19] This framing also appears in a blogpost about SCoPEx – in that contribution, solar geoengineering is referred to as a "break-the-glass response" (Osaka, 2021, para. 9). The very recent report by the UNEP (United Nations Environment Programme, 2023, sec. Foreword) also makes use of the emergency framing.

seems to be a rather unpopular take on the technology today in the academic contributions about it, it is still brought up every now and then in more recent discussions of the technology.[20] This narrative of "buying time" has been criticized by scientists who are rather wary about solar geoengineering:

> Deployment of albedo hacking [another term for solar geoengineering] does not in any way "buy time" to get carbon dioxide emissions under control, since once emitted, carbon dioxide cannot to any significant extent be unemitted with known economically feasible technology (Pierrehumbert, 2019, p. 217)

In general, depictions of solar geoengineering that fall into the Plan B framing (like the "buying time" narrative) have been criticized so much that some scholars have diagnosed a recess in its popularity. Anshelm & Hansson (2016), for example, have shown that the Plan B framing of climate engineering technologies has been brought up in mass media particularly often back when solar geoengineering in general was a rather novel idea to the public and scientific community.[21] However, they do note that since then the popularity of the Plan B framing within mass media has declined and that even scientists who were known for advocating for the idea earlier took a more critical stance about it later on (Anshelm & Hansson, 2016). One reason for this might be that the Plan B framing been criticized extensively by activists and scientists alike. But it might be too early to claim that the idea of geoengineering as a Plan B has "run out of steam" (Anshelm & Hansson, 2016, p. 64). Even critics of the Plan B framing have accredited it to be a good representation of what the reality might be like one day:

> The Plan B frame suggests that society can avoid social-structural change and that society can continue to increase rates of production and consumption. It makes it easier to cast aside social alternatives capable of deep emissions reductions. We anticipate that SAI and other forms of geoengineering that maintain current structures and priorities will be increasingly debated and developed as reaching emissions goals seem progressively impossible and inconvenient and, if a social alternative is not pursued, deployed in response [*sic*] dangerous climate change. Despite its misleading simplicity, logical flaws, and irrational rationality, the Plan B frame is a relatively valid representation of geoengineering in current political-economic conditions. (Gunderson et al., 2018, pp. 710–711)

The reality is that we do not know what the future holds for the Plan B framing as a legitimization for the employment of solar geoengineering. However, what we can

[20] Like for example in this educational video (Kurzgesagt – In a Nutshell, 2020).
[21] Concretely, they talk about the time from 2006 to 2013.

already see today is that the Plan B framing and its rejection both are tightly coupled with discussions about the role of research on solar geoengineering technologies. It is precisely this debate about solar geoengineering research that will take center stage in the next section.

2.3. Research on solar geoengineering: Halting it or furthering it?

Now after we have taken a short deep dive into discussions about which strategies to tackle climate change should be prioritized and how they relate each other, it is time to turn to another essential part of the discussion around solar geoengineering, namely the dispute around the role of research on the topic. Ever since Crutzen has famously brought solar geoengineering technologies to the attention of a broader academic community (2006), the extent and necessity of research into solar geoengineering has been controversially debated in many contributions. An important distinction that needs to be made here in advance is the one between research that is conducted within models and research that is planning to make use of field experiments. The latter tends to evoke a lot more controversy than the former.

2.3.1. Solar geoengineering research as a necessity

Give research into solar geoengineering a chance. This is the title of a paper published in *Nature* in May 2021 and it is a nice example of a common framing that is being put forward by proponents of solar geoengineering research. In this paper, the author argues that we should encourage research into solar geoengineering in order to have more information on risks and benefits of the technology (Nature, 2021). The basic narrative that lies behind this way of arguing is that there is not enough evidence on the effects and problematics connected to solar geoengineering; but evidence is seen as a precondition to enable policy makers to make good decisions. Within this reasoning, the author calls for more research on the topic (Nature, 2021).

The same narrative can be found in the report by the National Academies of Sciences, Engineering, and Medicine. Scientific research is depicted as "enabling future decision makers" (2021, p. 111). Interestingly enough, these calls for more evidence on solar geoengineering technologies often emphasize its importance for deciding against the technology. Like the author of the paper in *Nature* writes: "If solar geoengineering is harmful, leaders will need evidence so that they can rule out the technology" (Nature, 2021). Such an understanding of evidence as a basis to decide against solar geoengineering is also especially brought up when actors argue in favor of field experiments (2.3.3).

Another striking way of arguing for funding and carrying out research on solar geoengineering are concerns about that the research might otherwise happen non-officially "in the shadows", like Holly Jean Buck puts it in an interview (Osaka, 2021, para. 24). Buck –an assistant professor who has mainly researched various topics around climate engineering– elaborates on her concerns about not funding and conducting solar geoengineering research in another paper:

> Intense social pressure to cease solar geoengineering research won't mean that all such research will end — it means that researchers who care about openness and transparency might stop their activities, and the ones who continue might be less responsive to public concerns. They will be supported by funders that don't care about public opinion — perhaps private actors or militaries — and we might not hear about all the findings. Autocratic regimes would be able to take the lead; we might have to rely on their expertise in the future if we're not successful in phasing out fossil fuels. (Buck, 2022, para. 10)

In that understanding, public funding for solar geoengineering research is seen as a prerequisite to ensure that the research is carried out in a responsible manner. Other actors sort of take a middle ground and do neither explicitly call for or oppose research on solar geoengineering. Instead, they emphasize that the decisions about how to deal with solar geoengineering should be put into the hands of the public and be debated within (ideally global) political forums such as the United Nations:

> There, the world should debate, and then it could decide on a moratorium on further research, or it could do the opposite. We need these conversations now. The longer we delay, the greater the risk of hasty, ungoverned actions or decisions. (Pasztor, 2021, paras. 3–4).

A similar demand also appears in a paper by Lawrence & Crutzen in which they write that a "well-informed sociopolitical dialogue is needed to determine whether humanity as a whole is likely to actually someday provide broad support for the pursuit of full-fledged climate engineering" (2017, p. 141). Either way, the importance of societal acceptance for the furthering of solar geoengineering research is acknowledged.

2.3.2. Solar geoengineering research as a danger

It might not be a surprise that the paper *Give research into solar geoengineering a chance* mentioned at the beginning of the previous section (Nature, 2021) was promptly met with a response titled *It is dangerous to normalize solar geoengineering research*. In this correspondence signed by 17 scientists, the author criticizes the position being put forward in the previous paper. He writes:

> We disagree with your view that research into solar geoengineering as a means to cool the planet should be given "a chance" … Any future use of the approach would require complex decisions at a planetary scale on where, how and for how long it would be deployed, and on who would take responsibility for any harm caused. In our view, the current world order is unfit to devise and implement such far-reaching agreements on planetary management. (Biermann, 2021)

This quote is interesting because it problematizes the anticipated difficulties in the governance of solar geoengineering once it has been deployed. Other accounts have also argued against solar geoengineering with anticipated problems in governance, often closely connected with the speculative future of solar geoengineering becoming an infrastructure that needs to be maintained and is prone to failure (2.2.2).

Opponents of solar geoengineering research often argue that research on this topic cannot be conducted in a safe or responsible way. This framing is predominantly argued for by drawing on the moral hazard narrative that has already been described earlier (2.2.1). But the notion of solar geoengineering research being inherently irresponsible also emerges elsewhere. One example for this is the future misuse of solar geoengineering by individual nation states. The concern of authoritarian regimes making use of albedo modification technologies was already raised in the last section within the quote from Buck (2022). What is intriguing is that McKinnon (2019) –who takes a very critical stance on solar geoengineering research– raises almost the same concern. She writes: "It is far from fanciful to worry that a ruthless political regime could see deployment [of SRM] as an opportunity to perpetuate existing unjust distributions of power and resources." (2019, p. 446). Both McKinnon and Buck envision regimes that make use of the technology in a morally concerning way.

However, they both have very different opinions about how we need to deal with solar geoengineering research in order to avoid such a scenario. While Buck pleas for public funding of solar geoengineering research, McKinnon argues that more research would actually worsen the situation: "A well-researched and tested technology could be more dangerous than an untested technology in the hands of a ruthless regime precisely because it would be more likely to work." (2019, p. 446). This and other considerations lead McKinnon to argue that we should pursue a solar geoengineering governance structure that is rather "shackling" than "stimulating" (2019, p. 443).

What does this discrepancy tell us? It tells us that opponents and proponents of solar geoengineering research tend to have different perceptions of what the production of evidence means and how it can be used. While proponents often frame evidence produced within science as an important basis to decide against solar geoengineering,

opponents like McKinnon tend to see the production of evidence as furthering and stabilizing the existence of the technology. This is what leads other scholars like Blomfield to the conclusion "that maintaining our uncertainty about the impacts of geoengineering might be wise for the time being." (2015, p. 48). The idea behind this is to not invest too many resources into (certain kinds) of solar geoengineering research until we know exactly what mechanisms of governance will be employed should the technology become real and move beyond the speculative. That governance is an important point for solar geoengineering technologies which needs to be thought of beforehand is a sentiment that is also shared by scholars who are actively involved into research on solar geoengineering (Jinnah[22] et al., 2019).

But as already becomes apparent in the quote at the beginning of this section, not everyone shares the opinion that there can be something like a sound governance of solar geoengineering. On the website of the initiative *Solar Geoengineering Non-Use Agreement* it is stated that "Solar geoengineering deployment at planetary scale cannot be fairly and effectively governed in the current system of international institutions" (Solar Geoengineering Non-Use Agreement, 2021, para. 1). This leads the people behind the initiative to demand commitments like no public funding for research and no outdoor experiments (2021, sec. A call for 5 core commitments and measures). As an outdoor experiment (SCoPEx) is at the center of this thesis, let us take some time to go deeper into how such outdoor experiments of solar geoengineering are discussed.

2.3.3. The struggle with climate models and in situ experiments

As the two previous sections have shown, there are significant tensions in the scientific community about whether and how research on solar geoengineering should be conducted. These tensions also extend beyond the scientific debate and have especially emerged (almost) every time that researchers publicly announced that they plan to do field experiments or outdoor activities related to stratospheric aerosol injection – SCoPEx itself of course is an example for this, but also other projects like SPICE (Stilgoe, 2016) or Make Sunsets (2023). Contrary to research via field experiments, research on SAI with climate models does not tend to evoke such controversy, but still has its own set of problems.

While some studies have investigated how SAI would affect the climate by drawing on data gathered in the context of volcanic eruptions (Proctor et al., 2018), most research of SAI that is concerned with environmental effects of the technology draws on climate

[22] Jinnah is a member of the SCoPEx Advisory Committee.

models (Aswathy et al., 2015; Kravitz et al., 2014; Oschlies et al., 2017; Weisenstein et al., 2022). Thus, insights gathered from the work with climate models form an important basis for the discussion of the effects of SAI. However, the ability of climate models to predict what would happen if SAI were deployed in the world has been equally questioned by proponents and opponents of SAI-research. Some scientists identify not so much the models themselves as the source of problems, but more the way how scientists use them to make claims about the real world:

> Physical scientists are imperfect, and sometimes make empirical claims that go far beyond the empirical data. For some reason, the field of solar geoengineering seems particularly susceptible to this failing. This typically involves a small group of scientists performing a limited number of simulations of a small set of scenarios in a single climate model, and then making very broad claims about what would happen in the real world in a much broader range of possible scenarios (Caldeira & Bala, 2017, p. 13)

In this quote, Caldeira and Bala criticize the irresponsible use of the climate models by scientists and not so much the climate models themselves. But other scholars have also pointed towards issues with using climate models in general for making predictions of how SAI would affect the climate. It has been particularly criticized that the models used for predicting the effects of SAI have not been created for that purpose and thus only have limited explanatory power when it comes to aerosol processes in the stratosphere (Stilgoe, 2015; Zarnetske et al., 2021). Another point of critique is that while climate models might perform reasonably well in terms of predicting overall global effects of SAI, they cannot accurately predict the impact of SAI on a regional scale – like Mike Hulme puts it in a discussion with David Keith published in *The Guardian*:

> The point here is how much faith we can place in climate models to discern these types of regional changes. As the recent report from the UN's Intergovernmental Panel on Climate Change has shown, at sub-continental scales state-of-the-art climate models do not robustly simulate the effects of greenhouse gas accumulation on climate. What you [David Keith] are claiming then is that we can rely upon these same models to be able to ascertain accurately the additional effects of sulfur loading of the stratosphere. Frankly, I would not bet a dollar on such results, let alone the fate of millions … What we can be sure about is that once additional pollutants are injected into the skies, the real climate will not behave like the model climate at scales that matter for people. (Keith & Hulme, 2013, para. 16-17)

Despite the skepticism forwarded by scholars like Hulme, climate models remain the central way to learn about and assess possible future impacts of SAI on the climate for now (Flegal & Gupta, 2018). However, some actors like the scientists who work within

SCoPEx take the limitations of climate models as an occasion to advocate for more research into SAI using different methods.

Which brings us to the topic of outdoor experiments or *in situ* experiments of SAI. In situ experiments play a crucial role in the debate about SAI and they mark a critical point in the technology development trajectory that is interpreted in different ways. At the core of the debate are two different positions about what such an experiment would mean: The first position is that the main purpose of in situ experiments is to simply gather more evidence on how SAI would work outside of climate models and the laboratory so that we can make a better decision about whether we want to use the technology or not (Dykema et al., 2014; Nature, 2021). Small-scale experiments related to SAI are understood as something that would help to reduce the uncertainties connected to SAI:

> some initial phase of testing at a reduced amplitude could first be used to reduce (not eliminate) uncertainty about the effectiveness and risks of SRM, by improving our understanding of the climate response to SRM forcing. (MacMynowski et al., 2011, p. 5045)

In that understanding, data gathered from in situ experiments would be an important contribution to improve the models used for assessing the impacts of SAI on the climate (Golja et al., 2021). This is in stark contrast to the second position, namely that in situ experiments mostly serve to advance the technology development and that pursuing such experiments would make the deployment of SAI at a later stage more likely (Frumhoff & Stephens, 2018; McKinnon, 2019). Scholars like Pierrehumbert cast doubt on the idea that conducting in situ experiments would help to deliver information that can help to decide for or against the deployment of SAI:

> for the most part, small-scale outdoor experimentation would serve to develop the technologies needed for deployment without providing the most important information bearing on whether it would ever be safe to do so. (Pierrehumbert, 2019, p. 219)

Scholars who draw on this framing tend to be rather critical of SAI in general and bring up the issue of the moral hazard (2.2.1); the deployment or even the prospect of deployment of SAI is seen as something negative that is just about reducing the symptoms of climate change, while also making mitigation measures less attractive (Schneider, 2019).

Another crucial aspect that is worth noting in the discussion about in situ experiments on SAI is the level at which it takes place. Environmental concerns about the small-scale experiment itself (like for example the effect of released aerosols on the environment) do not really play a big role within the debate, they are not even brought up as a problematic

category by the vocal critics of small-scale in situ experiments. Instead, the prime point of critique in the majority of papers on the topic are the sociopolitical implications that such an experiment might have (Mettiäinen et al., 2022; United Nations Environment Programme, 2023). Like Low et. al conclude after comparing the controversy around SPICE to the controversy around SCopEx: "it is not the (negligible and localized) physical risks that continues to concern opponents of small-scale tests, but "a slippery slope towards normalization and deployment" [112]."[23] (2022, p. 7). Thus a major part of the academic discussion on SAI is about how to (not) govern its research and eventual deployment in a responsible and just way (Galbraith, 2021; Reynolds & Wagner, 2020; Táíwò & Talati, 2021).

2.4. Solar geoengineering and postcolonial dimensions

The last big part of the academic debate that I want to shine light on in this thesis are contributions which approach solar geoengineering by exploring its relation to global power dynamics or postcolonialism.[24] Like the climate, the potential deployment of solar geoengineering is global; it does not respect the borders of nation states and cannot be applied to individual countries only. If it is deployed on a large scale, it will be deployed for all and it is well established that deployment would have different effects on different countries (Baatz, 2016; Ricke et al., 2010). However, while some scholars argue that solar geoengineering would be especially beneficial for people in the Global South because they would otherwise be most affected by the consequences of climate change (Horton & Keith, 2016), others argue that developing countries would be negatively affected by the technology in a disproportionate way, as the deployment of SAI would deepen their dependency on countries that have control over the technology (Biermann & Möller, 2019). Either way, the effects of SAI on individual countries play a major role in the discussion of SAI – and connected to this also the relation between these individual countries and questions of power. Stephens and Surprise nicely point towards these power struggles when they ask: "Who will decide when conditions are bad enough to declare a planetary-scale emergency justifying intervention in the climate system?" (Stephens & Surprise, 2020, p. 3)

While these are all issues connected to the deployment of SAI, the discussion about global inequalities starts already at a much earlier point in time of the development trajectory

[23] The quote within this quote was taken from Sandahl et al. (2021). The concept of the *slippery slope* and how it matters within the case of SCoPEx will be addressed in more detail in section 5.1.2.
[24] A more in-depth dealing with the concept of (especially STS-informed) postcolonialism approaches will be provided within the sensitizing concepts (3.2).

of solar geoengineering, namely with the solar geoengineering research community. Belter and Seidel have conducted a bibliometric analysis of climate engineering research and conclude that involved scholars are mainly from the northern hemisphere (2013). Biermann and Möller go even further and expand this critique of representation to the entire climate science community, arguing that there is an "overrepresentation of the Global North in climate science" (2019, p. 153). They write:

> The current low level of involvement of developing countries, and particular least developed countries, in this [climate engineering] debate seems hence less a consequence of purposeful exclusion than of persistent structural inequalities in global science — which makes the situation no less problematic. (Biermann & Möller, 2019, p. 157)

Stephens and Surprise provide a similar argument and expand upon why they view the composition of the solar geoengineering research community as highly problematic:

> solar geoengineering research is being advocated for by a small group of primarily white men at elite institutions in the Global North, funded largely by billionaires or their philanthropic arms … Solar geoengineering research advances an extreme, expert–elite technocratic intervention into the global climate system that would serve to further concentrate contemporary forms of political and economic power. For these reasons, we argue that it is unethical and unjust to advance solar geoengineering research. (Stephens & Surprise, 2020, p. 2)

While Stephens and Surprise take a very critical stance on solar geoengineering research and argue that furthering the research on it is unjust, other scholars do acknowledge the same structural inequalities, but without condemning solar geoengineering research in general. Instead, they demand more inclusion and engagement of actors from developing countries in solar geoengineering research (Rahman et al., 2018; Winickoff et al., 2015). In the same vein, there are funding initiatives that are specifically tailored towards "putting developing countries at the centre of the SRM conversation" (The DEGREES Initiative, 2023) by funding research activities on solar geoengineering by researchers based in the Global South. Stephens and Surprise are not convinced by such suggestions and measures:

> Expanding the global distribution of SAI researchers does not address the structural power imbalances associated with who is advancing solar geoengineering research. In addition, it is well recognized that creating mechanisms for the inclusive 'participation' of Global South organizations in transnational policy networks has often been used as a vehicle to generate consent for policy prescriptions that flow from the Global North (Stephens & Surprise, 2020, p. 3)

But the take of Stephens and Surprise on matters of SAI and the relation between Global North and Global South do not remain uncontested. Táíwò & Talati (2021) have criticized them for writing about what the Global South's interests are while themselves both being from the Global North:

> These Global North-based researchers, without any disclosed consultation with Global South organizations or researchers, pronounced the Global South's interests from a microphone based in the North … We have also observed that often, if Global South organizations are quoted or consulted, the same few groups are consistently used by authors and organizations that advocate against research on this topic. (Táíwò & Talati, 2021, p. 13)

They continue to argue that a ban of solar geoengineering research would be "premature and undemocratic" and that "it is presumptuous and self-contradictory to categorically declare that either inclusive research or governance of SG [solar geoengineering] is impossible" (Táíwò & Talati, 2021, pp. 14-16). From these quotes it should become clear that Táíwò & Talati are of the conviction that inclusive research and governance of solar geoengineering is possible, even when considering its entanglement with global inequalities. This conviction has been equally affirmed (Buck, 2022; Parson & Reynolds, 2021) and rejected (Pierrehumbert, 2019; Schneider, 2019) by other researchers.

3. Sensitizing concepts

From the topics that have been raised in the State of the Art, it should have become clear that SAI experiments and discussions about the deployment of SAI are an incredibly rich field with manifold dimensions to it. It is easy to imagine how different theoretical traditions of STS could use the case to point our attention towards different kind of aspects in the debate. An ANT-approach (Callon, 1986) could steer our attention towards how non-humans like volcanoes, different kind of aerosols or different flight apparatuses matter within the debate; feminist STS (Subramaniam et al., 2017) could help with analyzing how gender inequalities matter in SAI research and eventual deployment; the sociology of expectations (Borup et al., 2006) could help with engaging more thoroughly with how future-making matters in the debate. All of these (and many others!) are legitimate and important lines of inquiry into the field of SAI.

However, drawing on too many sensitizing concepts all at once puts the researcher at risk of using their analytical focus. Which is why in the end I decided to draw "only" on three different broad bodies of literature that will all help me to make sense of the case at hand. Within this section I want to go into these bodies of literature and show how they are relevant for SCoPEx. I begin by mapping out some concepts from STS on (controversial) technologies (3.1), followed by a short dive into postcolonial STS (3.2) and STS-related literature about public engagement (3.3).

3.1. Understanding (and anticipating) controversial technologies

An essential part of the intellectual endeavor of STS has been and still is to show that technology needs to be understood as something that is always embedded into societal relations and thus is always political. This stands in stark contrast to the still widespread understanding of technological development that has been termed as *technological determinism* (Wyatt, 2008) within STS. Technological determinism is based upon two assumptions: (1) "Technological developments take place outside society, independently of social, economic, and political forces" and (2) "technological change causes or determines social change" (Wyatt, 2008, p. 168). Often connected to the idea of technological determinism are accounts that view technologies as something neutral. According to this understanding, technology is neither bad or good; what matters instead

is how humans make use of the technology: "A knife may be used to murder an innocent person or peel an orange for a starving person, but the knife itself is a mere instrument, not subjectable to moral evaluation." (Miller, 2021, p. 54).

A great part of STS-scholarship has been dedicated to debunking technological determinism by showing the sociopolitical dimensions of technological artifacts and/or showing how the development trajectory of technologies is dependent on sociopolitical context. While there are more obvious cases like nuclear power (Felt, 2015) or genetically modified organisms (Hicks, 2017), STS-scholars have also shown how this applies in less obvious examples like water pumps (de Laet & Mol, 2000) or keys (Latour, 1996). Contributions like these have made clear that technological artifacts need to be understood not just as something that symbolizes social order, but rather as something that is an essential part of shaping and enacting social order.

Perhaps the most famous example when it comes to political properties of technologies within STS-scholarship is Langdon Winner's book chapter on the politics of artifacts (Winner, 1986), in which he writes about low-hanging overpasses on Long Island that "were deliberately designed and built that way by someone who wanted to achieve a particular social effect" (Winner, 1986, p. 23). That someone is Robert Moses —a highly influential urban planner in New York— and the social effect that he allegedly wanted to achieve with the low-hanging overpasses was to keep public transport —and thus poor and black people— away from the roads that led to Jones Beach. Although today historians are divided about whether Moses really chose the design of the overpasses with these intentions (Kessler, 2021), the argument that Winner builds around this case remains an important one today. As MacKenzie and Wajcman put it: "His is one of the most thoughtful attempts to undermine the notion that technologies are in themselves neutral - that all that matters is the way societies choose to use them. Technologies, he argues, can be inherently political." (1999, p. 4). The assumption that technologies have the capability to be inherently political (not just in their use, but also in their design) still holds today and it is safe to claim that it is an important basic assumption of every STS-scholar who conducts research on technologies.

One important, more recent pool of literature that is based on this assumption is the research around the concept of Responsible Research and Innovation (RRI). This concept has not only been quite influential within STS, but has also gained significant traction in the policy context of the European Commission (Owen et al., 2012), particularly in the funding program *Horizon 2020*. There are several different definitions of what RRI entails exactly, but the basic idea behind the concept is to make sure that innovation and the research connected to it are more responsive to the needs

of society from the very start by fostering interactions between societal actors, researchers, and innovators — ideally in a bottom-up way. Like René von Schomberg puts it in his well-known definition of RRI:

> Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society) (von Schomberg, 2011, p. 9)

Another popular definition of RRI is that it is made up of four dimensions: anticipation, reflexivity, inclusion, and responsiveness (Stilgoe et al., 2013). Going into detail about what each of these dimensions entails in the case of solar geoengineering would go beyond the scope of this section, but I do want to briefly address the dimension of anticipation because I think it is an essential one when it comes to solar geoengineering.

A common misconception that one might have when they hear the term *anticipation* is that it is all about knowing and predicting the future. However, *anticipating* does not necessarily mean that we need to know about the future. As Alfred Nordmann puts it: "One can be prepared for the future without seeking to know what the future will be like. In fact, trying too hard to imagine possible or plausible futures may diminish our ability to see what is happening." (Nordmann, 2014, p. 88). Nordmann expands on this argument by drawing on the example of fracking:

> The idea [of fracking] is not new and yet it crept up, stealthily, on policy-makers and technology assessors who were fixated on the notion that the energy mix of the future will be determined by the latest scientific and technological developments and what they might bring. If it was not anticipated, it is because the powers of anticipation were geared to the future and missed what was right before their eyes. (Nordmann, 2014, p. 88)

On the one hand, scholars who want to *anticipate* within the framework of RRI need to be careful to not pay too much attention to the future. On the other hand, possible futures and different scenarios about a technology's trajectory do of course matter. RRI-scholars have suggested various techniques like constructive technology assessment (Rip et al., 1995) or upstream public engagement (Wilsdon & Willis, 2004) that draw on "anticipatory discussions of possible and desirable futures" (Stilgoe et al., 2013, p. 1571). Such techniques are different than more prediction-based approaches like for example classical, risk-focused technology assessments. Stilgoe writes: "Anticipation is here distinguished from prediction in its explicit recognition of the complexities and uncertainties of science and society's co-evolution (Barben et al., 2008)" (Stilgoe et al., 2013, p. 1571). By sensitizing about the uncertainties which are involved in a technology's

development trajectory, *anticipation* as envisioned in the RRI framework should help scholars to no fall into the trap of carrying out a technology assessment that enforces the anyway widespread take of technological determinism (Stilgoe et al., 2013).

With this section, I tried to outline the most important ways of conceptualizing technology development that I had in the back of my head when I engaged with the case of solar geoengineering and SCoPEx. However, in order to be able to better account for dimensions of global power relations that matter within technology development, I opted to additionally draw on some works from the field of postcolonial STS.

3.2. Postcolonial STS

Scientists of an elite university from the Global North decide to carry out an experiment that might have consequences on a global scale and an indigenous people's organization is at the forefront of protesting against this undertaking. This dynamic is no mere coincidence or a specificity of the SCoPEx project; many scholars have discussed how solar geoengineering in general needs to be scrutinized against the background of global power dynamics (2.4). While I will go into more detail about how postcolonial issues play out concretely in the case of SCoPEx and SAI more generally (5.3), I want to use this section to give the reader an idea about how STS-scholars have made use of the notion of the postcolonial as a theoretical resource in the past and how this matters for the case at hand.

First and foremost, it is important to be clear about what postcolonial STS entails. One can get a good first impression about this by reading some of the works of Sandra Harding, who is known for her compelling efforts to connect feminist and postcolonial theory to each other (Harding, 2009; Subramaniam et al., 2017). She argues that from the very beginning, postcolonial STS steered the attention towards social orders within science and technology:

> From their beginnings one can find in both the gender-focused and the postcolonial STS the understanding that scientific and technological projects are co-constituted with their social orders, as Northern science and technology studies came to put the point sometime later. That is, no sciences and technologies are or could be autonomous and value-free, as the rhetoric of 1950s modernization theory and its science policy held. (Harding, 2009, p. 403)

In this regard, postcolonial STS makes a similar point as the beforementioned literature on the political properties of technologies (3.1). However, what sets postcolonial STS apart from other theoretical approaches is that it can sharpen our perception of how global inequalities matter in science and technology. Suman Seth summarizes it

concisely when he writes: “For many, if not most, scholars engaged in postcolonial science studies today, the language of the postcolonial is used to signal the persistence of colonial structures and categories into the present.” (2017, p. 75). Or how Warwick Anderson puts it:

> Even if explicit recourse to postcolonial theory remains rare in science and technology studies, a postcolonial sensibility has infiltrated its critical scholarship … The imperial gaze sees smooth, inescapable global flows; postcolonial critics instead see messy, uneven politics and diverse, contending agents amid the historical debris. (Anderson, 2015, p. 652, as cited in Clarke, 2016, p. 175)

Having such a *postcolonial sensibility* is vital when one engages with a case like SCoPEx, because it makes it less likely that researchers like me –who grew up and live in the Global North and whose thinking is predominantly informed by concepts that also emerged from the Global North– favor Western perspectives over indigenous ones. Ideally, such sensibility results in what Law & Lin have called a “postcolonial version of the principle of symmetry”, which essentially means that STS-scholars treat “non-western and STS terms of analysis symmetrically” (Law & Lin, 2017, p. 214). By using the term *symmetry*, Law & Lin build neatly upon a well-known concept within STS:

> As we know, STS treats all beliefs, true and false, in the same terms … Symmetry between true knowledge claims and those that are false was crucial to the sociology of scientific knowledge (SSK). Its actor-network theory (ANT) extension to human and nonhuman actants by Michel Callon was equally significant (Bloor, 1976; Callon, 1986), but our suggestion is that it is time to extend it again. (Law & Lin, 2017, pp. 213–214)

While Law & Lin exemplify the use of this concept by examining the relation between Euro-American and Taiwanese STS (2017), I do think that the basic gist of this concept –treating non-Western and Western ways of perceiving the world as equal in analysis– can and should also be applied to the case of SCoPEx. Ironically, in the end I was not able to go as much into indigenous perspectives as I would have liked to because of problems with data collection (4.3.1). When conceptualizing this research, part of my plan was to offer an insight into how representatives of the Saami perceive and frame the debate around SCoPEx through the use of qualitative interviews. However, as I was not able to conduct any interviews with representatives of the Saami, I was dependent on publicly available material, which offers only a very limited insight into their perspective. Nevertheless, postcolonial STS remained an important body of literature which informed my thinking while engaging with the case.

3.3. Public engagement

The next and final body of literature that I used for making sense of the case at hand centers around public engagement (or public participation as it is also often referred to). Discussion around SCoPEx features public engagement quite prominently (5.4) and thus I want to use this section to show from which context public engagement as a concept originated from and briefly shed light on some selected works that have dealt with it more in depth.[25]

In most accounts which attempt to describe what public engagement is, one will sooner or later find mention of the famous report on *The Public Understanding of Science* (The Royal Society of London, 1985). This is because that report promoted a way of understanding the science-society relationship which STS-scholars soon after termed the *deficit model*.[26] In short, subscribing to the deficit model means to view the public as somewhat deficient in terms of its ability to understand science. Bucchi & Neresini summarize it as follows:

> This model has emphasized the public's inability to understand and appreciate the achievements of science … and adopted a linear, pedagogical and paternalistic view of communication to argue that the quantity and quality of the public communication of science should be improved. (Bucchi & Neresini, 2008, p. 450)

An often-told story is that the genesis of concepts like public engagement –which are based more on dialogue rather than on one-way, top-down communication– need to be understood as a counter-development to concepts which are based on the deficit model. There have been "shifts from Public Understanding of Science towards Public Engagement with Science" (Michael, 2009, p. 619). Or as Brian Trench puts it:

> Science communication has been telling a story of its own development, repeatedly and almost uniformly, for almost a decade. The story is a straightforward one: science communication used to be conducted according to a 'deficit model', as one-way communication from experts with knowledge to publics without it; it is now carried out on a 'dialogue model' that engages publics in two-way communication and draws on their own information and experiences. (Trench, 2008, p. 119)

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[25] Literature on public engagement is vast and it is impossible to do justice to the multifaceted academic discussion within the scope of this section. I will only be able to offer a very limited and necessarily superficial insight into some aspects of selected works. For an excellent overview of the work on public engagement in STS and beyond, refer to Delgado et al. (2011).
[26] For a comprehensive summary of how the concept of the *deficit model* emerged within STS-scholarship, refer to McNeil (2013).

Unsurprisingly, Trench does not continue his book chapter by asserting that this story is an adequate one. Instead, he debunks the claim that the deficit model has been replaced by the dialogue model by listing a range of (back then) contemporary examples that still draw on the deficit model.[27] Instead of subscribing to the story of the dialogue model having seamlessly replaced the deficit model, he argues that they both can and do coexist at the same time (Trench, 2008); which is similar to the stance that Michael takes when he writes that the classical public understanding of science has been replaced in some (but not all!) instances with a new, critical public understanding of science[28] (Michael, 2009).

This is the background against which public engagement needs to be understood, not least because oftentimes one of the first defining features of public engagement that gets mentioned in texts about it is that it does not operate with the logic of the deficit model (Delgado et al., 2011). Approaches which draw on public engagement tend to make sense of the interaction between science and society as a "two-way process" (National Co-ordinating Centre for Public Engagement, 2020, sec. Our definition) and attempt to give more agency to laypeople, who are "conceived in terms of local communities whose views are sufficiently important to require change in scientific institutions" (Michael, 2009, p. 619).

Public engagement does not remain without critique. Although the shift from a traditional towards a critical public understanding of science is welcomed by many –if not most– STS-scholars, it also does bring along its own set of problems. Delgado et al. write that: "while our mentors presented us with the idea that public participation was *the solution*, we increasingly feel that we have inherited it as *the problem*." (2011, p. 826). They argue that this is because STS-scholars now must put public engagement activities into practice, and doing so is connected to a range of hard-to-answer questions that are decisive for how public engagement is actually carried out. These "top topics of tension" as carved out by Delgado et al. (2011, p. 828) are (continues on next page):

[27] The book chapter of Trench is already more than a dozen years old, but there are also more recent contributions which show how the deficit model still persists today (Simis et al., 2016; Suldovsky, 2016).

[28] I am aware that in this section I throw around many different terms for the same thing (in this case *critical public understanding of science* as more or less synonymous for the *dialogue model;* also in equalizing *public participation* with *public engagement*), but this is owed to the fact that these different terms and the phenomena they describe are also not clearly delineated within the academic discussion itself; a circumstance that has also been criticized by other STS-scholars (Delgado et al., 2011). This poor delineation of terms is reminiscent of the terminological issues around SAI (1.4).

(1) *Why* should [public engagement] be done?

(2) *Who* should be involved?

(3) *How* should it be initiated?

(4) *When* is the right time to do it?

(5) *Where* should it be grounded?

After listing these questions, Delgado et al. (2011) continue their paper by showing how there are many competing answers to each of these questions within STS-literature, followed by an analysis of how these dimensions play out in the concrete case of nanotechnology. Going into the details of this is beyond the scope of this section, but I wanted to mention these five questions in their entirety anyway because some of them will be useful for me later when I think through how public engagement is practiced in the case of SCoPEx (6.4).

4. Assembling a case

As the State of the Art already showed (2), SAI is a controversial technology in many ways. This is especially the case when it comes to questions about the potential deployment of SAI, but it is also true for in situ experiments that aim to gather knowledge about SAI. One of the major reasons for this is that the relation between in situ experiments and deployment of SAI is a contested one, with some scholars arguing that in-situ experiments will make the deployment of solar geoengineering more likely, while others are arguing that they are necessary to make an informed decision about whether to deploy SAI or not.[29]

In situ experiments of SAI tend to evoke public debate about SAI and its sociopolitical implications[30] and as such they are pivotal points in the technology development trajectory that offer themselves for social scientific investigation. Analyzing elements of the debate such as articles, open letters, interviews and the like offers valuable insights into what assumptions different actors have about SAI and how they assess the assumptions of other actors. Since research on SAI and societal debates about it are inextricably woven together, examining these different framings is vital if one wants to understand what the technology is about and what its sociopolitical implications are imagined to be. Which is why in this thesis I want to do just that by focusing on the debate around the research project SCoPEx.

4.1. SCoPEx

SCoPEx stands for *Stratospheric Controlled Perturbation Experiment* and is the latest example of a planned in situ experiment connected to SAI at the point of writing.[31] Before this thesis goes into the ins and outs of this project throughout the course of the empirical chapter (5), I want to shortly introduce the basic properties of this project. Researchers have made a case for this in situ experiment as early as 2014, arguing that there are

[29] These different takes on in situ experiments have already been raised in section 2.3.3 and will be discussed more in detail later.
[30] The SPICE-project (2.1) is a good example for this dynamic.
[31] If one does not consider SATAN to be a serious research project that is (2.1.1).

limitations to experimental settings in the laboratory and climate models specifically when it comes to drawing attention to 'unknown unknowns' of SAI:

> While laboratory experimentation can improve the current state of knowledge and atmospheric models can assess large-scale climate response, they cannot capture possible unknown chemistry or represent the full range of interactive atmospheric chemical physics. Small-scale, in situ experimentation under well-regulated circumstances can begin to remove some of these uncertainties. (Dykema et al., 2014, p. 1)

SCoPEx is carried out by the Keutsch Group at Harvard University and is part of Harvard's Solar Geoengineering Research Program (Harvard University, 2022). Involved scientists hope "to advance understanding of stratospheric aerosols that could be relevant to solar geoengineering." (Keutsch Group at Harvard, n.d., para. 1) by launching a balloon twenty kilometers high into the atmosphere. Attached to this balloon would be an equipment gondola that can release materials such as calcium carbonate or sulphates while at the same time measuring how the released materials affect factors like aerosol density or light scattering (Keutsch Group at Harvard, n.d.).

The plan of the researchers is to split the in situ experiment into two parts. First, there would be a so-called platform test, in which the flight apparatus itself would be tested. According to the researchers, this is necessary "because SCoPEx will use a new flight platform that has not flown before" (Keutsch Group at Harvard, n.d., sec. FAQ). After having conducted one (or several, if needed) test flights, the second planned part of the project is the "science flight" (Keutsch Group at Harvard, n.d., sec. FAQ), in which aerosols would be released so that their actual behavior in the stratosphere can be measured.

The research project is accompanied by the SCoPEx Advisory Committee, a committee that was appointed by Harvard[32] and has the purpose of evaluating certain parts of the SCoPEx-project and advising the involved scientists about the research and the governance of the project. Its mission statement reads as follows:

> The purpose of the Advisory Committee is to provide advice on the research and governance of SCoPEx, operating independently from the Research Team. The Committee's goal is to ensure that the SCoPEx project is undertaken in a transparent, responsible, and legitimate manner by ensuring that it contributes to scientific

[32] A more detailed account about the SCoPEx Advisory Committee's appointment along with details about its composition, function and criticisms thereof will be provided in section 5.2.

> understanding and establishes means for meaningful public engagement in the experiment. (SCoPex Advisory Committee, n.d., para. 2)

Although formally speaking, the Advisory Committee is only giving advice to the research team, members of the SCoPEx-project have underlined repeatedly that they will heed the advice of the committee, especially when it comes to the question of whether to conduct the experiment of not. Like it says on the project-webpage of SCoPEx: "the team will **not** proceed with this flight without a formal recommendation from the Advisory Committee to Harvard leadership authorizing the flight" (Keutsch Group at Harvard, n.d., sec. FAQ).

Originally, the balloon launch was supposed to be carried out in Tucson, Arizona in 2018 (Chen, 2017; Temple, 2017) and the SCoPEx-team also explored possibilities of conducting the experiment in New Mexico (Temple, 2021) – but in the end the experiment did not take place in neither of those places.[33] In late 2020, members of SCoPEx announced that they plan to partner with the Swedish Space Corporation (SSC)[34] to conduct their first platform test in Kiruna, Sweden in June 2021 (Keutsch Group at Harvard, 2020).

Just a few days after this announcement, first NGOs already heavily criticized the undertaking (Geoengineering Monitor, 2020) and called for a cancellation of the experiment. A decisive moment for the course of the SCoPEx-project happened in February 2021, when an open letter to the SCoPEx Advisory Committee, the Swedish Space Corporation and the Government of Sweden was published (Henriksen et al., 2021). Signed by the president of the Saami Council –an NGO promoting the rights and interests of the Saami indigenous people– and representatives from three other NGOs[35], the open letter criticizes SAI technology in general and articulates clear rejection of SCoPEx. Among other things, the letter criticizes that the SCoPEx Advisory Committee does "not have any representation from the intended host country, Sweden" and that the

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[33] Unfortunately, I was not able to find any information about the reasons why the experiment did not happen in these locations at that time. The only information that I could find in this regard is a passage on the webpage of SCoPEx in which it says that "because of COVID-19 and other logistical and scheduling challenges, there were no US based options that could provide a 2021 early-summer launch with a landing on land, and that had already secured launch equipment." (Keutsch Group at Harvard, n.d., sec. FAQ). However, this passage is about the time-frame of 2021 and not about the time in which there were plans for conducting it in Arizona (2018).

[34] SSC is "a global provider of advanced space services and has been launching scientific balloons for over 40 years." (Keutsch Group at Harvard, 2020, para. 9). Members of SCoPEx justify their decision to partner with SSC with "their availability for summer 2021, promising flight trajectories, and significant experience launching scientific balloons." (Keutsch Group at Harvard, 2020, para. 9).

[35] *Greenpeace Sweden*, *Friends of the Earth Sweden* and *Swedish Society for Nature Conservation*.

project has not "entered into any dialogue with either the Swedish government, its authorities, the Swedish research community, Swedish civil society, or the Saami people, despite the controversial nature of SCoPEx." (Henriksen et al., 2021, p. 2).

Roughly one month after this open letter was published, the SCoPEx Advisory Committee announced that they have decided to recommend to the SCoPEx-project team that they should suspend the experiment indefinitely (SCoPex Advisory Committee, 2021), but not without adding that they will continue their efforts in organizing a "robust and inclusive public engagement in Sweden" (SCoPex Advisory Committee, 2021, para. 1). Since then, it has become rather quiet around SCoPEx, with the Advisory Committee only publishing occasional updates about changes in the composition of the committee, the publishing of reviews or the organization of events. However, it is important to note that the experiment has never been officially cancelled –only suspended– and up to this date (May 2023) it is still unclear whether the SCoPEx project team and its Advisory Committee will attempt to schedule another date for the experiment in Sweden or elsewhere.

4.2. Research Questions

Although the empirical case of SCoPEx is not fully concluded and there might be further developments down the line that cannot be considered in this thesis, I do think that going deeper into the debate about it up to this day is a compelling research endeavor. To get a deeper understanding of the debate around SCoPEx, I want to comprehensively show and analyze both the perspective of people who contribute to SCoPEx and the perspective of people who have publicly voiced their opposition of the SCoPEx project. The main research question that guides this thesis is thus:

> ***How is SCoPEx depicted and assessed by the various actors who have a stake in the debate?***

With "actors who have a stake in the debate" I mean three actor groups: the scientists who work in the SCoPEx-project; SCoPEx Advisory Committee members and people who have publicly expressed their opposition of the SCoPEx. While the depiction of SCoPEx by these three actor groups entails many different aspects, there are four subject areas that I want to pay particular attention to, namely:

SQ 1: How do the different actors frame the relation between SCoPEx and Stratospheric Aerosol Injection (SAI) in general? (5.1)[36]

SQ 2: How do the different actors frame the SCoPEx Advisory Committee and issues of governance? (5.2)

SQ 3: How do the different actors frame global power dynamics and (post-)colonialism in relation to SCoPEx? (5.3)

SQ 4: How do the different actors frame public engagement in relation to SCoPEx? (5.4)

Like I will spell out in the next section, I conducted this research in a cyclical way, always switching back and forth between data collection and data analysis. This cyclical approach was also applied to a certain extent to the sub-questions – what were the most dominant themes within the debate of SCoPEx sometimes only became clear at later stages of the research project. I had all the themes in the sub-questions on my radar from the very beginning, but I did not always know in all cases that they would be the central categories at the end. For example, public engagement as a theme turned out to be way more dominant in the data than I anticipated. And other topics which I deemed to be central in the beginning and which were also part of previous versions of my sub-questions (e.g. valuation practices) did not turn out to be as central as I thought they would within the data material I had access to.

To answer the research questions, I will draw on different kinds of data. One the one hand I will use thematic analysis on publicly available resources by various stakeholders in the SCoPEx debate, on the other hand I will draw on one interview that I conducted with an expert who opposes the SCoPEx project. Why I draw on these different sets of data is spelled out in the next section.

4.3. Methods

4.3.1. A short note on research adaptation

When I first conceptualized this research project, I had a slightly different vision of how to realize it. Originally, the main empirical material for this thesis was supposed to be data gathered from qualitative, semi-structured expert interviews (Bogner et al., 2014) with representatives of each of the three actor groups. The idea behind this approach was to show how representatives of these actor groups perceive SCoPEx and its advisory

[36] The numbers in brackets indicate in which section of the results the questions will be mainly addressed. I will also return to all topics raised in the sub-questions within the discussion (6).

committee — most likely in different ways. However, during the research project I had to adapt my approach because the field was not as easily accessible as I anticipated it to be.

I started my empirical fieldwork by reaching out to members of the Advisory Committee. I figured that contacting members of the Advisory Committee first would be a good idea for two reasons: Firstly, I assumed that because of the work they are doing, they would be well connected to the scientists within SCoPEx and stakeholders who are rather critical of SCoPEx, thus potentially offering a good entry point into the empirical field. I thought that once I would have conducted an interview with an AC-member, they might be able to connect me to other relevant stakeholders in the debate. Secondly, I assumed that members of the Advisory Committee would be eager to talk to me because one of their central tasks that they spell out on their webpage is to engage with the public. I presumed that an organization which is responsible for conducting a public engagement process would in general be easily accessible for inquiries from the public and thus also for an interview request from my side.

With these assumptions in mind, I started contacting members of the Advisory Committee. I got a few responses from some members and a preliminary confirmation of an interview with one committee member. However, that committee member told me that they had to check back with other members of the committee whether they are ok with them talking to me. After this consultation, the committee member that I was in contact with informed me that they had decided collectively that they cannot talk about ongoing processes within the committees work but that they would be generally willing to talk about it after processes have concluded. As back then (and at the time of writing [May 2023]) it was still not clear when this public engagement process would be concluded and I had to proceed with data collection, I had to give up on interviewing members of the Advisory Committee. I also tried to reach out to the scientists working within SCoPEx several times, but I did not receive a response from them. The critical stakeholders were also not so easy to get hold off as I expected. After many mails sent out and several calls made, I managed to get an interview with one expert who at the time of writing worked within an organization that has publicly voiced its opposition of solar geoengineering and the SCoPEx-project in particular.

Due to these difficulties in the data collection process, I had to change my methodological approach and shift from conducting interviews to analyzing documents, websites and videos that were available on the case. Luckily, the case of SCoPEx offers plenty of publicly available data material that is susceptible to social scientific inquiry. Making this shift has advantages and disadvantages. One advantage is that this approach allowed me

to maintain my research focus without making large amendments to the research questions; I am still able to learn about the ways that the different actor groups depict the various issues connected to SCoPEx. But of course, this switch in data material also changes the kind of conclusions that I can draw from investigating this empirical case. The great advantage of qualitative interviews –and the reason why they were my first choice of method– is that they would have offered a glance "behind the scenes" of the public debate. This is an aspect that is lost with the switch in data material. On the other hand, predominantly focusing on publicly available data material has the advantage that it allows me to go deeper into the arguments that are being put forward and exchanged publicly between the relevant actor-groups.

4.3.2. Material used

The primary source of data for this thesis were the websites of important actors within the debate about SCoPEx. The text of the websites was imported into MAXQDA® and coded[37] just like all the other data material. Contributions on websites analyzed have been included until May 31st, 2023. Updates that have been published since then within the primary websites of investigation have not been included into the coding process. The following websites were imported and coded:

Table 1: Websites analyzed for this thesis

Institution	Represented Group	URL
Keutsch Group SCoPEx	Project members of SCoPEx	https://www.keutschgroup.com/scopex
SCoPEx Advisory Committee	Members of the SCoPEx Advisory Committee	https://scopexac.com/
Geoengineering Monitor	People critical of the SCoPEx-project	https://www.geoengineeringmonitor.org/

The webpages of Keutsch Group and the SCoPEx Advisory Committee have been imported as a whole – all sections and parts of the website that I could find during my engagement with it are part of the data material. Analysis also included documents that were retrievable through these websites. This entailed particularly the fourteen reviews

[37] Details about the coding process will be supplied in the next section (4.3.3).

that can be downloaded from the SCoPEx Advisory Committee webpage and includes documents like a legal review, a societal review, and a financial review.

In the case of Geoengineering Monitor, I only imported selected contributions from the News-section of their website, since not all parts of their website are dedicated to solar geoengineering.[38] In general, the data material from critical stakeholders is more dispersed than the data material of scientists who are part of SCoPEx and Advisory Committee-members. This is because criticisms of solar geoengineering and SCoPEx have been articulated from different places and cannot be attributed to one clear organizational entity like the scientists who are part of SCoPEx or the members of the Advisory Committee. Therefore, I also included selected relevant contributions from other webpages into the data material. These contributions were gathered through rather explorative means like web-searches and snowballing – meaning that although the list of selected pieces about solar geoengineering and SCoPEx is quite extensive, it is by no means exhaustive.

From the three main websites elected for analysis, the webpage of SCoPEx itself offers the least rich material. Just using the material gathered from the website of SCoPEx for analysis would have created an imbalance in the quantity and quality of data material between the different actor groups. I thus additionally drew on transcripts of publicly available videos on YouTube in which SCoPEx-scientists made statements within talks or interviews. The data material obtained this way mainly includes statements from two people who have a vital role within SCoPEx: Frank Keutsch, who is the project lead and David Keith, who is also part of SCoPEx and one of the most well-known scientists who have been working on solar geoengineering for a long time.

The number of videos selected for analysis in this thesis is of course not exhaustive, there could have been more videos included. Videos were selected by paying attention to whether scientists from within SCoPEx offer any insights into the project that is not offered on their project website. Once I had the impression that I had enough data material that extensively covers the perspective of the involved scientists on the project itself, I stopped including more videos. What really helped here was the fact that at the time of selecting the videos I had already gone through and coded all the other data, which means that I already had a good overview of how extensive the data of the other actor groups was. This made it much easier for me to judge how much more material I would need from the scientist's perspective so that the extent of the data material

[38] For example, many sections of Geoengineering Monitors webpage are about carbon dioxide removal technologies.

between the different actor groups is as balanced as possible.[39] Finally, I also included the one semi-structured expert interview with a critical stakeholder that I conducted for this thesis back when I was still under the assumption that interviews would be my main source of data material. I decided to include it among the other data sources because it was so rich in content and offered many insights into the case which did not appear in the rest of the data material. The full list of data material used with detailed references can be found in the Appendix (8.1).

4.3.3. Data analysis

The text of the webpages, documents, the transcripts of the videos and the transcript of the interview conducted for this thesis were all imported into MAXQDA® – a software for qualitative data analysis. All the data that I gathered was analyzed the same way, whether it was a transcript of an interview or a text passage retrieved from a blog-post. My approach to data analysis drew some inspiration from grounded theory (Strauss & Corbin, 1999) in the sense that it followed a circular logic. Rather than understanding the process of data collection and analysis as something linear and independent from each other, I went back and forth between data collection and data analysis. A good example for this is the data material of the SCoPEx-scientists that I already mentioned in the previous section (4.3.2); throughout the data analysis I realized that the website of the SCoPEx-project itself is not as extensive as I had thought, so I had to go back to the stage of data collection to make sure that the quality and quantity of the data material is approximately the same for all actor groups.

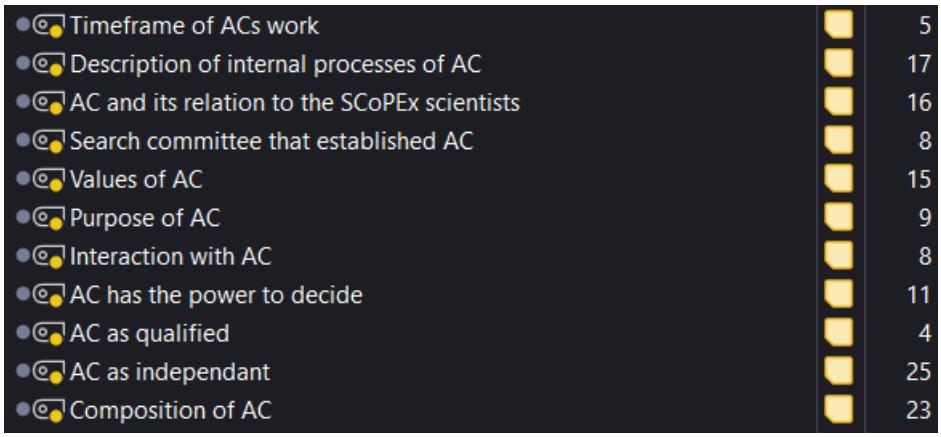
Although I did not adhere to a strict methodological protocol, the way I coded is best described as fitting into the "family of methods" (Braun & Clarke, 2022, p. 1) that is thematic analysis or thematic coding (Rivas, 2017). I conducted a text-based analysis, so I did not account for aspects like website layout, pictures used within contributions or the video footage that accompanied the interviews. My coding-process was an inductive one; I did not have a pre-made selection of codes, but developed the codes from scratch as I went through the data material. I understood *themes* as broad topics that have so many different layers that it does not make sense to pack them into one single code. Instead, I understood *themes* as something which is made up of several dimensions.

[39] The list of data material that has been used (8.1) might evoke the impression that the data on the scientist's perspective is not that extensive because there are less entries than for the critical stakeholders or the AC-members. Here it is important to note that the entries include six transcripts of talks of SCoPEx-scientists (which are up to one hour long) and are far more extensive than most of the other documents included. So, while there is a difference in the number of individual documents for each actor group, the sheer extent of text available for each group is approximately the same for all.

These dimensions within the broader themes are what I tried to record by categorizing them into different *codes*.

To illustrate this, an example might help: The Advisory Committee (AC) and its meaning for SCoPEx is a *theme* that I labeled with the color yellow[40]; this theme is made up of several different dimensions, each of which I tried to mirror with individual codes that I established inductively while I read through the data material:

Figure 1: Codes related to the Advisory Committee



When creating a code, I always added a memo to the code in which I explained what the code means exactly. By creating code-memos I ensured that I would always be able to reconstruct what I meant when initially creating the code. If I decided to add an additional layer of meaning to a code, I also made sure to document this within the code-memos. The table below shows some examples of code-memos from codes that belong to the theme of the Advisory Committee:

Table 2: Examples of codes and their descriptions/memos

Code	**Code-Memo; Description of code**
AC and its relation to the SCoPEx scientists	How is the relation between SCoPEx scientists and AC members described? Independent from each other, closely working together, dependent on each other, etc.
Search committee that established AC	Any mention, critique or praise of the search committee that was established to determine the composition of the AC

[40] In the picture below, this is indicated by the yellow dots on the left side.

Values of AC	What values are invoked in relation to the AC? What values do they or others say that they have that influences their work? What do they feel obliged to, what are their core values?

After having fully coded all the data material, I was able to interrogate how, to what extent and when the codes appear in the accounts of the different actor groups. The process of going through the data material again along the codes that I considered to be most relevant for this thesis was the foundation upon which the next section is built.

5. Results of the empirical investigation[41]

Throughout the analysis of data gathered for this thesis, several different themes and recurrent framings emerged. This chapter gives an overview of the most predominant framings while always drawing on the perspective of three different actor groups: the scientists involved in SCoPEx (SCoPEx-scientists), members of the SCoPEx Advisory Committee (AC-members) and stakeholders who have publicly voiced their opposition of the project (critical stakeholders). It consists of four parts. The first part examines questions around the relation of SCoPEx to the technology of SAI in general by going into the relation between SCoPEx-scientists and the eventual deployment of SAI (5.1.1), the concept of the slippery slope (5.1.2), financial dimensions of SCoPEx (5.1.3), issues around climate modelling (5.1.4), the relation between SCoPEx and mitigation (5.1.5) and potential military uses of SAI (5.1.6). After that, I will investigate how issues of governance are debated in the case of SCoPEx by examining how the Advisory Committee depicts itself (5.2.1), how it is criticized (5.2.2) and how all this plays out in the concrete example of the topic transparency (5.2.3). The third section will show how postcolonial dimensions are brought up differently depending on who talks about it (5.3) and lastly, the final section will scrutinize how public engagement is perceived and depicted by AC-members (5.4.1), SCoPEx-scientists (5.4.2) and the critical stakeholders (5.4.3).

[41] For better oversight and saving space, the referencing system has been adapted in this section. Documents that were analysed for this thesis have been numbered and are referenced by referring to that number. The first time a document is referenced, the full reference is supplied in a footnote – except for when more than three references are mentioned at once. For the full reference to each document please click the hyperlinked document numbers or go to the table in the section *Data Material* (8.1).

5.1. SCoPEx and its implications for SAI in general

> Such outdoor experiments are focal points because they somehow also push the debate [on SAI] definitely and you totally saw that. There were so many media reports about it, there was a — although it was only to a limited degree I would say — a societal debate about it, it got more visibility (Interviewee 1, 2022 – CS-Interview 1[42])

Like this quote from the interviewee for this thesis exemplifies, SCoPEx is inextricably tied to discussions of SAI in general. It is impossible to write about SCoPEx without also addressing broader questions that are connected to the research and potential deployment of SAI. For the empirical part of this thesis, I always tried to stay as close as possible to the concrete empirical context of SCoPEx without going too much into general discussions of SAI. But the more I wrote, the more it became apparent that this was neither always possible nor always analytically purposeful. In reality, these two debates are closely intertwined and hard to separate. Therefore, the empirical chapter starts off by addressing some themes within the debate around SCoPEx that also come up in or relate strongly to broader discussions of SAI.[43]

5.1.1. SCoPEx-scientists and the deployment of SAI

> My goal here is not to convince you that solar geoengineering is something we ought to do or must do. Indeed, I really think the latter is a crazy claim. My goal is to convince you that we ought to take it seriously. (David Keith, 2022 — IS-Transcript 4[44])

This quote taken from a talk by David Keith — who is a member of the SCoPEx research team and is often referred to by critical stakeholders as "one of the most prominent geoengineering proponents" (CS-Document 14[45], sec. The Geoengineering Clique) — is a great example of how SCoPEx-scientists usually depict themselves and their motivations in public accounts. On the one side it clearly displays caution about deploying the technology, on the other side there is the plea that we must still deal with solar geoengineering and that we cannot ignore it.

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[42] *CS-Interview 1* is the interview that has been carried out for this Thesis in September 2022. The person interviewed is a representative of an organization that is critical of SCoPEx.
[43] Of course, the other themes that are being addressed in the empirical chapter are also connected to SAI more broadly, but not as strongly as the ones featured in this section.
[44] Harvard Museum of Natural History (2019, December 12). *The Peril and Promise of Solar Geoengineering* [Video]. https://www.youtube.com/watch?v=xWI2w2F1gMg
[45] Geoengineering Monitor. (2014, November 28). *Reasons to Oppose Geoengineering*. https://www.geoengineeringmonitor.org/reasons-to-oppose/

There are many examples in which Keith talks about deployment of SAI and the problems that are connected to it (e.g. IS-Transcript 1[46], 3[47], 4), The hypothetical deployment of SAI is depicted as being comparatively cheap (IS-Transcript 1, 3) and rather easy to do from an technical and logistic point of view (IS-Transcript 1, 4):

> And this could be done using a fleet of something of an order of 100 aircraft. There have been several people who have now looked in real detail, aircraft engineers, of what it would be like to do that. These would be newbuild aircraft, but really using existing engines, existing commercial design standards, with sort of 100,000 or so flights per year, and the annual direct cost of the order of $5 billion. I mean, a lot of these numbers have big error bars. Maybe it's $10 billion. But as you'll see, that really is nothing compared to the scale of the cost of the climate problem, which is not a claim this is a good idea. It's just a fact about it, for good or bad. (David Keith, 2020 — IS-Transcript 1)

The last two sentences of this quote already hint at something that the data material analyzed for this thesis clearly shows, namely that SCoPEx-scientists undertake efforts to disassociate themselves and their work as pushing the deployment of SAI. Another example for this distancing from deployment is the following passage in a document provided by the SCoPEx-scientists to the advisory committee. Here they underline that the hardware used in the experiment cannot be used for future deployment of SAI:

> On this point, we would like to make clear that we are not conducting SCoPEx to develop hardware that can be used for deployment. In fact, this is one of the reasons why we chose to loft the particles using a balloon rather than an aircraft. Overall, the purpose of SCoPEx is NOT to advance our understanding of the aircraft or other platforms for deployment of solar geoengineering. (David Keith, 2020 — AC-Document 35[48], p. 4)

Another argumentative frame that is frequently drawn upon by the scientists is that the data that will be gathered within the experiment is something that will enable the scientists to better see and assess the risks connected to SAI through the work with

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[46] Talks at Google (2020, October 30). *David Keith | A Case for Integrating Solar Geoengineering into Climate Policy | Talks at Google* [Video]. https://www.youtube.com/watch?v=j7VCIrIPyNM

[47] Harvard Kennedy School Events (2022, February 28). *Cooling the planet with David Keith* [Video]. https://www.youtube.com/watch?v=dZIfFovwDTw

[48] Keith, D. W. (2020). *Financial Review: Response to Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/Full-Financial-Disclosure_Website.pdf

climate models[49] (IS-Document 3[50], IS-Transcript 5[51]). What these framings have in common is that they portray the scientists as people who do not have any interest in pushing the technology of SAI. Instead, they position themselves as somewhat disinterested actors that just want to do the science and put evidence on the table so that other people can decide:

> We're not the ones who are going to decide. Our decision now is whether to study it seriously. And from my perspective doing serious investigation of what its risks are and how well it could work provides the next generation with better information to make a more informed decision. It doesn't guarantee they'll make the right decision, but in my view it's a duty to provide them with that information so they can make those decisions in the face of really horrific climate risks. (David Keith, 2020 — IS-Transcript 5)

From the contextual information of the video that this quote is taken from it becomes apparent that *studying it seriously* also implies conducting field experiments of solar geoengineering. So, findings from solar geoengineering research and field experiments are depicted as an important decision basis for future policy makers. This take on the meaning of solar geoengineering field experiments has been criticized extensively by the critical stakeholders whose statements have been analyzed for this thesis. For example, the person interviewed for this thesis attests the SCoPEx-scientists a lacking awareness of how research on technologies such as SAI is embedded into power relations:

> I think that the SCoPEx team, I don't know if they really are naïve or if they just say that, at the end of the day that doesn't matter, but to act on the assumption of neutral research which just develops something because it might just be needed one day or not … this is a narrow perspective which completely ignores in which political economy and in which balances of power we live in and who has the power to decide whether this will be used or not. So including things like the military or other actors where it is hard to imagine that it will be a very democratic negotiation whether it will be used and how and to what extent and at whose expense and who has to bear the losses (Interviewee 1, 2022 – CS-Interview 1)

In this quote, Interviewee 1 relates the efforts of the SCoPEx-team to the actions of powerful actors. But since this interview has been conducted, two more releases of sulfur dioxide into the stratosphere as part of a SAI-related efforts – Make Sunsets (2023) and

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[49] This aspect has been already brought up in the State of the Art (2.3.1) and will also be dealt with in more detail in section 5.1.4.
[50] Keutsch Group at Harvard. (n.d.). *SCoPEx*. Retrieved November 11, 2022, from https://www.keutschgroup.com/scopex
[51] WebsEdge Science (2020, December 3). *SCoPEx, Harvard University—New Frontiers in Climate Change Research* [Video]. https://www.youtube.com/watch?v=w_qkmavwE54

SATAN (Temple, 2023) – have become publicly known (2.1.1), which are not necessarily connected that much to powerful actors. Which brings up another field of problems, namely individual actors who attempt to conduct SAI-related activities without consultation from the public. David Keith has made clear that he does not approve of the activities of Make Sunsets (Garrison, 2023; Temple 2023), but what is more interesting is how critical stakeholders relate Make Sunsets to SCoPEx. In a contribution on Geoengineering Monitor, it is strongly insinuated that even though SCoPEx-scientists have condemned Make Sunsets, they are partly to blame for the events that have occurred:

> Since Make Sunsets continues to generate headlines, [it's] worth remembering that Silicon Valley ethos and $ are a feature of the SRM world, not a bug, actively cultivated by the likes of Harvard … and their funders. This recklessness is a logical outcome of a process started by "responsible" researchers, which should serve as a lesson: implementation will be out of the hands of any well-intentioned researcher or governance framework. In this case, it's idiotic tech bros, in future, it will more likely, and more seriously, be the military. (Kevin Surprise[52], 2023 – CS-Document 32[53], sec. What is the risk?)

> The existence of Make Sunsets shows how easy it is for someone to take action based on speculative ideas and well-funded dominant pro-geoengineering narratives and activities around them (Laura Dunn, 2023 – CS-Document 32, sec. What is the risk?)

From these examples it should become clear that critical stakeholders do just the opposite of what the SCoPEx-scientists do: they argue that research on solar geoengineering with field experiments needs to be seen in context with potential deployment and that small-scale testing is just a first step in a series of many to push the technology. Differently put: critical stakeholders often frame the process of researching solar geoengineering with field experiments as a *slippery slope*.

5.1.2. SCoPEx as a slippery slope or part of phasing in

Like in many debates around technologies that have been controversial from the start, the *slippery slope*[54] argument also plays an important role within the case of SCoPEx.

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[52] This is a secondary quote of a Tweet from Kevin Surprise.
[53] Dunn, L. (2023, January 23). By prohibiting solar geoengineering experiments, Mexico sets a global example of precaution. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/01/by-prohibiting-solar-geoengineering-experiments-mexico-sets-a-global-example-of-precaution/
[54] The metaphor of *sliding down the slippery slope* refers to the assumed dynamic that once certain steps in technology development are taken, there is no way back from having it implemented at a broad scale with manyfold consequences.

Critics frame the experiment as something that would most likely contribute to the technology of SAI moving down the slippery slope that ultimately leads to the deployment of SAI (CS-Document 1[55], 22[56]). One example for this framing is this quote from a contribution that appears on Geoengineering Monitor:

> open-air testing of SAI won´t provide information about the effects of SAI on climate, but would set the stage for additional, larger-scale testing of a technology that should never be deployed. (Geoengineering Monitor, 2021 — CS-Document 12[57], p. 2)

In one common statement which is part of the open letter exchange between the SCoPEx-scientists and the AC, the SCoPEx-scientists make clear that they do not think that the slippery slope argument applies to the case of SCoPEx:

> Yet, we must not lose sight of the fact that research is not deployment, nor does it inevitably lead to deployment. Rather, it delivers information that can inform potential deployment — information that may reveal new risks, new benefits, or previously unknown challenges around solar geoengineering. In short, while research and deployment are linked, there is a clear distinction between the two. (Frank Keutsch, 2020 — AC-Document 29[58], p. 1)

However, in other passages SCoPEx-scientists do acknowledge the slippery slope as a problem within SAI-research (IS-Transcript 6[59]). In one interview, Keith mentions the slippery slope as a problem but not without the addition that we should think about ways how we can do research on SAI without moving down the slippery slope (IS-Transcript 1). In this case the slippery slope argument is acknowledged, but not without mentioning that within SCoPEx it might be possible to circumvent it.

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[55] Fuhr, L. (2019, March 11). Geoengineering at UNEA-4: Why the SDGs Require a Governance Debate Based on Precaution, Rights and Fairness. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2019/03/11/geoengineering-unea-4-why-sdgs-require-governance-debate-based-precaution-rights-and

[56] Sandahl, J., Vänner, J., Swedish Society for Nature Conservation, ETC Group, Biofuelwatch, Center for International Environmental Law, Friend of the Earth International, Heinrich Böll Foundation, Indigenous Environmental Network, & WhatNext? (2021, February 8). *Letter to Swedish Government on planned SCoPEx test flight*. https://www.geoengineeringmonitor.org/wp-content/uploads/2021/02/Letter-re-SCoPEx-to-Swedish-government.pdf

[57] Geoengineering Monitor. (2021, February 7). *Current Geoengineering Attempts Briefing: SCoPEx 2021*. https://www.geoengineeringmonitor.org/2021/02/current-geoengineering-attempts-briefing-scopex-2021/

[58] Keutsch, F. N. (2020). *Response to the Societal Engagement Process from the SCoPEx Research Team*. https://scopexac.com/wp-content/uploads/2021/01/FINAL-SCoPEx-Societal-Engagement-Outline-1_8_2021.pdf

[59] Seeker (2019, October 13). *Why the World's First Solar Geoengineering Test Is So Controversial* [Video]. https://www.youtube.com/watch?v=ReBPqguolu8

Even though some of the SCoPEx-scientists acknowledge the slippery slope argument, some critical stakeholders are not convinced that they take it that seriously. For instance, the critical stakeholder interviewed for this thesis is wary of whether the SCoPEx-scientists would be really willing to abort their experiment:

> This strategy of uhm well so to speak starting very small-scale, to say that this does for now not have any effect at all. This this is certainly true, so I don't want to say that this is just tactics or something like that. But uhm to counter this slippery slope argument and then somehow say: anytime, I don't know, we could, we would stop this anytime if X. At which I am not really clear on under which circumstances this actually would happen and who needs to say no uhm because (laughs) the no of the Saami now in Sweden did definitely not lead to them cancelling the whole thing, even though they had to cancel it in Sweden. (Interviewee 1, 2022 – CS-Interview 1)

Closely connected to the concept of the slippery slope is the assumption that SCoPEx is the first step in what critical stakeholders repeatedly refer to as *phasing in*. Phasing in is the deliberate attempt to use the alleged slippery slope in one's favor to introduce SAI slowly by only taking small steps in the development of the technology. In the case of SCoPEx, this framing essentially implies that SCoPEx-scientists have deliberately set up SCoPEx in such a small scale to be able to introduce the technology in an incremental way. One example for this framing can be found within a manifesto against Geoengineering published on the website of Geoengineering Monitor:

> [Geoengineering is] untestable. To know if geoengineering proposals would have an effect on climate change, it would need to be deployed at such a large spatial and temporal scale (to differentiate it from other ongoing climate phenomena) that it wouldn't be an experiment – it would be outright deployment, with all its potential intended and unintended impacts. Therefore, small scale experiments only serve the purpose of testing hardware and tools to advance research and investments that will then be used to justify "the need" for larger experiments and eventually deployment. (*Hands off Mother Earth! Manifesto against Geoengineering*, 2018)[60]

In this quote, it is strongly insinuated that the researchers who work on SAI[61] are conducting the experiment with the intention of pushing more and larger research (and thus more investments) on SAI. Which brings us to another issue within the debate,

[60] This exact passage is also directly quoted in CS-Document 19 (para. 9), which is why it is part of the data corpus. To avoid a second-hand quote, I indicated the original reference.
[61] Although SAI is not mentioned explicitly in this quote, the text that follows this quote within the manifesto makes it clear that the quote is not about Geoengineering technologies in general, but about SAI.

namely how the different actor groups frame the connection of SCoPEx to financial interests and actors from industry.

5.1.3. Financial dimensions within SCoPEx

A common argument from the side of the critical stakeholders is that researchers involved in SAI research have commercial interests in pushing the technology (CS-Document 1, 5, 19, 30):

> many of those advocating geoengineering have worked for, been funded by, or stood to profit from the fossil-fuel industries that created the climate crisis in the first place. (Carroll Muffet, 2019 – CS-Document 5[62], para. 10)

> these are not dispassionate scientists, but entrepreneurs backed by venture capitalists who stand to become fabulously wealthy if governments should opt to move forward with an SRM project in the future. (Geoengineering Monitor, 2017 – CS-Document 30[63], sec. Possible Impacts)

Even more commonly, critical stakeholders argue that actors from the fossil-fuel industry are funding and pushing solar geoengineering (and geoengineering in general), because they would supposedly profit from the existence of a technofix for the climate crisis as it would enable them to continue their business as usual (CS-Document 14, 16, 20, 25). This way of framing the funding for solar geoengineering is essentially reiterating the moral hazard argument, which is one of the most recurrent arguments in the debate about SAI (2.2.1 and 5.1.5). In an interview, one of the critical stakeholders also positions billionaires in the same context as the actors from the fossil-fuel industry:

> [They] do not want to transform the systems that allowed them to get so rich and powerful, and now some of them have chosen to invest in this extreme technological global intervention … Investing in solar geoengineering research is presumably attractive to these billionaires because it advances a climate mitigation strategy that does not threaten or disrupt the systems they rely on for their wealth accumulation. (Jennie Stephens, 2021 – CS-Document 15[64])

So, actors from the fossil-fuel industry and billionaires who fund solar geoengineering research are depicted as actors who are interested in maintaining the status quo and solar

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[62] Muffett, C. (2019, February 18). Geoengineering is a dangerous distraction. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2019/02/18/geoengineering-dangerous-distraction
[63] Geoengineering Monitor. (2017, November 23). *Current Geoengineering Attempts Briefing: SCoPEx*. Geoengineering Monitor. https://www.geoengineeringmonitor.org/2017/11/scopex/
[64] Jay, D. (2020, July 8). Hidden Injustices: Interview with Dr. Jennie Stephens. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2020/07/hidden-injustices-interview-with-dr-jennie-stephens/

geoengineering is understood as something that would help them to do so. This framing is also picked up in an open letter to the SCoPEx Advisory Committee by some critical stakeholders, in which they argue that:

> The most devastating effect of your participation in SCoPEx, however, may be psychological and political. It gives political leaders a false but enticing way to avoid confronting the carbon giants. The fossil fuel industry has been promoting and funding several forms of geoengineering projects for years for one simple reason: it will allow them to continue with their oil, gas and coal business, and avoid addressing the root causes of climate chaos … the existence and development of solar geoengineering undermines the pathway to the climate transition that the world urgently needs. (Geoengineering Monitor, 2019 – CS-Document 29[65], para. 9-10)

Following this framing of solar geoengineering as detrimental to a just way of dealing with the climate crisis, the authors of the open letter address the AC-members directly and urge them to withdraw from the committee:

> As those newly recruited to provide SCoPEx with legitimacy, you face a stark decision. Your current role legitimizes a project that furthers the interests of climate disrupting forces, such as the fossil fuels industry. We urge you to break your complicity with this path, and to withdraw your participation from the SCoPEx Advisory Committee. (Geoengineering Monitor, 2019 – CS-Document 29, para. 13)

As with all external open letters to the AC, the AC did not publicly respond to this.[66] However, the AC and the SCoPEx-scientists do try to address financial issues such as the ones brought up above within their online presence. The most important group of documents in this regard are the open letters on the financial review that have been exchanged between the AC and the SCoPEx-scientists.[67] In the first open letter by the AC (AC-Document 34[68]), AC-members pose a couple of questions to the SCoPEx-scientists which they answer in their reply (AC-Document 35). After that, the AC poses some

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[65] Geoengineering Monitor. (2019, August 21). *Open Letter to SCoPEx Advisory Committee*. https://www.geoengineeringmonitor.org/2019/08/open-letter-scopex/

[66] And the data gathered for this thesis suggests that they also did not respond to it non-publicly (5.2.3).

[67] Some parts of this open letter exchange which concern the transparency of funding streams for SCoPEx are also covered later in more detail (5.2.3).

[68] SCoPEx Advisory Committee. (2020). *Financial Review: Financial Review Process and Questions*. https://scopexac.com/wp-content/uploads/2020/11/Financial-Disclosure-Review-Process.pdf

follow-up questions (AC-Document 36[69]), which are also responded to publicly by the SCoPEx-scientists (AC-Document 37[70]).

Unsurprisingly, the SCoPEx-scientists do not depict themselves as having a commercial interest in furthering the development of SAI. Instead, they argue that they have no intentions of creating intellectual property in connection with solar geoengineering:

> key SCoPEx personnel have personally committed to not file for patents associated with SCoPEx … In fact, David Keith and John Dykema authored a blog post on this topic, explaining why they oppose commercial work on solar geoengineering and will not file solar geoengineering patents. (David Keith, 2020 – AC-Document 35, p. 3)

In this case, the framing of the SCoPEx-scientists clearly diverges from the framings provided by the critical stakeholders. But things get a little more complicated when it comes to the role of the fossil-fuel industry in solar geoengineering research. Initially, SCoPEx-scientists seem to take a similar stance here as the critical stakeholders, arguing that indeed the moral hazard is a problem within solar geoengineering research and that actors from the fossil-fuel industry might take advantage of the technology:

> As we noted above, we take issues of conflict of interest very seriously. And we take the "moral hazard" concern very seriously … we, like others, are concerned that fossil fuel companies or other interests will seek to exploit solar geoengineering to slow down or block mitigation. (David Keith, 2020 – AC-Document 35, p. 5)

However, within the argumentation of the SCoPEx-scientists, these concerns do not automatically mean that SCoPEx cannot accept money from actors who are or have been involved with the fossil-fuel industry. After having displayed a wary stance towards actors from the fossil-fuel industry, the SCoPEx-scientists continue to argue that they deal with this issue in their own project by implementing certain principles to decide on whether to accept a donation for their research or not:

> To address this concern in our own work, SGRP [Harvard's Solar Geoengineering Research Program] does not accept donations from corporations, foundations, or individuals if the majority of their profits or wealth come from the fossil fuel industry unless they can clearly demonstrate that they do not have a conflict of interest and present

[69] SCoPEx Advisory Committee. (2020). *Financial Review: Additional Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/Committee-Letter_Financial-Review_David-Keith.pdf
[70] Keith, D. W. (2020). *Financial Review: Response to Additional Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/SGRP-Financial-Response_Website.pdf

> a strong track record of supporting efforts that address climate change. (David Keith, 2020 – AC-Document 35, p. 5)

In order to get an insight into how the SCoPEx-scientists argue for or against a donation for their research, it is worth to scrutinize their "rough weighing system" (AC-Document 35, p. 5), which they use to assess the credibility of potential donors. It works like this:

> We rate the donor's ties to fossil fuels on a 1 to 5 scale, where 1 has no connection with fossil fuels and 5 has nearly all of their current wealth and social connections tied to coal. Then, we rate the donor's commitment to climate from 1 for a donor who has long devoted a majority of their time and resources to climate action to 5 for a donor who has no visible interest in climate. We then take the product of the two ratings, rejecting donors with a multiplicative combined rating that is larger than 10. (David Keith, 2020 – AC-Document 35, S. 5)

The SCoPEx-scientists argue that the use of this weighing system would lead them to reject a donation from Exxon – which would in their opinion score a 25 – but accept a donation from The Rockefeller Foundation – which would in their opinion score a 6 (AC-Document 35). In their response, the AC-members state that they consider this to be a "relative subjective rating scale" (AC-Document 36, p. 1) and ask the SCoPEx-scientists to explain how they justify that they have accepted a contribution from John and Laura Arnold – two philanthropists who have (amongst other things) investments in oil and gas.

The SCoPEx-scientists respond that John and Laura Arnold's contribution is a good example of how complicated it can be to determine conflict of interest in a real-world scenario. They explain that using their weighting system, one could give John and Laura Arnold a score somewhere between 6 and 12 (AC-Document 37). Nevertheless, they argue that it is still legitimate to accept a donation from them:

> From our point of view, John and Laura's leadership roles in climate initiatives, significant donations to climate organizations, and investments in renewable energy demonstrate a real interest in and commitment to reducing greenhouse gas emissions despite their investments in oil and gas. We recognize, however, that our final judgment is subjective and could certainly be critiqued (David Keith, 2020 – AC-Document 37, p. 2)

Within the statement of the critical stakeholders that have been analyzed for this thesis, this particular example of John and Laura Arnolds' contribution is not commented on explicitly. But based on the previous accounts which show clear resentment of the financial involvement of actors who are close to the fossil-fuel industry, it is reasonable

to assume that most of the analyzed critical stakeholders would not support the decision-making process that has been spelled out here by the SCoPEx-scientists.

5.1.4. What role do climate models play?

Another central theme within the discussion of SCoPEx is its relation to and meaning for climate modelling. Although all actor-groups seem to agree that the evidence which is generated with models only has limited explanatory power, they all rely on these models while at the same time casting doubt on them. Both opponents and proponents of SCoPEx point out that climate models are limited in regards to what they can tell us about what SAI would do to the climate if deployed (CS-Document 17[71]; AC-Document 30[72]). However, the conclusions that they draw from this shared understanding are fundamentally different.

When it comes to the take of the SCoPEx-scientists, they argue that the key purpose of SCoPEx is to generate data which can be used to improve the ability of existing climate models to calculate the potential impacts of SAI (IS-Document 3, IS-Transcript 4, AC-Document 30). In the document about the scientific merit of SCoPEx, they write:

> The scientific goal of the Stratospheric Controlled Perturbation Experiment (SCoPEx) is to improve process models that will, in turn, reduce uncertainties in global-scale models, thus reducing uncertainty in predictions of important SRM risks and benefits (Frank Keutsch, 2020 — AC-Document 30, p. 2)

One of the most interesting arguments that the scientists put forward in relation to models is that conducting SCoPEx is actually a way to counteract overconfidence in SAI. They write that "such simulations are the primary tool for estimating the risks and benefits of solar geoengineering, but current limitations may make the simulations look too good." (IS-Document 3). This framing of SCoPEx as a way to potentially counteract overconfidence in SAI is also evoked on the website of the Advisory Committee and in an interview with Keutsch:

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[71] Geoengineering Monitor. (2020, October 27). *Geoengineering in the Global South (ETC Podcast)*. https://www.geoengineeringmonitor.org/2020/10/geoengineering-in-the-global-south-etc-podcast/

[72] Keutsch, F. N. (2020). *The Stratospheric Controlled Perturbation Experiment (SCoPEx)—Scientific and Technical Review Foundational Document -Version 1.0*. https://scopexac.com/wp-content/uploads/2021/03/1.-Scientific-and-Technical-Review-Foundational-Document.pdf

> Currently, there is a concern within the Project that limitations of information results in an overestimation of the simulations. (Setterwalls Law Firm, 2021 — AC-Document 38[73], p. 5)

> These models might be in some way biased to make solar geoengineering look too good and to examine that we need to … think hard about the ways that existing models might be wrong, to think about how to improve those models (David Keith, 2020 — IS-Transcript 5)

The way how SCoPEx-scientists depict their intentions with the experiment (to potentially introduce more skepticism towards SAI) can be seen as a part of the larger framing that SCoPEx does not intend to further the development — let alone deployment — of SAI. A framing that is employed by SCoPEx-scientists and members of the Advisory Committee but is refused by the critical stakeholders.

When critical stakeholders write about models, they mainly do it to steer attention towards potential negative consequences that would result from the deployment of SAI. Examples for this are the take that "geoengineering interventions can have regional winners and losers" (CS-Document 14, para. 3) or the risk of droughts that would come with deployment of SAI (CS-Document 14). In an interview, one critical stakeholder is wary of optimistic conclusions derived from climate models, arguing that "Climate models have limited utility in guiding us toward a climate just future because climate models do not include people, politics and power dynamics." (CS-Document 15, para. 13). Silvia Ribeiro — Director of ETC Group Latin America — argues in a similar vein when she remarks in an interview:

> [Models] are being used as a way of influencing policy. It's influencing to allow for geoengineering to be deployed, even if they don't know what will happen. And everything that they do will have terrible effects, particularly on the South. Even if they do this kind of tweaking with the model, they cannot– what is hidden is that they are implying, for instance, the massive use of other forms of geoengineering. They are implying that there is a global mechanism that will control [all geoengineering activities] so that they can use a little bit here and then there, and then take it down. (Silvia Ribeiro, 2020 — CS-Document 17, para. 25)

So, Ribeiro goes as far as claiming that not only models are inadequate to include important factors such as power and politics into the equation, but she also claims that

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[73] Setterwalls Law Firm. (2021). *Legal Review: Memorandum to Harvard University regarding project SCoPEx*. https://scopexac.com/wp-content/uploads/2021/04/Memorandum-Project-SCoPEx-Setterwalls-2021-02-18-1.pdf

they are being used intentionally to influence policy.[74] Another critical stakeholder also notes that modelling research results from modelling activities are taken up by the IPCC and thus have an influence on political processes (CS-Interview 1), albeit without claiming that this process is intended by the scientists.

5.1.5. SCoPEx and mitigation

As one might expect, the relation between SAI and the reduction of greenhouse gas emissions (2.2) also figures as an important element of the debate around SCoPEx. Like the section on financial dimensions of the SCoPEx-project (5.1.3) already showed to a certain extent, the moral hazard argument in particular plays an important role within the accounts of stakeholders who voice their opposition of SCoPEx.

While the existence of the moral hazard issue in the context of SAI is contested within the academic debate (2.2.1), this is only partly true in the case of SCoPEx: All stakeholders acknowledge that the moral hazard might be a problem for SAI, but they do so with varying intensity. All critical stakeholders that bring up issues around the moral hazard seem to be of the strong conviction that the existence of SAI would have a negative impact on efforts to reduce greenhouse gas emissions (CS-Document 1, 2, 3, 7, 8, 10, 11, 12, 14, 17, 19, 22, 26, 29). While the takes about moral hazard are mostly about SAI and greenhouse gas emissions in general, there are also some critical stakeholders who associate the actions of the SCoPEx-scientists as contributing directly to the moral hazard:

> Members of the SCoPEx team promote SAI as a quick and cheap way of engineering the climate. This can create a false sense that a technological quick-fix could tackle the climate crisis, which risks deflating the necessary pressure to rapidly phase out fossil fuel production (Geoengineering Monitor, 2021 – CS-Document 12, p. 1)

Within the documents of the AC, moral hazard of SAI as an issue is also acknowledged, but it is not portrayed as a clear matter of fact like in the material of the critical stakeholders. Instead, it is depicted as something that might be problematic and that needs to be discussed within the public engagement process of the project (AC-Document 42[75]). Issues connected to moral hazard are not as frequently discussed, but the AC does emphasize that reducing greenhouse gas emissions needs to be the number

[74] Unfortunately, it is unclear from the quote itself whom exactly Ribeiro attests the intention of wanting to influence policy towards deployment of SAI, but it seems likely that she means scientists who are involved into research about SAI.
[75] SCoPEx Advisory Committee. (2021). *SCoPex Advisory Committee Workplan and Operating Guidelines (Version of May 12)*. https://scopexac.com/wp-content/uploads/2021/05/SCoPEx-Advisory-Committee-External-Document_Website_Final_5_21.pdf

one measure in dealing with climate change and that solar geoengineering can in no way be a substitute for mitigation (AC-Document 5, 18[76]). They also make clear that they do not want SCoPEx to be understood as a distraction from more established ways of dealing with the consequences of climate change:

> SCoPEx is not a valid reason for shifting the global focus away from current, better known and understood adaptation and mitigation measures, especially the reduction of emissions. (SCoPEx Advisory Committee, 2020 – AC-Document 5, para. 9)

The SCoPEx-scientists have essentially the same take on mitigation; they also underline repeatedly that they are of the conviction that it is essential to reduce greenhouse gas emissions and that this way of dealing with climate change should be the first priority and cannot be substituted by solar geoengineering (IS-Transcript 1, 2, 4, 5). As David Keith puts it:

> One of the big misconceptions about solar geoengineering is that it is an alternative, a substitute to cutting emissions. That's nonsense! (David Keith, 2020 – IS-Transcript 5)

> I think there's no way that solar geo [Solar Geoengineering] can substitute for emissions cuts. The way I think about it is it can supplement emissions cuts. So emissions cuts plus solar geo might produce a world with less risk than emissions cuts alone. (David Keith, 2020 – IS-Transcript 1)

When it comes to the issue of the moral hazard, the take of the SCoPEx-scientists is somewhat ambivalent. In terms of how the issue can be addressed within SCoPEx, they point towards something that has already been shown in the State of the Art: it might not be possible to determine whether the moral hazard exists or not (2.2.1):

> it is impossible for SCoPEx to answer this big question. Indeed, since a judgement about moral hazard is a judgement about how political disputes will play out over decades, we are skeptical than [*sic*] anyone can make a confident judgment. (AC-Document 29, p. 4)

On a more general note, they do acknowledge the moral hazard problem and say that it is a legitimate concern (AC-Document 35; IS-Transcript 1, 4, 6[77]). However, there are also moments in which they cast doubt on the basic idea of the moral hazard. The example that stands out the most in this regard is their response (AC-Document 29) to

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[76] SCoPEx Advisory Committee. (2019). *July 29, 2019*. https://scopexac.com/july-29-2019/
[77] Seeker (2019, October 13). *Why the World's First Solar Geoengineering Test Is So Controversial* [Video]. https://www.youtube.com/watch?v=ReBPqguolu8

the societal engagement process suggested by the AC (AC-Document 28[78]), in which they quote a study that turns the moral hazard argument on its head and argues that: "people who have been informed about SAI mitigate more than people who have not" (Merk et al., 2016, p. 1). The SCoPEx-scientists also praise the method used by these scientists – arguing that it is more accurate because they are studying actual behavior instead of asking people for estimations about other's future behavior (AC-Document 29).

5.1.6. Military uses

Another scenario that pops up occasionally in the debate around SCoPEx is that SAI or solar geoengineering in general can be weaponized and thus might one day be used for military purposes. This scenario is mainly brought up and talked about by critical stakeholders (CS-Document 1, 2, 12, 14, 15, 17, 21; CS-Interview 1), but also briefly makes its appearance in the data material of the SCoPEx scientists (IS-Transcript 1). It does not get mentioned on the website of the SCoPEx Advisory Committee.

Geoengineering Monitor makes clear that they consider SAI to have the potential to be weaponized (CS-Document, 12); in one section of their website, they even write that a weaponization of geoengineering is inevitable (CS-Document 14). Because of this potential weaponization (and "the unequal global impacts") Geoengineering Monitor concludes that "solar geoengineering carries insurmountable challenges for governance" (CS-Document 21[79], sec. Overview) which leads them to the demand of an international ban of solar geoengineering.

Another part of the discussion which some actors see as an indication that SAI might be used for military purposes is the discussion of ideas like counter-geoengineering (Heyen et al., 2019). In a nutshell, counter-geoengineering is the idea to reverse the cooling effects of solar geoengineering if it were needed. The expert interviewed for this thesis describes it like this:

> And some of them also wrote these papers on counter-geoengineering, that was a few years ago, where a few from this group also wrote that one should already build capacities for counter-geoengineering in case that one uhm well that somehow you again introduce warming agents into the atmosphere if it gets too cold or if it is not in your interest,

[78] SCoPEx Advisory Committee. (2021). *Proposed Engagement Process for SCoPEx*. https://scopexac.com/wp-content/uploads/2021/01/FINAL-SCoPEx-Societal-Engagement-Outline-1_8_2021.pdf
[79] Geoengineering Monitor. (2021, February 4). *Stratospheric Aerosol Injection (technology briefing)*. https://www.geoengineeringmonitor.org/2021/02/stratospheric_aerosol_injection/

> probably rather the latter. And this was a real, these were real war scenarios, total madness! (Interviewee 1, 2022 – CS-Interview 1)

In the material analyzed, SCoPEx-scientists do not go much into aspects of weaponization. The only exception is an interview with David Keith, in which he briefly mentions the risk of "climate wars" (IS-Transcript 1) without going further into it. The fact that weaponization does not feature prominently in the data material of the scientists and the Advisory Committee might be surprising at first glance but at second glance it makes sense because weaponization and military uses of SAI are seldomly discussed in direct relation to the envisioned experiment within SCoPex — even by the critical stakeholders. Much more, this topic comes up mainly when discussing speculative futures of SAI in general.

However, as the general discussion of SAI and SCoPEx are very much intertwined, I felt like this aspect needed to be mentioned here, if only briefly. What is more, there are also accounts (although they are rare) in which SCoPEx is positioned in direct relation with issues of weaponization. An example is this quote from Interviewee 1, in which they talk about the scientist's awareness of issues of weaponization:

> And all these things, of course they are aware of that, and they are super problematic … but still they stick with this position that well, no we are just doing a small, so this is just, this is just bullshit (Interviewee 1, 2022 – CS-Interview 1)

So, to sum up: weaponization is brought up by critical stakeholders in the context of discussing SCoPEx, but mainly in relation of what the future might hold for SAI in general. Weaponization and military uses in the future are not one of the main points of critique of the SCoPEx-project; it is rather secondary and only pops up occasionally in broader discussions of SAI.

5.2. The Advisory Committee and issues of governance

One of the most central and recurrent themes in the data material are questions of governance surrounding SCoPEx and experiments of SAI in general. Since SCoPEx is the latest attempt to carry out an in-situ experiment of SAI, the debate about the experiment is strongly connected to the governance of SAI-technology in general. The fact that Harvard has established an Advisory Committee — whose central task it is to deal with governance — shows that the actors within SCoPEx are aware of the vital importance of governance within the debate of SAI-research.

The SCoPEx Advisory Committee thus takes a pivotal role within the debate. It can be seen as an attempt by the research team at Harvard to establish a sound governance for their research project. However, the AC has not remained uncontested and there are

stark differences in the framings of what the AC is and what it does depending on who writes about it. This section aims to show the range of framings that exist about the AC. It does this by focusing firstly on how the AC depicts itself (5.2.1) and then follows up with the framings of the AC by the critical stakeholders (5.2.2). In the final part of this section, the differing takes on the AC are exemplified by examining issues of transparency (5.2.3).

5.2.1. Self-depiction of the Advisory Committee

Purpose and values of the Advisory Committee

In their mission statement, the AC describes its purpose like this:

> The purpose of the Advisory Committee is to provide advice on the research and governance of SCoPEx, operating independently from the Research Team. The Committee's goal is to ensure that the SCoPEx project is undertaken in a transparent, responsible, and legitimate manner by ensuring … meaningful public engagement in the experiment. (SCoPEx Advisory Committee, n.d. — AC-Document 4[80], sec. Mission Statement)

The key themes that are brought up within this mission statement — independence, transparency, responsibility and public engagement — are reiterated throughout the different sections of the AC-website.[81] Other values and purposes that make an appearance on the website –albeit not being drawn on as repeatedly as the key themes above– are the intention of the AC to build trust in SCoPEx (AC-Document 36), the general desire to do something against climate change (AC-Document 18[82]) or the conviction that the reduction of greenhouse gases is of the highest priority in addressing climate change (AC-Document 5[83], 18).

It is interesting to note that some of the key themes mentioned in the mission statement are not only portrayed as a purpose that the AC needs to work on, but that they are also being positioned as personal values and beliefs of the AC-members. One example for this is public engagement; the AC writes on several occasions that they *believe* that public engagement needs to play a vital role within SCoPEx (AC-Document 28, 29, 42). At another point, the AC underlines the importance of personal values when they write that

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[80] SCoPEx Advisory Committee. (n.d.). *Mission and Values*. Retrieved November 12, 2022, from https://scopexac.com/advisory-committee-mission-and-values/
[81] To just give one example: The notion of the AC being independent comes up in AC-Document 1, 2, 5, 12, 15, 16, 28, 29, 36, 42. The other notions appear in a similar frequency.
[82] SCoPEx Advisory Committee. (2019). *July 29, 2019*. https://scopexac.com/july-29-2019/
[83] SCoPEx Advisory Committee. (2020). *About*. https://scopexac.com/

"we will remain true to our values and beliefs as we conduct this work" (AC-Document 4). However, the website of the AC remains rather vague when it comes to what exactly these values and beliefs are, except for the examples mentioned above.

Another key value that is not explicitly addressed within the mission statement but does pop up on several different occasions is the framing that the AC is a disinterested entity. This becomes apparent in the AC's operating guidelines and their call for new members:

> Committee members must be undecided on whether or not small scale field research on solar geoengineering should be conducted until such time that all review materials (enumerated above) are collected, analyzed and discussed by the Committee. (SCoPEx Advisory Committee, 2021 — AC-Document 43[84], p. 8)

> we are especially interested in people who … are willing to work with other committee members to achieve consensus, and are willing to set aside any personal feelings about the deployment of geoengineering. (SCoPEx Advisory Committee, 2021 — AC-Document 11[85], para 7)

Elsewhere the AC writes: "None of us is undertaking this work with a predetermined outcome in mind." (AC-Document 5, Sec. Statement from the SCoPEx Advisory Committee)[86], further emphasizing the importance of disinterestedness for the committee.

Composition of the Advisory Committee

An essential part of the AC are of course the members that it consists of. The website of the AC is quite detailed on the formal process of how AC-members have been selected. According to their website, an independent search committee — consisting of three members[87] — has been established even before the AC. This search committee recommended an Advisory Committee chair who together with the search committee recommended potential AC-members. Besides assisting in selecting AC-members, the search committee was also involved in reviewing and suggesting adjustments to the draft

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[84] SCoPEx Advisory Committee. (2021). *SCoPex Advisory Committee Workplan and Operating Guidelines (Updated Version of July 27)*. https://scopexac.com/wp-content/uploads/2021/07/SCoPEx-Advisory-Committee-External-Document_Website_Final_7_27_2021.pdf
[85] SCoPEx Advisory Committee. (2021). *April 8, 2021*. https://scopexac.com/april-8-2021/
[86] This framing also appears in AC-Document 16.
[87] The members of the search committee were: Chris Field, Stanford University; Peter Frumhoff, Union of Concerned Scientists; Jane Long, Lawrence Livermore National Laboratory (retired) (AC-Document 1).

Terms of Reference of the AC and working with other actors from Harvard[88] to agree on the final Terms of Reference (AC-Document 1[89]).

After the committee has been criticized for not being diverse enough in February 2021 (5.2.2), the AC published a call for applications in April 2021, writing that they "would … like to broaden the geographic and other forms of diversity of people participating on the committee" (AC-Document 11). In September 2021, the AC announced on their website that two new members joined the committee and that they "are continuing to search international members to increase representation and diversity on the committee" (AC-Document 10[90]). In April 2022, the AC announced that they "decided that a more regular leadership structure would better serve the objectives for the Committee" (AC-Document 8[91], sec. Leadership Committee) and elected three members of the AC to form a leadership committee. Over the course of writing this thesis, some members have stepped down from the committee, others have joined. Some have stepped down and re-joined again at a later point in time. At the time of writing (May 2023), the AC consisted of ten members. A detailed table with the names and background information such as profession, education and work experience of the AC-members is supplied in the Annex (8.3).

In one section of the AC's website, it is argued that an important criterion for selecting AC-members was "their experience as well as their reputation for integrity in international environmental research and governance" (AC-Document 4, sec. Integrity and Impartiality). Furthermore, the AC writes that "Committee membership is intended to represent a wide range of perspectives, experiences, and expertise that are relevant to governing the experiment." (AC-Document 4, sec. Integrity and Impartiality). All members of the AC have an academic background, with many of them being professors. AC-members are largely based in the USA and some of them have been or still are part of governmental entities. Most of them also serve on other boards than the AC.

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[88] These other actors are the Harvard Dean of the School of Engineering and Applied Sciences, the Harvard Vice Provost for Research, the person chairing the SCoPEx Advisory Committee to the beforementioned Dean and Vice Provost and the SCoPEx Principal Investigator.
[89] SCoPEx Advisory Committee. (n.d.). *Advisory Committee Selection*. Retrieved November 11, 2022, from https://scopexac.com/advisory-committee-selection/
[90] SCoPEx Advisory Committee. (2021). *September 17, 2021*. https://scopexac.com/september-17-2021/
[91] SCoPEx Advisory Committee. (2022). *April 2022 Update*. https://scopexac.com/scopex-advisory-committee-april-2022-update/

SCoPEx and its governance as a role model

In its mission statement, the AC states that it is working "to develop and implement a credible and sound governance framework for this research project" (AC-Document 5). The purpose of this governance framework is often described as two-fold: On the one hand it is depicted as a necessity for an experiment on a complex technology such as SAI. On the other hand, AC-members also underscore the importance of the governance process for future research. These two goals become nicely apparent in the following quote:

> The SCoPEx project presents an opportunity to pilot comprehensive and inclusive approaches to research governance that are commensurate with the myriad, interconnected, and complex challenges presented by geoengineering research. We modestly hope that the processes we develop and employ to evaluate SCoPEx can both responsibly guide this particular experiment and serve as a model for other geoengineering research. (SCoPEx Advisory Committee, 2020 — AC-Document 5, sec. Statement from the SCoPEx Advisory Committee)

This take on the governance process as a role model for future research is reinforced repeatedly throughout the online presence of both SCoPEx-scientists and AC-members. The quote above is just one example among many in which this notion is brought up.[92] It is quite common for AC-members and SCoPEx-scientists to position the work on governance being done within SCoPEx as beneficial for future research, as these three quotes illustrate:

> The SCoPEx team seeks to perform the experiments in a manner that exemplifies good governance by developing and implementing norms, mechanisms, and practices that can serve as useful templates for possible future solar geoengineering field experiments (Keutsch Group at Harvard, n.d. — IS-Document 3, sec. How will the experiment be governed?)

> The Committee shares a belief that societal engagement and review is a critical and essential piece of our work and one that we hope will serve as a model for others (SCoPEx Advisory Committee, n.d. — AC-Document 3[93], sec. Societal Engagement and Review)

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[92] Concretely, this framing appears in one form or another in AC-Document (1, 3, 18, 19, 24, 28, 29, 42, 43), IS-Document (1, 2, 3) and IS-Transcript (2, 5, 6).
[93] SCoPEx Advisory Committee. (n.d.). *Framework and Deliverables*. Retrieved November 12, 2022, from https://scopexac.com/framework-deliverables-and-timeline/

> Our hope is that the process we develop and feedback we receive will be adapted to engage various and distributed publics for future experiments and help shape future research governance. (SCoPEx Advisory Committee, 2021 — AC-Document 28, p. 7)

These and other passages within the analyzed documents show that AC-members and SCoPEx-scientists consider the work on governance that is being done within SCoPEx as something valuable that will be useful for future solar geoengineering research and beyond. This framing is completely absent from the documents of the critical stakeholders that have been analyzed for this thesis. Rather than being a role-model for the future, the SCoPEx governance process is criticized as being fundamentally flawed. The next section will give an overview over the arguments used within this framing.

5.2.2. Critique of the Advisory committee

Purpose of the AC and composition

The previous section showed that members of the AC and SCoPEx-scientists position the AC and its work as necessary for the experiment and beneficial for future research. This framing stands in stark contrast to the framing that critical stakeholders employ when they write or talk about the AC. For example, the composition of the AC has been criticized in the open letter by the Saami Council to the Swedish Government and the Swedish Space corporation; a document which is likely to have been decisive for the suspension of SCoPEx. In this letter, Saami representatives criticize several things about SCoPEx, one important point being the overrepresentation of US-based members within the AC:

> It is noteworthy that Harvard University considers it reasonable for a committee whose role it is to decide whether this controversial project should go ahead, to not have any representation from the intended host country, Sweden. Instead, the committee is composed of almost exclusively US citizens and/or residents. (Saami Council, 2021 — CS-Document 1194, p. 2)

Geoengineering Monitor provides a similar critique when they write:

> Convening an advisory committee with members appointed by a small group of scientists selected by Harvard University officials related to the project is in no way a path towards multilateral democratic governance of SAI. And it is far from an inclusive, democratic,

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94 Saami Council. (2021, February 24). *Letter to the SCoPEx Advisory Committee*. https://www.saamicouncil.net/news-archive/open-letter-requesting-cancellation-of-plans-for-geoengineering

> process with the communities and rights holders that would be affected by SAI. (Geoengineering Monitor, 2021 — CS-Document 12, p. 2)

The composition of the AC and its imbalance in terms of representation as well as how the AC has interacted with some of the critical stakeholders (5.2.3) has led to fierce criticism of the AC, with one organization — the HOME-campaign — even going as far as saying that they "denounce" the AC (Geoengineering Monitor, 2020 — CS-Document 19[95], para. 11).

Another interesting point of critique comes from the person interviewed for this thesis. They also criticize the composition of the AC and frame it as an instrument to prevent certain critique:

> These kind of high-profile outdoor experiments … also serve to create legitimation for a particular technology and I would say one also sees that in that they have established this Advisory Committee. So they try — and they are quite smart about this probably — to prevent and counteract particular demands or critique by somehow setting up this governance instrument that is, I don't know, supposedly independent from them and gives advice. So I think this is, and we have criticized this from the beginning, this is a self-selected committee and it is not at all diverse enough. This is a kind of self-governance that we definitely do not approve of. Instead, we advocate for international, multilateral so to say, democratic governance of these technologies (Interviewee 1, 2022 – CS-Interview 1)

What is interesting about the last two quotes is that that they do not only criticize the composition of the AC, but that they also provide a fundamental critique of the governance mode that the AC represents – namely project-based governance through a self-selected committee. This means that no matter how diverse the composition of the AC would be, concerns about the flaws of the governance mode itself would still remain. Critical stakeholders have their own set of suggestions when it comes to the proper governance of solar geoengineering, as the next section will show.

Suggestion for improvements of SAI-governance

Most strikingly, within the data material analyzed there is no indication that critical stakeholders are trying to improve upon the governance process that has been envisioned by SCoPEx by e.g. participating in the AC or suggesting amendments to the AC

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[95] Geoengineering Monitor. (2020, December 22). *SCoPEx in Sweden: First step down the slippery slope of risky solar geoengineering experiments*. https://www.geoengineeringmonitor.org/2020/12/scopex-in-sweden-first-step-down-the-slippery-slope-of-risky-solar-geoengineering-experiments/

governance process. Instead, they demand governance on another level; mainly within already existing institutions with democratic legitimacy such as the United Nations (UN). When asked about how they envision the governance process for a project like SCoPEx, Interviewee 1 puts it like this:

> Well, I think we would, and we is *Organization 1*[96] but also *Organization 2*, we would not set up a governance on the level of one single project at all, so that is already a basic problem … These are manually selected individuals … so it is impossible to somehow attain a democratic representation … and at the end of the day, these people are, and this is also a problem, they do not feel obligated to a constituency as far as I know … So I think the place in which we would imagine it would be the UN, so the multilateral system that we have. We also always said that and advocated for that and it is still the same. So we, so in the broader sense the organizations that are very critical of this, we are not at all against governance to be frank, rather the opposite. But we want a strong restrictive governance which can also be enforced because it is under the UN and concretely relating to solar geoengineering definitely an international ban (Interviewee 1, 2022 – CS-Interview 1)

The interviewee acknowledges that governance processes within the UN have their own set of problems but underlines that they still think that governance of solar geoengineering within the UN would be better than project-based governance like in the case of SCoPEx. One reason that they mention for this is that the UN has mechanisms in place that account for groups such as indigenous people in a better way:

> But there is the established practice that there are constituencies in the UN. I mean they are not even close to being considered enough, but there is an indigenous caucus, there is a women's group, there are so to say within the different processes there are these organized groups of interest which account for civil society and different rightsholders and different groups somehow (Interviewee 1, 2022 – CS-Interview 1)

Besides this call for setting up governance at a multilateral level, the most widespread demand of critical stakeholders in terms of governance is an international ban of solar geoengineering (CS-Interview 1, CS-Document 1, 3, 10, 12, 21, 24, 25, 26, 27, 34)

5.2.3. Transparency

Transparency is such a dominant part of the online discussion of governance and the AC, that it needs to be dealt with in its own section. Transparency is a rather broad topic when it comes to the AC because it pertains to so many issues and there are many different opinions on what it should look like and what one should be transparent about.

[96] To hinder identification of the interviewed individual, names of organizations have been removed from the quotes.

This section aims to offer a short deep dive into some aspects of the SCoPEx-controversy that are related to transparency.

Transparency? Yes – but only to a certain degree

Transparency is a central part of the mission statement of the AC which is reiterated many times throughout different parts of their website. As a reminder: "The Committee's goal is to ensure that the SCoPEx project is undertaken in a transparent, responsible, and legitimate manner" (AC-Document 4, sec. Mission Statement).

Therefore, transparency is written about a lot on the ACs website and there are definitely cases and aspects in which they are very transparent. An example that stands out in this regard are the letter exchanges between them and the SCoPEx-scientists.[97] But also the selection process of the AC-members (5.2.1.) is an instance in which the publicly available information seems to give a good insight into the internal processes of the research project. Additionally, just the fact that the AC is running a website that is still being updated can be seen as an effort of transparency.

However, it seems like the core issue with transparency in the case of SCoPEx and the AC is that it is only pursued to a certain extent. A good example to illustrate this is the exchange of open letters between the AC and the SCoPEx scientists about the financial review of the SCoPEx-project (AC-Document 34, 35, 36, 37). The AC describes the financial review like this:

> The Advisory Committee has worked with the SCoPEx Research Team to conduct a review of the project's funding sources to ensure transparency and public disclosure of all funding information. (SCoPEx Advisory Committee, n.d. – AC-Document 3)

Alone the fact that this exchange is happening via open letters is an effort to be transparent about financial aspects of the project. Some key questions that one might have (e.g. Who provides the funding?) are addressed within these exchanges, but other key questions (e.g. Who provides how much funding? What is the overall funding for the project?) remain inaccessible to the public, referring to the privacy of the donors. Information about level of support by the individual donors and overall funding has been communicated to the AC, but was not released publicly (AC-Document 35).

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[97]This includes the letters about the financial review that will be covered in this section (AC-Document 34, 35, 36, 37), but also correspondences on exchanges about the planned platform launch (AC-Document 39, 40, 41) or the engineering and safety review (AC-Document 30, 31, 32, 33).

This example shows very well how there are different degrees of transparency. Are there efforts by the AC and the SCoPEx-scientists to be transparent? Yes definitely. Does the AC and SCoPEx disclose "all funding information" like they claim in the quote above (AC-Document 3)? Definitely not, because who is funding how much and what is the overall funding is an essential part of the funding information and this information is not made available to the public. Like the next section will show, these inconsistencies in processes related to transparency also appear elsewhere and have been cause for critical stakeholders to cast doubt on whether the SCoPEx-scientists and AC-members really mean to be transparent about the research project.

Lack of transparency – Interactions between AC and critical stakeholders

As we have seen, the interactions between the AC and SCoPEx-scientists are quite well documented on the website of the AC since a part of their communication took place via publicly accessible open letters. However, the interactions between the AC and the critical stakeholders are something that happened mostly behind the scenes away from the public and was only described in the interview that I conducted for this thesis and very few documents within the analyzed material of the critical stakeholders.

At this point it is worth noting that in general the AC is not really picked out as a central theme within the accounts of the critical stakeholders. The AC is only discussed in relatively few of the accounts that have been analyzed; contributions of critical stakeholders tend to focus more on the experiment and especially on discussions of SAI in general. But the AC does get mentioned at certain points and it becomes quite clear how some of the critical stakeholders think about the committee.

An example that stands out in this regard is the statement by the Hands Off Mother Earth (HOME) campaign that has been published on Geoengineering Monitor (CS-Document 16[98]). In this statement, the authors mention an open letter signed by 40 organizations which they sent to each member of the AC in August 2019. In this letter, the signatories acknowledge that the AC wants to "contribute to a consideration of some of the global dimensions of this project", but they also state that "it should be clear that an appointed body cannot replace global, democratic and transparent governance of a geoengineering project that has far-reaching implications" (CS-Document 29, para. 3). According to the HOME-campaign, the AC never responded to this open letter:

[98] Geoengineering Monitor. (2020, July 31). *No to Solar Geoengineering and Meaningless participation!* https://www.geoengineeringmonitor.org/2020/07/no-to-solar-geoengineering-and-meaningless-participation/

> The Committee never responded to this letter, and instead, they are now calling for comments on the project to be sent to them in a process that totally lacks transparency – incredibly, only the committee will see the comments! We consider this a mockery of participation, and a clear step towards legitimating the project. We therefore refuse to participate in this charade. (Geoengineering Monitor, 2020 – CS-Document 16, para. 9)

A similar experience is also depicted by the critical stakeholder who has been interviewed for this thesis. Although they did not interact with the AC directly, they worked together closely with other people and organizations who have tried to. They describe the experience of these actors like this:

> Well and so to say the interaction that Organization 3, well it is interaction slash non-interaction somehow, I don't know in detail, I can't reconstruct exactly how this went off so to say who contacted who and responded or not, but we always heard that they [the AC] primarily did not respond to being contacted (Interviewee 1, 2022 – CS-Interview 1)

Another quote that is interesting in context of discussions about lack of transparency within the AC is one point of their operating guidelines. In there they write that: "Individual member opinions concerning SCoPEx or the work of the Committee should not be conveyed on social media or to the press until the work of the Committee is complete" (AC-Document 42, p. 13). In other contexts, it would not be especially noteworthy that a member of an organization is not allowed to speak about internal processes during their time within the organization. But given the ACs plentiful claims that transparency is such an important and central part of their work, this point of the operating guideline does evoke the impression of being another inconsistency in the proclaimed transparency of the AC.

5.3. Postcolonial dimensions

> If we look at who is funding and who is researching, this is definitely a Northern project. But the most important thing on why this is a Northern project is that geoengineering is a way of perpetuating the system we already are in. (Geoengineering Monitor, 2020 – CS-Document 17, para. 8)

As has been shown in the State of the Art, the discussion about SAI is intertwined with a wide range of postcolonial issues (2.4). This tendency in the scientific discourse also transfers to the empirical context of SCoPEx. Although postcolonial issues are given a lot more attention within the data material of the critical stakeholders, they also do appear in the accounts of the AC and the SCoPEx-scientists.

For example, David Keith frequently brings up global inequality in the sense that people in the Global South are and will be more affected by the consequences of climate change

(IS-Transcript 1). Building upon this framing, he positions SAI as a technology that would especially benefit "the poorest in the world" (IS-Transcript 3). As Keith puts it in an interview: "a world with solar geoengineering might be a world with less inequality, quite literally, than a world without" (IS-Transcript 3).

It might be no big surprise that critical stakeholders disagree with this take on SAI. In an interview with *Stop Solar Geo,* Raymond Pierrehumbert — a geophysicist who has repeatedly voiced his opposition of SAI — disagrees with the framing above and claims that it is inadequate:

> I think you only have to look at the example of Harvard's attempted SCoPEx experiment on Saami lands in Northern Sweden, where they didn't even feel the need to consult the Sami Council to see how they actually felt about having this kind of experiment done in their territory. You only have to look that far to see that the notion that solar geoengineering would be used for the benefit of the poor and the unrepresented in the world is just an excuse. (Raymond Pierrehumbert, 2021 – CS-Document 6[99], para. 14)

Within the website of the AC, postcolonial issues mainly come up in the document about their proposed engagement process (AC-Document 28):

> The Advisory Committee and the experimental team agree that any decision to utilize solar geoengineering should be based on an intentional, deliberative process that is inclusive (especially of the Global South and of those people who are likely to be most impacted by climate change or solar geoengineering) (AC-Document 28, p. 2)

Like in the accounts of David Keith, postcolonial dimensions are put in relation with deployment of SAI here. But there are also instances in which the AC highlights possible biases when it comes to how the research community working on SAI is constituted — something that is also relevant when it comes to postcolonial issues:

> An extremely important consideration is that currently the people with the capability to do the research don't currently represent, and might not take into the account, the interests of the people who are most likely to be impacted by climate change and solar geoengineering. (SCoPEx Advisory Committee, 2021 – AC-Document 28, p. 2)

Although it is not made explicit in this quote, this consideration addresses one of the key concerns that critical stakeholders have voiced: Namely that research on SAI and solar geoengineering in general is dominated by researchers from the Global North (CS-

[99] Stop Solar Geo. (2021, June 1). *What's wrong with 'it's just about research'?* https://stopsolargeo.org/?page_id=253

Document 15, 17, 26[100]). Another indication that the AC has this field of topic on their radar can be found in a call for contributions on their webpage in which they pose questions such as "What can be done to invite more public input from citizens in the Global South?" or "How do we ensure processes for public deliberation don't inherit or perpetuate systemic racism and colonialism?" (AC-Document 7[101], sec. Open Call for AGU Fall Meeting Abstracts).

While reading through these questions evoke the impression that members of the AC are really trying to grapple with these topics, many of the critical stakeholders are not convinced that this is the case and argue that postcolonial power relations are omnipresent in how the SCoPEx-project is organized. For example, when Interviewee 1 was asked about whether they agree with the critics of SCoPEx that locate the project within postcolonial power dynamics, they said:

> Yes totally, well actually from start to finish. So starting from the original I don't know money of [Bill] Gates that flowed into the project as startup funding somehow, so the question of who is pushing the funding, who is pushing such a project, where does it come from, this is simply so clear … at which university is this, where does this research take place? In Harvard and this is only somehow symptomatic for other universities in the Global North and especially the USA (Interviewee 1, 2022 – CS-Interview 1)

Pierrehumbert — whose interview has already been quoted at the beginning of this section — is another critical stakeholder who mentions SCoPEx specifically and casts doubt on their intentions of wanting to help the Global South with their technology. He claims that SAI serves mainly the interests of people in the Global North:

> When has, for example, the Global South ever been allowed a strong voice in matters that affect them? If it comes to a decision about what climate is best for a banker in New York or the Nigerian or Somalian farmer, you know that it's the interests of the New York or Frankfurt or Paris or London Banker that's going to take primacy. Really, solar geoengineering is just another tool that the rich world can use to clobber the Global South and other people who's voices just never get adequately taken into account. (Raymond Pierrehumbert, 2021 – CS-Document 6, para. 15)

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[100] Geoengineering Monitor. (2022, May 2). *Geoengineering Supporters Plan to Set up a New Climate Overshoot Commission*. https://www.geoengineeringmonitor.org/2022/05/geoengineering-supporters-plan-to-set-up-a-new-climate-overshoot-commission/

[101] SCoPEx Advisory Committee. (2022). *July 2022 Update*. https://scopexac.com/july-2022-update/

Within the other data material that has been analyzed for this thesis, critical stakeholders who bring up postcolonial issues do not refer to SCoPEx directly, but rather to SAI in general. One of the main arguments that is repeatedly brought up in this context is the assumption that the employment of SAI would disproportionately affect people in the Global South in a negative way (CS-Document 12, 16, 17, 29). Examples for this are changes in the monsoon patterns in Asia (CS-Document 12) or an increase in droughts in Africa (CS-Document 29). In one contribution it is also argued that livelihoods that are more present in the Global South (such as small artisan fisheries, pastoralists, or peasants) which are in a close relationship with ecosystems would be more directly affected by supposed weather changes that would result from employing SAI (CS-Document 17).

But the focus of the critical voices is not only about actual geophysical consequences of employing SAI — like monsoon patterns or droughts — but also on societal and political implications of having SAI available as a technology. A central theme here is the deployment of SAI and its connection to issues of power and inequality. For example, one critical stakeholder suggests that "Northern researchers" have the power of deciding about when, for how long and to what extent SAI is needed:

> They define what is an emergency, how long this will last, what will be the measures we need. We're exposed to this all the time in the geoengineering discourse … In the geoengineers' mentality, they are not thinking that people in the South and governments in the South may want to do something completely different, even if facing an emergency. (Silvia Ribeiro, 2020 – CS-Document 17)

Lili Fuhr — a former expert for international politics at a German NGO — takes the same line when she writes that: "[Geoengineering] would introduce a power imbalance between those who control the thermostat and key infrastructures and those who do not." (CS-Document 1, para. 3). The key concern that emerges from these two quotes is that actors in the Global South would have very little say in whether SAI would be deployed or not. In reference to the framing that the Global South would be disproportionally affected by the geophysical consequences of employing SAI, this is framed as particularly problematic (CS-Document 17).

5.4. Public engagement

One of the most crucial topics within the debate about SCoPEx is public engagement. It is brought up most frequently within the data material of the AC, followed (albeit with a large gap) by the SCoPEx-scientists. Comparatively, critical stakeholders do not raise the issue that often.[102] It is one of the few topics within SCoPEx in which initially one can find broad agreement among all stakeholders. As this chapter will show, AC-members, SCoPEx-scientists, and critical stakeholders alike all argue that public engagement should be an essential part of solar geoengineering research. However, besides this agreement that public engagement should take place, there is also wide disagreement as soon as one goes into the details of what public engagement is supposed to mean and what it needs to do. This section will show how AC-members (5.4.1), SCoPEx-scientists (5.4.2) and critical stakeholders (5.4.3) publicly express their takes and expectations of public engagement within the debate about SCoPEx.

5.4.1. Public engagement from the standpoint of the AC

Public engagement envisioned by the AC – A balancing act between local and global

Public engagement plays a central role within the website of the AC. Often also referred to as *societal engagement* or *stakeholder engagement*, it is among one of the most prominent topics within the accounts of the AC. The most relevant document in the data material of the AC in terms of public engagement has been published on their website within the section *societal review* (AC-Document 25[103]) and is called *Proposed Engagement Process for SCoPEx* (AC-Document 28). In this document and in other places, the AC lays out what they intend to happen within the public engagement process that is partly facilitated by them.

After the AC recommended to suspend the experiment in Sweden, the SCoPEx scientists followed suit and announced that they would suspend the experiment for the time being. According to their website, the AC is still planning to conduct a public engagement process in Sweden, even though SCoPEx has been suspended. In fact, they frame public engagement as a prerequisite for the continuation of the experiment:

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[102] Just to give an idea about the scale: In MAXQDA®, I assigned the code "Public Engagement" a total of 105 times. 75 times within the data material of the AC; 20 times in the data material of SCoPEX-scientists and 10 times in the data material of the critical stakeholders.
[103] SCoPEx Advisory Committee. (2022). *Societal Review*. https://scopexac.com/societal-review/

> the SCoPEx Advisory Committee is recommending that societal engagement should occur in Sweden before any SCoPEx research is conducted in the country … The Committee has recommended to Harvard and the research team that any equipment test flights in Sweden need to be suspended until the Committee can make a final recommendation about those flights based on a robust and inclusive public engagement in Sweden (SCoPEx Advisory Committee, 2021 – AC-Document 12[104], para. 1)

So, what is this public engagement process that the AC is suggesting? Basically, the public engagement process envisioned by the AC is two-fold: On the one hand there is the engagement with local people in the direct vicinity of the envisioned experiment and on the other hand there is the global dimension of the implications of that experiment:

> An independent engagement facilitator will work with the research team to organize and conduct local engagement activities … The engagement process will also include a trusted, local partner to serve as a convener and host for the above work. (SCoPEx Advisory Committee, 2022 – AC-Document 27[105], sec. Independent Engagement Facilitator and Local Partner(s))

> The Committee will supplement this local engagement with engaging and gathering input from members of the global public who reside outside of the region of the experiment. (SCoPEx Advisory Committee, 2022 – AC-Document 28, p. 6)

The AC frequently underlines the importance of including the local population into the decision about whether to conduct small-scale experiments or not. For example, they plan to design a briefing book which will lay out risks and benefits of the experiment and is supposed to serve as a basis for discussion (AC-Document 28, p.5). Another thing that they plan are *deliberative dialogues* with the local population. "In these dialogues, members of the stakeholder groups will offer their perspectives about the SCoPEx experiment. As stated previously, these dialogues will also consult the participants on ideal research governance processes for future outdoor experiments." (AC-Document 28, p. 6).

Processes like these are targeted at the local population in the vicinity of the planned experiment, but they are not always clearly demarcated from more global dimensions of the public engagement process. For instance, the AC describes their public engagement

[104] SCoPEx Advisory Committee. (2021). *March 31, 2021*. https://scopexac.com/march-31-2021/
[105] SCoPEx Advisory Committee. (2022). *Guidance on Local Engagement*. https://scopexac.com/guidance-on-local-engagement/

process with the local population as a template for future engagement activities that might take place on a larger scale:

> Our intent with this process is not to engage all local stakeholders in the larger issues of solar geoengineering research or deployment, but to investigate a process for engagement around this research that can be used in multiple places to engage a larger, more globally representative, set of publics. (SCoPEx Advisory Committee, 2022 – AC-Document 28, p. 4)

This framing of *the local informing the global* is sometimes also turned around when the AC writes that their consultation with local publics will be informed by a "global perspective" (AC-Document 42, p. 10; also appears in AC-Document 43, p. 5). However, this claim is not dealt with in more detail, and it remains unclear what exactly is meant with this.

For the global aspect of the engagement process, the AC plans to hire another organization which will "support a global societal engagement process" (AC-Document 9[106], sec. Global Societal Engagement). Results from that global engagement process in turn will be examined by the AC itself and taken as a basis to make a recommendation about further courses of action to the SCoPEx-scientists. At the point of writing (May 2023), no details about that other organization or about what exactly such a global societal engagement process would entail were available on the website of the AC or elsewhere.

(Unwanted?) Extension of the public engagement process

Originally, the public engagement process of the AC was intended to only focus on the part of the experiment in which particles would be released, but not on the platform test.[107] However, after the public criticisms of SCoPEx and the decision to suspend the experiment in Sweden, the AC adapted this approach and included the platform test into the public engagement process:

> Based on public input the Committee has decided to expand the societal review to encompass the equipment test flights in addition to the particle release flights. (SCoPEx Advisory Committee, 2021 –AC-Document 12[108], para. 3)

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[106] SCoPEx Advisory Committee. (2021). *November 2021 Update*. https://scopexac.com/november-2022-update/
[107] The division of the research project in two phases — the platform test and release of particles — is explained in section 4.1.
[108] SCoPEx Advisory Committee. (2021). *March 31, 2021*. https://scopexac.com/march-31-2021/

It cannot be determined for certain with the data available, but the extension of the public engagement process to include the platform test is likely to have been a direct reaction to the open letter by the Saami council that was published one month before. In that letter, the authors write that:

> The first flight's direct purpose to enable release of particles in a later test can not be treated in isolation to SCoPEx overall intentions. We request the Advisory Committee to ensure that SCoPEx does not continue pursuing such hollow claims, but instead treat the test flight as integral to the overall goal of SCoPEX. (Saami Council, 2021 – CS-Document 11, p. 2)

Although the Saami Council did not demand an extension of the public engagement process onto the platform test –in fact they state quite clearly in the letter that they want the platform test to be cancelled– the AC seems to have taken the demand of the Saami Council to treat the platform test as integral to the overall experiment as a reason to extend their public engagement process onto that platform test.

External engagement experts and deliberative dialogues

In the following I am going to go more into detail about how the AC envisions the public engagement process to happen. First and foremost, it is important to note that the AC is not going to carry out the public engagement process all by itself. Instead, the AC suggests that the SCoPEx scientists hire one or several public engagement experts that would mostly take over this process (AC-Document 27). At the point of writing, this process was still ongoing and it was neither clear who those experts are going to be or when this process will start. It is also important to note that the suggestion to hire external public engagement experts to carry out this process has been around well before the decision to suspend SCoPEx (e.g. in AC-Document 28). However, details on what the requirements for these engagement experts are and what exactly their tasks will be have only been published on the website of the AC much later – 1 ½ years after the decision to suspend SCoPEx has been made (AC-Document 27). The main task of the hired engagement experts would be to design, carry out and report about the deliberative dialogues, which essentially are a series of workshops with local stakeholders (AC-Document 27).

Although the material offered on the website is rather fuzzy on the details of the public engagement process, it does give the reader a rough impression of what the AC is planning. Besides the booklet mentioned earlier, the deliberative dialogues are probably the most central measures that are suggested by the AC. In a section called *Framing the dialogue*, the AC writes that in cooperation with the externally hired team of public

engagement experts, they will design questions for the dialogues that on the one hand "prompt consideration of the multiple dimensions of SCoPEx, including consideration of any known and potential risks to local communities and ecosystems" and on the other hand "focus on what ideal research governance for outdoor experiments might look like" (AC-Document 28, p. 5).

The dialogues itself would be led by the external engagement team and are described like this:

> Using the briefing book as the reference source, the team will lead and facilitate deliberative dialogues. In these dialogues, members of the stakeholder groups will offer their perspectives about the SCoPEx experiment. As stated previously, these dialogues will also consult the participants on ideal research governance processes for future outdoor experiments. The external team will subsequently prepare an analysis and summary of the dialogue, and a synthesis of the main points raised. (SCoPEx Advisory Committee, 2021 – AC-Document 28, p. 6)

At this point in time, it is hard to tell whether these deliberative dialogues will take place in Sweden or not. Back when the AC announced that they recommend to suspend the experiment in Sweden, they also stated that they only would recommend the continuation of the experiment once robust public engagement in Sweden has concluded (AC-Document 12). So, the last available information on the location of public engagement does insinuate that it will take place in Sweden. However, at the time of writing, more than two years have passed since then and there has been no indication that this public engagement is taking place in Sweden. The description of the deliberative dialogues and public engagement in general is not focused on Sweden (in fact, Sweden is not mentioned once in AC-Document 28), but it is held in a very general language and does not indicate where the public engagement and the experiment should take place. The same applies to more recent publications on the website of the AC, like the description of the requirements for the external engagement experts and the deliberative dialogues which has been published on the website in October 2022 (AC-Document 6[109]).

5.4.2. Public engagement from the standpoint of the SCoPEx-scientists

Within the data material of the scientists, public engagement is not such a central topic as within the data material of the AC. In most of their accounts, SCoPEx-scientists just

[109] SCoPEx Advisory Committee. (2022). *October 2022 Update*. https://scopexac.com/october-2022-update/

state that public engagement is important and that they have appointed the Advisory Committee for dealing extensively with these matters. They seldomly go into the details of what this public engagement is and what it needs to entail. However, there is one exception to this tendency and that is a document that appears on the AC-website (AC-Document 29) in which the SCoPEx-scientists comment on the public engagement process that has been suggested by the AC (AC-Document 28)[110]. Examining this document in more detail gives a good impression of how the SCoPEx-scientists[111] make sense of public engagement.

The SCoPEx-scientists start their comment off by emphasizing that they consider public engagement to be an important undertaking. They write that they "believe deliberative public engagement is essential for developing an agenda for solar geoengineering research." (AC-Document 29, p. 1) and clarify repeatedly that they think it is important to include the public into discussions of solar geoengineering research. However, they also point out in this context that it is "important to maintain a distinction between research and deployment during these discussions (AC-Document 29, p. 1) and frame solar geoengineering research as something that does not automatically lead to deployment, but is much more about delivering information which is essential to make a decision about deployment.

This lack of a strong enough distinction between issues concerning deployment and issues concerning solar geoengineering research seems to be a significant topic for the SCoPEx-scientists, since their response to the AC regarding this topic is one of the very few instances in which they openly criticize something that the AC has suggested:

> The Committee's societal engagement process blurs the differences between research and deployment by tightly linking a debate about a specific small-scale experiment with no significant physical impact to big questions about the ultimate impacts of solar geoengineering … We do not believe that any one research project … can or should be able to answer these questions. Indeed, if every decision about solar geoengineering research must bear the weight of all future possibilities of potential solar geoengineering

[110] Very attentive readers might have noticed that the date (2020) of the response of the SCoPEx scientists (AC-Document 29) predates the date of the document (2021) that it is commenting on (AC-Document 28). It is unclear why this is the case, but as AC-Document 28 starts with the remark that it is a newly updated version from 2021, it might be that the comment of the scientists on the engagement process are based on an earlier version of the document that is not available anymore on the AC-website today.

[111] Although Frank Keutsch is the author of this open letter, I have treated the views that are articulated in this letter as the views of the SCoPEx-scientists, since the whole document is written in first person plural (We think, we believe, etc.). Even if not all the scientists within SCoPEx did participate in writing this piece, it is the project lead who is speaking on behalf of the SCoPEx-scientists.

> deployment, then no research can reasonably be conducted. Research would have to halt. This has not been the standard for most other areas of environmental research, and it should not be the burden for solar geoengineering research. (Frank Keutsch, 2020 – AC-Document 29, p. 2)

Similarly, the SCoPEx-scientists are wary of consulting the public about the details of the science of the experiment:

> just as it is not feasible or desirable for the public to answer all of the big questions related to solar geoengineering when evaluating SCoPEx, it is also not meaningful to ask the public detailed questions about the minutia of the experiment's science. (Frank Keutsch, 2020 – AC-Document 29, p. 2)

Throughout the document, the SCoPEx-scientists bring up several times that the public might need to be provided with some information in order to be able to participate well in the public engagement process, for example when they write that "some members of the public may not initially understand how experimental, laboratory, and modeling research are related, and would therefore benefit from learning how these different methods can inform one another." (AC-Document 29, p. 3). The public engagement process is thus also depicted as an opportunity to inform the public about solar geoengineering research.

Following this argumentation, the SCoPEx-scientists suggest that participants of the public engagement process should not be asked the *big questions* mentioned above, but should instead be supplied with "accurate and unbiased *background information* on all of the potential benefits, risks, and uncertainties of solar geoengineering, including those physical and societal" (AC-Document 29, p. 2). The rationale here is that while participants certainly should discuss these topics, they should not be expected to answer the big questions around solar geoengineering. Instead, they suggest that participants should focus more on the role of small-scale experiments for broader solar geoengineering research and its governance (AC-Document 29).

5.4.3. Public engagement from the standpoint of critical stakeholders

The most striking thing about the take of critical stakeholders on public engagement within the case of SCoPEX is the fact that it is almost not brought up at all. Within the whole data material analyzed for this thesis I could only find two instances in which critical stakeholders frame public engagement in the context of solar geoengineering as something that is important and desirable. One of them was articulated within the interview conducted for this thesis, the other on Geoengineering Monitor:

> I think that this would definitely be a prerequisite, that you have broad participation from this organized civil society, of these different groups with their different perspectives that they are somehow involved and accordingly this would have to be a multilateral process. (Interviewee 1, 2022 – CS-Interview 1)

> Legal, moral and Indigenous-rights obligations require the free, prior and informed consent of Indigenous Peoples from projects that could modify the land, water or air of their territories. Provisions for meaningful participation and consultation with all local communities that could be impacted by these projects must be assured. A public consultation by the Natural Environment Research Council (NERC) in the UK recently decided that a technology with implications for all should not be developed without consultation with all. We agree with this position. (Geoengineering Monitor, 2019 – CS-Document 29, para. 8)

While both accounts acknowledge the importance of public engagement processes in the context of solar geoengineering generally, they also both elsewhere explicitly criticize the public engagement process that has been in place for the SCoPEx-project. Most critical stakeholders seem to oppose the public engagement process that the AC has initiated because they do not find it purposeful or view the efforts of the AC as actually counteracting real public engagement.

One example for this can be found in a statement by the HOME-campaign which has been published on Geoengineering Monitor. They provide one of the harshest criticisms of the AC, as they doubt their intentions to work on public engagement at all, claiming that the real purpose of the AC is instead to prevent public engagement:

> The Advisory Committee serves as a cover-up to avoid any real and meaningful participation, democratic deliberation and critical perspectives from around the world, including from civil society and social movements (Geoengineering Monitor, 2020 – CS-Document 19, para. 9)

Apart from accounts like this, the AC and its public engagement process are mostly not even acknowledged within the public accounts of the critical stakeholders that have been analyzed for this thesis. Within the data material there is no account of people who are in general wary of the idea of SAI but praise the public engagement process that has been initiated by the SCoPEx team. Much more, reading through the few accounts that do mention the AC and its public engagement process evoke the impression that there is unequivocal resentment of this process among the critical stakeholders.

To illustrate this, it might be worth to go back to one interesting point in the history of the public engagement process initiated by the AC, namely when the AC issued a call for comments on their website. The interviewee for this thesis recalls:

> And there was a phase in which one could submit comments where one point of critique by us was that you could only hand things in in English and no other language … and the whole interface was in English and this is a thing which well within the UN for example it is totally clear that everything gets translated in six UN languages. So you see exactly how this looks in practice, who this includes and who it excludes (Interviewee 1, 2022 – CS-Interview 1)

As already spelled out earlier (5.2.3), this process of collecting comments is also criticized by actors from the HOME-campaign, who especially take issue with the fact that comments were not made public. They refer to the whole process as a "mockery of participation" (CS-Document 16, para. 9) and announce that they will not participate in further public engagement activities of the AC.

6. Discussion

In this section, I summarize and interpret what I consider to be the most important findings of this thesis. I do this in four different parts which are oriented along the four sub-research questions that I posed earlier (4.2). Rather than always trying to give the same space to each framing of the different stakeholders, I will use the discussion to go into the framings which I deem most interesting.[112] I start this section by going into how SCoPEx relates to SAI in general (6.1), followed by a critical assessment of the ACs work (6.2). Then, I reflect on postcolonial dimensions (6.3) and on the public engagement process carried out by the AC (6.4).

6.1. SCoPEx and its meaning for SAI in general

At its core, the debate about SCoPEx is also a debate about the worth, purpose and political implications of SAI experiments in general. As of May 2023, SCoPEx is the SAI-experiment that is seen by many as a pivotal point in the development trajectory of SAI-technology in general. Other attempts to experiment with SAI up to date (2.1.1) do not carry the same weight as SCoPEx does because they have been carried out by individuals who do not enjoy the same international reputation as the researchers at Harvard University.[113] With the institution of Harvard having such a high standing, SCoPEx has been and still is under the close watch of the public.

In an earlier part of this thesis, I have argued that SCoPEx needs to be put in relation with the past SAI-experiment SPICE (2.1.2), which was "a condensation point for controversy" (Stilgoe, 2016, p. 852). Since SCoPEx has evoked such a widespread response from critical stakeholders and media alike I think it is reasonable to claim that SCoPEx is just as much a condensation point for the debate about SAI in general like SPICE was. However, there are some important differences which set SCoPEx apart from SPICE. First and foremost, SCoPEx began a few years after SPICE had already been

[112] For the in-depth answers to the research questions and a more detailed insight into the framings of each actor group, please consult the corresponding sections within the results.
[113] Although it needs to be noted that it might be too early to tell how these events will further unfold and come to matter in the general discussion of SAI.

concluded – so SCoPEx-scientists had the opportunity to learn from how the events around SPICE unfolded. The researchers within SPICE intended to conduct a technical experiment and were surprised by how their project continued to develop into a *social experiment* (Stilgoe, 2015). SCoPEx on the other hand has been carefully conceptualized to manage the sociopolitical dimension of the experiment with the establishment of the SCoPEx Advisory Committee – even if it is reasonable to assume that this has not been the case from the very beginning of the project.[114] SCoPEx-scientists are well aware of the fact that SCoPEx is also (if not even mainly) a *social experiment*.

The second difference is the relation of the two projects to the deployment of SAI. SPICE had the explicit goal to learn about technical and economic aspects of SAI deployment. SCoPEx-scientists on the other hand repeatedly distance their project and their research in general from the deployment of SAI (5.1.1), despite the many instances in which they point towards potential positive effects of deploying SAI (IS-Transcript 1, 2, 3, 4). These frequent mentions of potential positive effects of SAI deployment might be part of what has led most critical stakeholders to attest the SCoPEx-scientists the intention to push the development of SAI – arguing that their research contributes to move the technology development of SAI further down the slippery slope towards deployment (5.1.2).

Another key topic within the discussion of SCoPEx and its relation to SAI is the meaning of evidence that would be produced within the experiment of the research project. Mirroring strands of the academic debate (2.3.1 and 2.3.3), SCoPEx-scientists claim that data generated within field experiments of SAI would enhance the capability of climate models to predict risks and benefits of eventual SAI deployment (IS-Document 3, IS-Transcript 4, AC-Document 30). This supposed reduction of uncertainty is framed as important for future decisionmakers, giving them better information when it comes to predicting the risks and benefits of eventual SAI-deployment (IS-Transcript 5). What is especially interesting about this is that SCoPEx-scientists depict this increase in information as vital to counteract overconfidence in SAI. They argue that current models might make SAI look too good and that having data from field experiments available might change this (IS-Document 3; IS-Transcript 5; AC-Document 38). This framing of SAI field experiments as potentially introducing more skepticism about SAI also needs

[114] From the data that was analysed for this thesis it can be concluded that the idea of establishing an Advisory Committee must have emerged sometime between 2014 and 2017. The issue of governance is only mentioned very briefly without going too much into detail in the paper which introduced SCoPEx (Dykema et al., 2014), but plans to set up an independent body for the review of governance structure were already articulated by the research team as early as 2017 (Temple, 2017).

to be seen as a part of the overall effort of SCoPEx-scientists to distance themselves and their actions from deliberately furthering the development of SAI (5.1.4).

As someone whose thinking is informed by STS-approaches, I am wary of the framing that more research can remove uncertainties in the case of such a far-reaching controversial technology as SAI. SAI is not only technically complicated because it operates at such a large scale (namely at the scale of the climate system), but its large scale also means that it is connected to manyfold sociopolitical questions. Rather than removing uncertainties, more research can just as well introduce new uncertainties, as Stilgoe has argued in his discussion of geoengineering:

> STS research has demonstrated that in many areas, research creates more questions than answers, expanding our uncertainty … We can imagine that given the social and political complexities of geoengineering, the range of uncertainties is likely to be ever-expanding. (Stilgoe, 2015, p. 5)

So, uncertainties around SAI will most certainly remain, no matter if SCoPEx or similar experiments like it are carried out or not. Governance of SAI will always have to operate with some residual uncertainty.

The last big topic that is connected to the general relation between SAI and SCoPEx is the question of whether SCoPEx represents a moral hazard.[115] One of the clearest tendencies that I could identify in the course of this thesis is that critical stakeholders are of the conviction that SCoPEx is an endeavor which aims to further the development of SAI and that as such it will have a negative impact on efforts to reduce greenhouse gas emissions (5.1.5). However, while there is no doubt about the existence of the moral hazard within the accounts of the critical stakeholders, the academic debate about the moral hazard of SAI shows that the question of its existence is still very much contested (2.2.1). SCoPEx-scientists hook on this uncertainty within the academic debate by simultaneously acknowledging the moral hazard of SAI as a potential problem (AC-Document 35; IS-Transcript 1, 4, 6) and relativizing its meaning for the concrete case of SCoPEx (AC-Document 29). Further, they write that they do not believe that any research project could possibly determine what a small-scale SAI experiment like SCoPEx would mean for the general development of SAI and the consequences of its potential deployment (AC-Document 29).

[115] The term *moral hazard* and the academic debate around it has been spelled out in detail in the State of the Art (2.2.1).

Critical stakeholders try to establish that outdoor experimentation of SAI is tightly linked and thus inseparable from the development and deployment of the technology. Their understanding of SAI aligns with that of scholars who have argued that SAI is an untestable technology (Hulme, 2014; Robock et al., 2010). SCoPEx-scientists try to do just the opposite: they mostly argue against the claim that small-scale experiments would contribute to the development and deployment of SAI. They frame SAI as something that can be tested and claim that we have a moral obligation to do so by conducting more research and outdoor experiments in particular (Horton & Keith, 2016; MacMynowski et al., 2011).

6.2. The SCoPEx Advisory Committee – a less-than-ideal governance mode?

The first entry in the "News & Updates"-Section of the ACs webpage dates back to July 2019 and is a statement from the then-chair of the AC Louise Bedsworth. In this statement, Bedsworth describes her goal for the work of the AC as follows: "My goal for our work is to provide a replicable model for conducting engaged and informed research on this critical and controversial issue" (AC-Document 18, para. 5). Since then, this goal of the AC to serve as a role-model for future research has been reiterated many times on different occasions by AC-members and SCoPEx-scientists alike (5.2.1). Almost four years later it seems appropriate to draw an interim résumé and ask: Has the AC achieved this goal thus far?

From the outside, it does not seem like it.[116] Critical stakeholders have criticized the AC and its work for being untransparent (5.2.3) and my own experience of interacting with the AC reinforces this impression (4.3.1). The refusal of the AC to talk about the ongoing process of the ACs work with interested parties and their apparent lack of interactions with critical stakeholders (5.2.3) would not infringe the credibility of the AC under different circumstances, but against the background that both transparency and public engagement are part of the mission statement of the AC (AC-Document 4), it does not shed a favorable light on the ability of the AC to live up to its promises. The decision to not allow committee members to talk about the ongoing process of the ACs work until it is complete (AC-Document 42) is a questionable choice for an organization that is supposed to facilitate a better interaction between a research project and the public – especially since the work of the AC has been going on for almost four years now and it is

[116] This thesis can only attempt to answer this question "from outside" and as such can only make limited statements about this. But to a certain extent it is still possible to assess the work of the AC from the outside with the extensive material available online.

still not communicated to the public for how long they envision to continue their work or what the future plans for SCoPEx are. As will be shown later in more detail, the public engagement process initiated by the AC is riddled with inconsistencies (6.4).

With the data available for this thesis, it can only be speculated why the governance process of the AC has been designed in the way that it has been designed. In the best case, the shortcomings mentioned above are owed to the fact that service on the AC is financially uncompensated for the individual members (AC-Document 42) and hence the AC-members are not able to take enough time and resources to give the attention to the governance process that it would need. In the worst case, these shortcomings point towards the AC not actually taking their proclaimed goals seriously because the AC has been strategically established to lend legitimation to SCoPEx (CS-Document 16).

Surely, the efforts of SCoPEx and its AC towards a process of governance and public engagement are preferrable to what other SAI-related endeavors such as Make Sunsets or SATAN (2.1.1) did – namely just going forward and releasing sulfur dioxide into the atmosphere without consulting the public at all. Nevertheless, critical stakeholders have raised doubts about whether a project-based governance approach such as the AC can do justice to a technology with global implications such as SAI (CS-Interview 1). The counter-suggestion that is articulated is to lift the governance of SAI-research to the level of multilateral institutions such as the UN (CS-Interview 1) and is also brought up in the academic discussion of SAI (Pasztor, 2021).

6.3. Postcolonial dimensions

Even though I could not pay as much attention to postcolonial dimensions of SCoPEx as I would have liked to due to limitations in the data gathered (3.2), they still do matter within SCoPEx and SAI-research more generally. SAI is a technology that can only be deployed globally and as such it would have consequences on a global scale. But at the same time, these consequences would not be the same for everyone, but rather vary between different regions (Baatz, 2016; Ricke et al., 2010). And this is just addressing the geophysical consequences of SAI. How well a country and its inhabitants can adapt to geophysical consequences of climate change or SAI is not only dependent on what these geophysical consequences are; it is also dependent on a complex range of socio-economic factors.[117] *Vulnerability* (O'Keefe et al., 1976) and *social resilience* (Keck & Sakdapolrak, 2013) are two helpful key terms in this regard that have been used

[117] A good impression of how individual countries might differ in their capability to respond to geophysical changes induced by climate change can be gathered in literature about adaptation to climate change. The contribution of Ober & Sakdapolrak (2020) is just one example for this.

conceptually to take "the naturalness out of natural disasters" (O'Keefe et al., 1976, p. 566) and draw our attention towards the socio-economic dimensions of how changes in the environment affect different societies.

Employing such a contingent understanding of how environmental changes affect societies is vital if one wants to approach SAI with a *postcolonial sensibility* (Anderson, 2015). However, the crux is that this insight can be used both to argue for and against SAI research. Horton & Keith (2016) argue that varying degrees of social resilience mean that we should do more research on SAI to protect the Global South from the worst consequences of climate change. Critical stakeholders on the other hand argue that SAI should not be researched because the consequences of its deployment would most likely have a more severe negative effect on the livelihoods of people in the Global South (5.3).

Another important part of SAI which is connected to postcolonial issues is the timing of its eventual deployment. Some scholars have looked at this from a legal perspective (Markusson et al., 2014), but it remains a difficult question precisely because the ideal time for a hypothetical deployment of solar geoengineering is so closely connected to global power dynamics. Who defines when the consequences of climate change are bad enough to take the risk of deploying SAI? Stephens and Surprise (2020) and critical stakeholders (CS-Document 1, 6, 17) have argued that it is most likely that the people and nation states who hold most power globally would make this decision.

These discussions are all about SAI in general, but since SCoPEx is discursively so tightly connected to SAI-deployment, they also matter for the case at hand. When it comes to SCoPEx specifically, SCoPEx-scientists and AC alike state that inclusion of people from the Global South into decisions about utilization of SAI is important to them (AC-Document 28). However, critical stakeholders have criticized that SCoPEx-scientists did not consult with the Saami Council or local stakeholders before the experiment was announced publicly (CS-Document 6, 11). Pierrehumbert argues that this lack of engagement in the case of SCoPEx exemplifies that researchers who push SAI-development do not care about engaging with underrepresented groups (CS-Document 6).

Looking at SCoPEx and SAI-research through the lens of postcolonial STS steers our attention towards the social orders that might be present therein (3.2). One of the most apparent characteristics of SCoPEX that relates to social order is the fact that is funded to a large extent by philanthropic donations (5.1.3). Another characteristic is the composition of the organizations which are part of SCoPEx. Earlier, I showed how critical stakeholders criticized the composition of the AC (5.2.2). A similar critique is also articulated towards SAI-researchers in general: Belter and Seidel (2013) and Biermann

and Möller (2019) have shown that researchers from the Global North are clearly overrepresented in the climate engineering research community. The SCoPEx-scientists are no exception to this tendency. There have been efforts to change the imbalance between research from the Global North and the Global South (The DEGREES Initiative, 2023), but similarly to the AC, they have been criticized for pushing SAI development under the disguise of inclusion (CS-Document 31, 33, 35, 36).

6.4. A bumpy public engagement process waiting to happen

Although AC-members and SCoPEx-scientists are not STS-scholars, they have also very much "inherited [public engagement] as *the problem*" (Delgado et al. 2011, p. 826). Carrying out real public engagement in a way that is meaningful to both scientists and the public(s) is by no means an easy task. But it becomes even more difficult in the case of research on technologies with global implications such as SAI. The question of "*Who* should be involved?" (Delgado et al., 2011, p. 828) is immensely difficult to answer in the case of SAI because "Everyone is a stakeholder" (United Nations Environment Programme, 2023, p. 4). AC-members have tried to account for this global dimension of SAI by conceptualizing their proposed public engagement process as both local and global (5.4.1). While they do supply a reasonably detailed outline of how they are planning to undertake the local engagement, the global dimension of the engagement process which they envision remains opaque or rather it has not been outlined yet in full detail.[118]

Critical stakeholders also acknowledge the global dimension of public engagement in the context of SAI by calling for international participation of local communities before going forward with small-scale outdoor SAI experiments (CS-Interview 1; CS-Document 29). But generally, public engagement as a topic is sparsely present within the accounts of the critical stakeholders. The public engagement process initiated by SCoPEx and its AC is mostly left unacknowledged and in the few instances in which it comes up, critical stakeholders either point to problematic aspects of it or frame it as a process which serves to prevent "real" public engagement (5.4.3). There seems to be an unequivocal rejection of the public engagement process initiated by the AC from then side of the critical stakeholders.

[118] As mentioned earlier (5.4.1), the AC plans to outsource this global engagement process to another organization. At the point of writing (May 2023), no details about that other organization or about what exactly such a global societal engagement process would entail were available on the website of the AC or elsewhere.

SCoPEx-scientists and AC-members want to start a conversation about the details of how SAI outdoor experimentation can be conducted safely and responsibly (5.4.1 and 5.4.2). Wanting to start such a conversation presupposes the assumption that safe outdoor experimentation of SAI *might* be possible. Critical stakeholders on the other hand have repeatedly made clear that they do not believe that SCoPEx can be conducted safely – mainly because doing so would allegedly put us on a *slippery slope* (5.1.2) in the development of a technology which in their opinion poses a *moral hazard* (2.2.1 and 5.1.5).

Another central question is "*Why* should [public engagement] be done?" (Delgado et al., 2011, p. 828). If one wants to get an insight into how the different stakeholders in the debate about SCoPEx answer this question, a good place to start is by examining one of the very few publicly visible disagreements between the SCoPEx-scientists and the AC-members. In its initial suggestion for the public engagement process, the AC frames issues around deployment of SAI as a vital part of public engagement exercises (AC-Document 28). In their response to this suggestion, SCoPEx-scientists voice their opposition of this take and argue that it is not purposeful for the public engagement process of SCoPEx to deal with the questions of deployment of SAI (AC-Document 29). Instead, they suggest that the focus of the public engagement exercises should lie mainly on questions around the governance of small-scale outdoor experiments related to SAI (AC-Document 29).[119]

As far as it can be determined with the material available online, the AC has mostly taken up the comments of the scientists in the final version of the proposed public engagement process. In the first draft of the proposed public engagement process that the scientists refer to in their feedback, the AC suggests that participants should discuss whether SAI represents a *moral hazard* or SAI-research a *slippery slope* (AC-Document 29). The SCoPEx-scientists criticize this, arguing that such questions could not possibly be answered within the public engagement process of SCoPEx (AC-Document 29). In the final version of the proposed public engagement process, both terms *moral hazard* and *slippery slope* do not appear anymore (AC-Document 28). By openly attempting –and seemingly succeeding– to shift the focus of the public engagement process away from questions of deployment of SAI towards the governance of small-scale SAI-experiments, the SCoPEx-scientists undertake yet another effort to disassociate themselves and SCoPEx from the deployment of SAI.

[119] A more detailed account of how the SCoPEx-scientists argue in this regard can be found in the results-section (5.4.2).

Now, it is neither unusual nor problematic that scientists give feedback on a public engagement process that concerns their own research project and that this feedback is also incorporated. One could also argue that the feedback of the SCoPEx-scientists makes sense and that the questions about the *moral hazard* and the *slippery slope* are indeed too big to be addressed within the scope of a public engagement process of one individual experiment. However, what makes this line of action so problematic is the fact that with it, SCoPEx-scientists –and the AC by following suit– detract from a rather dominant way of framing the experiment: namely that it cannot be treated separately from questions of deployment of SAI (2.2.1, 5.1.1, 5.1.2 and 5.1.5). This framing has been articulated repeatedly and clearly in public spaces with which the public engagement process is supposed to engage.

By arguing that the discussion of issues connected to deployment of SAI is not the "right" way to deal with SCoPEx in the public engagement process, the SCoPEx-scientists –and by taking up this feedback, also the AC– prioritize their interpretation over one which has already been articulated by parts of the public. It also insinuates that members of the public do not know how to discuss SCoPEx in the "right" way. With this, the SCoPEx-scientists and the AC demonstrate an understanding of the public engagement process which is not entirely based on a dialogue model (Trench, 2008), but rather on a understanding of the public which still has some remnants of the deficit model (Bucchi & Neresini, 2008) in it.[120] This dynamic lines up neatly with what Delgado et al. have written about public engagement exercises:

> "It has been argued that [public engagement] exercises commonly reproduce assumptions and consequences of the deficit model, whereby science still proceeds by excluding lay views instead of opening up for real dialogue." (Delgado et al., 2011, p. 827)

The decision to restrict the role of deployment in the public engagement process is not the only factor which evokes the impression that SCoPEx and its AC struggle to live up to the ideal of *opening up for real dialogue*. Not engaging with the Saami before the experiment (CS-Document 6, 11) and euphemistically referring to the vigorous resistance against the experiment as "public input" (AC-Document 12, para. 3); not talking about internal processes of the AC and its public engagement process to members of the public despite claims of transparency (AC-Document 42); not responding to open letters that have been sent to them and not publishing the comments that they collected at one point

[120] Both deficit and dialogue model have been explained in more detail in the Sensitizing Concepts (3.3).

of the project (CS-Document 16) – all these are courses of action which the AC took in their public engagement process which do not give the best impression.

A further, important point of critique is about how the AC indirectly responded to the open letter which called for a cancellation of the project (CS-Document 11). They advised the SCoPEx-scientists to suspend the project and expand the public engagement process to also include the platform test[121] – which the SCoPEx-scientists did. This is an instance of the public engagement process of SCoPEx which has been explicitly framed as disrespectful by critical stakeholders:

> Each time geoengineers promise to 'consult' better, deliberately missing the point that consultation does not equal consent. When communities and Indigenous people say no to planet-altering schemes being launched from their territories it is disrespectful to mishear that as 'needing more consultation'. No means no. Hands Off Mother Earth. (Jim Thomas[122], 2021 – CS-Document 39[123], para. 7)

Roughly 1 ½ years after the experiment was suspended, the AC published an update of their local engagement process on their website (AC-Document 27). What is noteworthy about this is that the history of SCoPEx and the significant resistance against it is not acknowledged at all in this document. The public engagement process is described very generically and is not context-specific – Sweden is not mentioned once. It is moments like these in the virtual presence of the AC which evoke the impression that the AC is just carrying on with their work in an unperturbed way.[124] What will come of the expansion of the public engagement process is still unclear at the point of writing (4.1). The budget of the AC has been renewed for 2023 (AC-Document 27[125]), so it is reasonable to assume that at the point of writing, the AC still plans to carry out its public engagement process in Sweden.

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[121] The division of SCoPEx into particle release flights and the platform test has been explained in section 4.1.
[122] This is a secondary quote, Jim Thomas has been quoted within CS-Document 39.
[123] ETC Group. (2021, April 1). *Saami, Swedes and civil society stop solar geoengineering trial balloon*. https://www.etcgroup.org/fr/node/6408?language=en
[124] Keep in mind that this is just the impression gathered from examining the data supplied on the website.
[125] SCoPEx Advisory Committee. (2022). *Guidance on Local Engagement*. https://scopexac.com/guidance-on-local-engagement/

7. Conclusion

With this thesis, I set out to provide a comprehensive overview of how SCoPEx-scientists, AC-members and critical stakeholders frame and shape the debate about the planned SAI outdoor experiment SCoPEx. Building upon the analysis of central websites, documents, selected YouTube-videos and one qualitative interview, I showed how in most cases, each actor group has their own way of depicting issues connected to SCoPEx and SAI. While the framings of SCoPEx-scientists and AC-members tend to align with each other, the framings of the critical stakeholders tend to argue in opposite directions of the SCoPEx-scientists and AC-members. However, I also showed that there are exceptions to this tendency. There are –albeit rare– aspects on which all actor groups agree on, like the fact that the reduction of greenhouse gases needs to be the number one priority in addressing climate change and that SAI can under no circumstances be a substitute for this measure (5.1.5).

Overall, this thesis has shown that like SPICE (2.1.2), SCoPEx is "a condensation point for controversy" (Stilgoe, 2016, p. 852). It laid out how there is severe disagreement about what the potential implications of carrying out SCoPEx would be. These disagreements are not about the direct geophysical impacts of carrying out SCoPEx. Instead, they are about what sociopolitical consequences the experiment and the evidence produced within it might have. While SCoPEx-scientists frame the evidence produced within the experiment as an opportunity to improve knowledge about SAI which would provide future decision makers with a better basis to decide about SAI-deployment, critical stakeholders claim that we already have all the evidence needed to decide against the deployment of SAI. Engaging in outdoor experimentation of SAI, critics argue, would make the deployment of SAI more likely in the future. Furthermore, critical stakeholders are convinced that carrying out SCoPEx and similar endeavors would pose a *moral hazard* (2.2.1 and 5.1.5); a take on SAI outdoor experimentation which SCoPEx-scientists acknowledge as a potentially relevant issue in general, while at the same time relativizing its significance for the concrete case of SCoPEx. Overall, all actors broach the issue of political dimensions of the scientific evidence produced; but they disagree about how that evidence would come to matter within political processes.

So, what can we learn from this case? Like other empirical contexts which have been studied by STS-scholars (Epstein, 1995), SCoPEx is a fascinating case which shows how in practice, science and experiments are connected to complex sociopolitical questions which in this case led the public(s) to question the authority of scientists and interfere with the plans which they had. The fact that SAI and SAI outdoor experimentation is deeply political should have become abundantly clear throughout this thesis. Having laid out the sociopolitical dimensions of SCoPEx, this thesis supplies yet another analysis of an empirical case which exemplifies how *technological determinism* (3.1) is an antiquated concept when it comes to making sense of controversial technologies. The debate about SCoPEx is symptomatic of the fact that SAI can never be a neutral technology; it will always be inextricable from sociopolitical issues.

I have argued that the notion of *anticipation* is a central one when it comes to solar geoengineering (3.1). Large chunks of the debate about SCoPEx are about anticipating future developments connected to SAI, such as the impact of SAI outdoor experiments on mitigation (5.1.5) or questions around the relation between SAI outdoor experimentation and deployment of SAI (5.1.2). Even SCoPEx itself is strongly connected to anticipation, since it is an effort to improve the capability of climate models to anticipate what the deployment of SAI would mean for the climate. At the first glance, the plan of the SCoPEx-scientists to carry out more science to produce more knowledge to anticipate better might seem like an unambiguous and desirable endeavor to most people. However, the debate around SCoPEx is an example of a case in which this process is anything but straightforward and takes on the controversiality of the technology itself. The efforts of the SCoPEx-scientists to anticipate better are contested and there is disagreement about what can and should be anticipated. Who should anticipate how and what? What kind of anticipation is preferrable? What do different kinds of anticipation mean for technology development? All these are relevant questions which show that it is not solely the anticipation of technologies itself which should be the subject of social scientific research; much more, research that deals with anticipation needs to engage critically with how different modes of anticipation are viewed and used by different actors within the controversy about a technology.

This thesis also showed that postcolonial dimensions are an important element of the debate about SCoPEx, SAI outdoor experimentation and SAI deployment. Due to the global nature of SAI, the scope of the discussion about its sociopolitical implications is also global in its scale. Global inequalities are used as an argumentative resource in different ways, depending on who talks about it. SCoPEx-scientists argue that the non-deployment of SAI is likely to negatively affect the most vulnerable countries the most.

Critical stakeholders, on the other hand, argue that the time and extent of SAI deployment would most likely be controlled by the countries that hold the most power globally, with only little consideration of the negative effects for the most vulnerable countries. Even if it is seldomly discussed explicitly within the debate about SCoPEx, the question of what a *postcolonial sensibility* (3.2) entails within the research and eventual deployment of SAI is just as contested as most other aspects in the debate about SAI.

Lastly, this thesis and the case that it deals with draws our attention to some central issues that can come up within public engagement processes. SCoPEx exemplifies how public engagement still must grapple with well-known problems such as the tension between global and local engagement or the problem of not just one public but several publics. The AC addresses these issues on their website (5.4.1), but since the public engagement process has not concluded at the time of writing (May 2023) and this thesis only engages with SCoPEx through data material available online, it is not possible to provide a verdict of how well the AC actually accounts for these issues. However, what can be derived from the material available online is the fact that SCoPEx-scientists and AC-members struggle to conduct a public engagement process which lives up to the basic tenets of the dialogue model. The public engagement process initiated by SCoPEx and its AC seems inconsistent and shows clear signs of being at least partly based on a deficit model of the public (6.4). This shows that just because researchers claim that public engagement is important to them, it does not automatically mean that they have a sound public engagement process in place. Especially in the case of controversial technologies like SAI, public engagement activities need to be scrutinized thoroughly regarding whether they do not actually operate with (remnants of) the deficit model. The inconsistencies in the public engagement process of SCoPEx should be a reminder for STS-scholars to be vigilant when it comes to public engagement processes being initiated in the context of controversial technologies. There is always the possibility that a public engagement process is carried out with the intention to legitimize the development of a controversial technology.

It is important to consider the limitations of this thesis. One of the key limitations are the different kinds of data material which have been drawn upon to analyze the framings of the different actor groups (4.3.2). I set out to do this research with the goal to treat the perspectives of all involved actor groups symmetrically and an important part of this was to have the same kind of data material for everyone. However, due to the difficulties in the data collection process (4.3.1), the data turned out to be rather heterogenous. Not having the same kind of data for everyone might have infringed my capability to treat the perspectives of all actors in the same way. Especially the lack of personal interaction in

the form of interviews with the SCoPEx-scientists and AC-members are a problem in this regard. In a qualitative interview, actors can go into detail, respond to criticisms, and generally offer a deeper insight into their motives and thoughts. If, for example, I am critical of a way of arguing by a SCoPEx-scientist and confront them with a question that points to this criticism, they can respond to this and share their thoughts. When analyzing websites, documents or videos, there is not this kind of reflexivity. Furthermore, the data material which has been used to represent the views of the SCoPEx-scientists mainly represents the views of two people: Frank Keutsch and David Keith. The perspective of other scientists involved in SCoPEx might be underrepresented.

This thesis supplied an overview of the debate around SCoPEx with a focus on the context of the planned experiment in Sweden. It is mainly constrained to the time between late 2020 and early 2023. The early history of the project and especially the previous attempts of conducting the experiment in Arizona and New Mexico have only been covered superficially (4.1). Since SCoPEx and its public engagement process is still ongoing at the point of writing, there might also be future developments which cannot be considered here. Scrutinizing the past and the future of SCoPEx seems like a worthwhile endeavor for social scientists who want to contribute to a more thorough understanding of the case at hand and through it, a better understanding of SAI outdoor experimentation and its sociopolitical implications.

Besides SCoPEx, there are other interesting cases which appeared within the research for this thesis that would justify research projects of a similar or even larger scope than this one. Make Sunsets (2023) is a noteworthy case of how individuals outside of scientific and political institutions interpret research around SAI as a cause to take actions towards the deployment of SAI. It raises interesting questions about how to deal with such events both in research and governance. The DEGREES Initiative (2023) is another institution connected to SAI which tries to further SAI research in the Global South by funding research projects. Examining how different stakeholders such as the scientists involved in research projects funded by it or the employees of the DEGREES Initiative perceive matters of SAI and global inequalities would be a fascinating endeavor, especially if related to literature from postcolonial theory. Finally, this thesis has shown how public engagement is a central topic in the context of SCoPEx and SAI outdoor experimentation in general. It would be enriching to expand upon this insight by analyzing how issues around public engagement have mattered differently in different solar geoengineering related projects and systematically relate that comparison to the broader academic discussion about public engagement.

8. Appendix

8.1. Data material

8.1.1. Critical Stakeholders (CS)

Documents that have been used to get an insight into the perspective of Critical Stakeholders consist of one interview that has been carried out for this thesis, blogposts of various organizations and particularly the News-Section of the Website *Geoengineering Monitor*. End of data collection: May 2023.

CS-Document 1	Fuhr, L. (2019, March 11). Geoengineering at UNEA-4: Why the SDGs Require a Governance Debate Based on Precaution, Rights and Fairness. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2019/03/11/geoengineering-unea-4-why-sdgs-require-governance-debate-based-precaution-rights-and
CS-Document 2	Unmüßig, B. (2017, October 17). The geoengineering fallacy. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2017/10/17/geoengineering-fallacy
CS-Document 3	Currie, D. (2018, January 29). Governing the Big Bad Fix? What to do about geoengineering. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2018/01/29/governing-big-bad-fix-what-do-about-geoengineering
CS-Document 4	Nansen, K. (2019, September 13). Who Benefits from False Climate Solutions? *Project Syndicate*. https://www.project-syndicate.org/commentary/climate-change-geoengineering-false-solution-by-karin-nansen-2019-09
CS-Document 5	Muffett, C. (2019, February 18). Geoengineering is a dangerous distraction. *Heinrich-Böll-Stiftung*. https://www.boell.de/en/2019/02/18/geoengineering-dangerous-distraction

CS-Document 6	Stop Solar Geo. (2021, June 1). *What's wrong with 'it's just about research'?* https://stopsolargeo.org/?page_id=253
CS-Document 7	Stop Solar Geo. (n.d.). *Warnings panels*. Retrieved November 16, 2022, from https://stopsolargeo.org/?page_id=431
CS-Document 8	Stop Solar Geo. (n.d.). *Home*. Retrieved November 16, 2022, from https://stopsolargeo.org/
CS-Document 9	Stop Solar Geo. (n.d.). *The defeat of the SCoPEx projects plans for Sápmi, Northern Sweden*. Retrieved November 16, 2022, from https://stopsolargeo.org/
CS-Document 10	Solar Geoengineering Non-Use Agreement. (n.d.). *Open Letter*. Retrieved November 16, 2022, from https://www.solargeoeng.org/wp-content/library/downloads/open-letters/The-Case-for-a-Solar-Geoengineering-Non-use-Agreement_Open-Letter_EN_211221.pdf
CS-Document 11	Henriksen, C., Sandahl, J., Sundström, M., & Wronski, I. (2021, February 24). *Regarding SCoPEx plans for test flights at the Swedish Space Corporation in Kiruna*. https://www.saamicouncil.net/news-archive/open-letter-requesting-cancellation-of-plans-for-geoengineering
CS-Document 12	Geoengineering Monitor. (2021, February 7). *Current Geoengineering Attempts Briefing: SCoPEx 2021*. https://www.geoengineeringmonitor.org/2021/02/current-geoengineering-attempts-briefing-scopex-2021/
CS-Document 13	Geoengineering Monitor. (2018, March 7). *Chemtrails: Distrust Drives Speculation*. https://www.geoengineeringmonitor.org/chemtrails/
CS-Document 14	Geoengineering Monitor. (2014, November 28). *Reasons to Oppose Geoengineering*. https://www.geoengineeringmonitor.org/reasons-to-oppose/
CS-Document 15	Jay, D. (2020, July 8). Hidden Injustices: Interview with Dr. Jennie Stephens. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2020/07/hidden-injustices-interview-with-dr-jennie-stephens/

CS-Document 16	Geoengineering Monitor. (2020, July 31). *No to Solar Geoengineering and Meaningless participation!* https://www.geoengineeringmonitor.org/2020/07/no-to-solar-geoengineering-and-meaningless-participation/
CS-Document 17	Geoengineering Monitor. (2020, October 27). *Geoengineering in the Global South (ETC Podcast).* https://www.geoengineeringmonitor.org/2020/10/geoengineering-in-the-global-south-etc-podcast/
CS-Document 18	Geoengineering Monitor. (2020, December 2). *Geoengineering and Decolonization (ETC Podcast).* https://www.geoengineeringmonitor.org/2020/12/geoengineering-and-decolonization/
CS-Document 19	Geoengineering Monitor. (2020, December 22). *SCoPEx in Sweden: First step down the slippery slope of risky solar geoengineering experiments.* https://www.geoengineeringmonitor.org/2020/12/scopex-in-sweden-first-step-down-the-slippery-slope-of-risky-solar-geoengineering-experiments/
CS-Document 20	Algo, J. L. C. (2019, November 23). Geoengineering 'false solution' to climate crisis. *Geoengineering Monitor.* https://www.geoengineeringmonitor.org/2019/11/geoengineering-false-solution-to-climate-crisis/
CS-Document 21	Geoengineering Monitor. (2021, February 4). *Stratospheric Aerosol Injection (technology briefing).* https://www.geoengineeringmonitor.org/2021/02/stratospheric_aerosol_injection/
CS-Document 22	Sandahl, J., Vänner, J., Swedish Society for Nature Conservation, ETC Group, Biofuelwatch, Center for International Environmental Law, Friend of the Earth International, Heinrich Böll Foundation, Indigenous Environmental Network, & WhatNext? (2021, February 8). *Letter to Swedish Government on planned SCoPEx test flight*. https://www.geoengineeringmonitor.org/wp-content/uploads/2021/02/Letter-re-SCoPEx-to-Swedish-government.pdf
CS-Document 23	Center for International Environmental Law, Friend of the Earth International, Heinrich Böll Foundation, Indigenous Environmental Network, & WhatNext? (2021, February 8). *Letter to Swedish Space Corporation on planned SCoPEx test flight*. https://www.geoengineeringmonitor.org/2021/02/letter

	-to-the-swedish-government-on-planned-scopex-test-flight/
CS-Document 24	Geoengineering Monitor. (2022, February 9). *Join global experts in calling on the UN for a solar geoengineering non-use agreement*. https://www.geoengineeringmonitor.org/2022/02/join-global-experts-in-calling-on-the-un-for-a-solar-geoengineering-non-use-agreement/
CS-Document 25	Schneider, L. (2022, March 2). High-risk geoengineering technologies won't reverse climate breakdown. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2022/03/high-risk-geoengineering-technologies-wont-reverse-climate-breakdown/
CS-Document 26	Geoengineering Monitor. (2022, May 2). *Geoengineering Supporters Plan to Set up a New Climate Overshoot Commission*. https://www.geoengineeringmonitor.org/2022/05/geoengineering-supporters-plan-to-set-up-a-new-climate-overshoot-commission/
CS-Document 27	Chalmin, A. (2022, May 6). Quarterly Review I (part 2): Solar radiation management – new field trials, research projects and funding – and growing opposition. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2022/05/quarterly-review-i-part-2-solar-radiation-management-new-field-trials-research-projects-and-funding-and-growing-opposition/
CS-Document 28	Geoengineering Monitor. (2021, July 8). *Support Indigenous Peoples calling for Harvard to shut down the SCoPEx solar geoengineering project*. https://www.geoengineeringmonitor.org/2021/07/sign-the-saami-councils-petition-to-stop-harvards-scopex-experiment/
CS-Document 29	Geoengineering Monitor. (2019, August 21). *Open Letter to SCoPEx Advisory Committee*. https://www.geoengineeringmonitor.org/2019/08/open-letter-scopex/

CS-Document 30	Geoengineering Monitor. (2017, November 23). *Current Geoengineering Attempts Briefing: SCoPEx*. https://www.geoengineeringmonitor.org/2017/11/scopex/
CS-Document 31	Chalmin, A. (2022, November 7). Geoengineering projects in Africa intensify along with oil and gas expansion. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2022/11/geoengineering-projects-in-africa-intensify-along-with-oil-and-gas-expansion/
CS-Document 32	Dunn, L. (2023, January 23). By prohibiting solar geoengineering experiments, Mexico sets a global example of precaution. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/01/by-prohibiting-solar-geoengineering-experiments-mexico-sets-a-global-example-of-precaution/
CS-Document 33	Chalmin, A. (2023a, February 15). Commercialization in geoengineering continues to increase. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/02/quarterly-review-iv/
CS-Document 34	Global Forest Coalition. (2023, March 2). Press release from Don't Geoengineer Africa: A Warning Call from African Civil Society Organizations. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/03/press-release-from-dont-geoengineer-africa-a-warning-call-from-african-civil-society-organizations/
CS-Document 35	Okereke, C. (2023, April 18). My Continent Is Not Your Giant Climate Laboratory. *The New York Times*. https://www.nytimes.com/2023/04/18/opinion/geoengineering-climate-change-technology-africa.html
CS-Document 36	Chalmin, A. (2023b, April 29). Geoengineering Map Update: Carbon markets are a major driver for geoengineering. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/04/geoengineering-map-update-carbon-markets-are-a-major-driver-for-geoengineering/
CS-Document 37	Geoengineering Monitor. (2023, May 12). *Briefing Debunks Myths about Solar Geoengineering*. https://www.geoengineeringmonitor.org/2023/05/briefing-debunks-myths-about-solar-geoengineering/

CS-Document 38	Raman, M. (2023, May 18). The earth should not be a climate laboratory. *Geoengineering Monitor*. https://www.geoengineeringmonitor.org/2023/05/the-earth-should-not-be-a-climate-laboratory/
CS-Document 39	ETC Group. (2021, April 1). *Saami, Swedes and civil society stop solar geoengineering trial balloon*. https://www.etcgroup.org/fr/node/6408?language=en
CS-Interview 1	Interview with representative of an organization that is critical of SCoPEx. Carried out in September 2022.

8.1.2. SCoPEx Advisory Committee (AC)

Documents that have been used to get an insight into the perspective of the SCoPEx Advisory Committee were solely retrieved from the official webpage of the SCoPEx Advisory Committee. The analysis included all sections of the website as well as all the downloadable material that was available on the website, such as open letters or reviews. End of data collection: May 2023.

AC-Document 1	SCoPEx Advisory Committee. (n.d.). *Advisory Committee Selection*. Retrieved November 11, 2022, from https://scopexac.com/advisory-committee-selection/
AC-Document 2	SCoPEx Advisory Committee. (n.d.). *Terms of Reference Established by Harvard University*. Retrieved November 11, 2022, from https://scopexac.com/terms-of-reference-established-by-harvard-university/
AC-Document 3	SCoPEx Advisory Committee. (n.d.). *Framework and Deliverables*. Retrieved November 12, 2022, from https://scopexac.com/framework-deliverables-and-timeline/
AC-Document 4	SCoPEx Advisory Committee. (n.d.). *Mission and Values*. Retrieved November 12, 2022, from https://scopexac.com/advisory-committee-mission-and-values/
AC-Document 5	SCoPEx Advisory Committee. (2020). *About*. https://scopexac.com/
AC-Document 6	SCoPEx Advisory Committee. (2022). *October 2022 Update*. https://scopexac.com/october-2022-update/

AC-Document 7	SCoPEx Advisory Committee. (2022). *July 2022 Update*. https://scopexac.com/july-2022-update/
AC-Document 8	SCoPEx Advisory Committee. (2022). *April 2022 Update*. https://scopexac.com/scopex-advisory-committee-april-2022-update/
AC-Document 9	SCoPEx Advisory Committee. (2021). *November 2021 Update*. https://scopexac.com/november-2022-update/
AC-Document 10	SCoPEx Advisory Committee. (2021). *September 17, 2021*. https://scopexac.com/september-17-2021/
AC-Document 11	SCoPEx Advisory Committee. (2021). *April 8, 2021*. https://scopexac.com/april-8-2021/
AC-Document 12	SCoPEx Advisory Committee. (2021). *March 31, 2021*. https://scopexac.com/march-31-2021/
AC-Document 13	SCoPEx Advisory Committee. (2021). *February 15, 2021*. https://scopexac.com/february-15-2021/
AC-Document 14	SCoPEx Advisory Committee. (2020). *December 15, 2020*. https://scopexac.com/december-15-2020/
AC-Document 15	SCoPEx Advisory Committee. (2020). *August 3, 2020*. https://scopexac.com/august-3-2020/
AC-Document 16	SCoPEx Advisory Committee. (2020). *June 11 & July 22, 2020*. https://scopexac.com/june-11-july-22-2020/
AC-Document 17	SCoPEx Advisory Committee. (2020). *May 18, 2020*. https://scopexac.com/may-18-2020/
AC-Document 18	SCoPEx Advisory Committee. (2019). *July 29, 2019*. https://scopexac.com/july-29-2019/
AC-Document 19	SCoPEx Advisory Committee. (2020). *Financial Review*. https://scopexac.com/financial-review/
AC-Document 20	SCoPEx Advisory Committee. (2022). *Scientific Merit Review*. https://scopexac.com/scientific-merit-review/
AC-Document 21	SCoPEx Advisory Committee. (2021). *Engineering Integrity and Safety Review*. https://scopexac.com/engineering-integrity-and-safety-review/
AC-Document 22	SCoPEx Advisory Committee. (2021). *Legal Review*. https://scopexac.com/legal-review/

AC-Document 23	SCoPEx Advisory Committee. (2021). *CEC21 SCoPEx Advisory Committee Workshop*. https://scopexac.com/cec21-scopex-advisory-committee-workshop/
AC-Document 24	SCoPEx Advisory Committee. (2021). *2021 AGU Fall Meeting Town Hall*. https://scopexac.com/2021-agu-fall-meeting-town-hall/
AC-Document 25	SCoPEx Advisory Committee. (2022). *Societal Review*. https://scopexac.com/societal-review/
AC-Document 26	SCoPEx Advisory Committee. (n.d.). *Reviews*. Retrieved November 12, 2022, from https://scopexac.com/reviews/
AC-Document 27	SCoPEx Advisory Committee. (2022). *Guidance on Local Engagement*. https://scopexac.com/guidance-on-local-engagement/
AC-Document 28	SCoPEx Advisory Committee. (2021). *Proposed Engagement Process for SCoPEx*. https://scopexac.com/wp-content/uploads/2021/01/FINAL-SCoPEx-Societal-Engagement-Outline-1_8_2021.pdf
AC-Document 29	Keutsch, F. N. (2020). *Response to the Societal Engagement Process from the SCoPEx Research Team*. https://scopexac.com/wp-content/uploads/2021/01/FINAL-SCoPEx-Societal-Engagement-Outline-1_8_2021.pdf
AC-Document 30	Keutsch, F. N. (2020). *The Stratospheric Controlled Perturbation Experiment (SCoPEx)—Scientific and Technical Review Foundational Document -Version 1.0*. https://scopexac.com/wp-content/uploads/2021/03/1.-Scientific-and-Technical-Review-Foundational-Document.pdf
AC-Document 31	SCoPEx Advisory Committee. (2020). *Engineering Integrity and Safety Review: Questions from the Advisory Committee to the SCoPEx Research Team*. https://scopexac.com/wp-content/uploads/2021/03/2.-Questions-from-the-Committee-to-Research-Team.pdf
AC-Document 32	Keutsch, F. N. (2021). *Engineering Integrity and Safety Review: Response from the Research Team*. https://scopexac.com/wp-content/uploads/2021/03/Response-from-the-SCoPEx-Research-Team.pdf

AC-Document 33	*Engineering Integrity and Safety Review: Platform Test Description*. (2020). https://scopexac.com/wp-content/uploads/2021/03/4.-Platform-Test-Description.pdf
AC-Document 34	SCoPEx Advisory Committee. (2020). *Financial Review: Financial Review Process and Questions*. https://scopexac.com/wp-content/uploads/2020/11/Financial-Disclosure-Review-Process.pdf
AC-Document 35	Keith, D. W. (2020). *Financial Review: Response to Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/Full-Financial-Disclosure_Website.pdf
AC-Document 36	SCoPEx Advisory Committee. (2020). *Financial Review: Additional Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/Committee-Letter_Financial-Review_David-Keith.pdf
AC-Document 37	Keith, D. W. (2020). *Financial Review: Response to Additional Financial Questions*. https://scopexac.com/wp-content/uploads/2020/11/SGRP-Financial-Response_Website.pdf
AC-Document 38	Setterwalls Law Firm. (2021). *Legal Review: Memorandum to Harvard University regarding project SCoPEx*. https://scopexac.com/wp-content/uploads/2021/04/Memorandum-Project-SCoPEx-Setterwalls-2021-02-18-1.pdf
AC-Document 39	Keutsch, F. N. (2020). *Proposed Platform Launch: Letter Requesting Authorization for the Proposed Platform Launch*. https://scopexac.com/wp-content/uploads/2020/12/Letter-Requesting-Authorization-for-Proposed-Platform-Test.pdf
AC-Document 40	SCoPEx Advisory Committee. (2020). *Proposed Platform Launch: Advisory Committee Response to the Proposed Platform Launch*. https://scopexac.com/wp-content/uploads/2020/12/SCoPEx-memo-re-Sweden-11-30-20.pdf

AC-Document 41	Keutsch, F. N. (2020). *Proposed Platform Launch: Research Team Response to the Advisory Committee*. https://scopexac.com/wp-content/uploads/2020/12/Response-to-Sweden-Memo-9-Dec-2020.pdf
AC-Document 42	SCoPEx Advisory Committee. (2021). *SCoPex Advisory Committee Workplan and Operating Guidelines (Version of May 12)*. https://scopexac.com/wp-content/uploads/2021/05/SCoPEx-Advisory-Committee-External-Document_Website_Final_5_21.pdf
AC-Document 43	SCoPEx Advisory Committee. (2021). *SCoPex Advisory Committee Workplan and Operating Guidelines (Updated Version of July 27)*. https://scopexac.com/wp-content/uploads/2021/07/SCoPEx-Advisory-Committee-External-Document_Website_Final_7_27_2021.pdf
AC-Document 44	SCoPEx Advisory Committee. (n.d.). *Advisory Committee Members*. https://scopexac.com/advisory-committee-members/

8.1.3. Scientists involved in SCoPEx (IS)

Documents that have been used to get an insight into the perspective of the Involved Scientists working within SCoPEx were solely retrieved from the section about SCoPEx within the webpage of the Keutsch Group at Harvard. In addition to that, publicly available transcripts of interviews or talks of scientists who work within SCoPEx have been used. End of data collection: May 2023.

IS-Document 1	Keutsch Group at Harvard. (2021). *SCoPEx Statements*. https://www.keutschgroup.com/scopex/statements
IS-Document 2	Keutsch Group at Harvard. (n.d.). *SCoPEx Governance*. Retrieved November 11, 2022, from https://www.keutschgroup.com/scopex/scopex-governance
IS-Document 3	Keutsch Group at Harvard. (n.d.). *SCoPEx*. Retrieved November 11, 2022, from https://www.keutschgroup.com/scopex

IS-Transcript 1	Talks at Google (2020, October 30). *David Keith | A Case for Integrating Solar Geoengineering into Climate Policy | Talks at Google* [Video]. https://www.youtube.com/watch?v=j7VCIrIPyNM
IS-Transcript 2	Carnegie Council for Ethics in International Affairs (2017, November 20). *Frank Keutsch: Solar Radiation Management & the Stratospheric Controlled Perturbation Experiment* [Video]. https://www.youtube.com/watch?v=APGKJvtoOFI
IS-Transcript 3	Harvard Kennedy School Events (2022, February 28). *Cooling the planet with David Keith* [Video]. https://www.youtube.com/watch?v=dZIfF0vwDTw
IS-Transcript 4	Harvard Museum of Natural History (2019, December 12). *The Peril and Promise of Solar Geoengineering* [Video]. https://www.youtube.com/watch?v=xWI2w2F1gMg
IS-Transcript 5	WebsEdge Science (2020, December 3). *SCoPEx, Harvard University—New Frontiers in Climate Change Research* [Video]. https://www.youtube.com/watch?v=w_qkmavwE54
IS-Transcript 6	Seeker (2019, October 13). *Why the World's First Solar Geoengineering Test Is So Controversial* [Video]. https://www.youtube.com/watch?v=ReBPqguolu8

8.2. Literature

Anderson, W. (2015). Postcolonial Science Studies. In J. D. Wright (Ed.), *International Encyclopedia of the Social and Behavioral Sciences* (2nd ed., Vol. 18, pp. 652–657).

Anshelm, J., & Hansson, A. (2016). Has the grand idea of geoengineering as Plan B run out of steam? *The Anthropocene Review*, *3*(1), 64–74. https://doi.org/10.1177/2053019615614592

Arnell, N. W., Lowe, J. A., Challinor, A. J., & Osborn, T. J. (2019). Global and regional impacts of climate change at different levels of global temperature increase. *Climatic Change*, *155*(3), 377–391. https://doi.org/10.1007/s10584-019-02464-z

Aswathy, V. N., Boucher, O., Quaas, M., Niemeier, U., Muri, H., Mülmenstädt, J., & Quaas, J. (2015). Climate extremes in multi-model simulations of stratospheric aerosol and marine cloud brightening climate engineering. *Atmospheric Chemistry and Physics*, *15*(16), 9593–9610. https://doi.org/10.5194/acp-15-9593-2015

Baatz, C. (2016). Can We Have It Both Ways? On Potential Trade-Offs Between Mitigation and Solar Radiation Management. *Environmental Values*, *25*(1), 29–49. https://doi.org/10.3197/096327115X14497392134847

Barben, D., Fisher, E., Selin, C., & Guston, D. (2008). Anticipatory governance of nanotechnology: Foresight, engagement, and integration. In E. J. Hackett, O. Amsterdamska, M. E. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies* (3rd ed., pp. 979–1000). MIT Press.

Belter, C. W., & Seidel, D. J. (2013). A bibliometric analysis of climate engineering research. *WIREs Climate Change*, *4*(5), 417–427. https://doi.org/10.1002/wcc.229

Biermann, F. (2021). It is dangerous to normalize solar geoengineering research. *Nature*, *595*(7865), 30–30. https://doi.org/10.1038/d41586-021-01724-2

Biermann, F., & Möller, I. (2019). Rich man's solution? Climate engineering discourses and the marginalization of the Global South. *International Environmental Agreements: Politics, Law and Economics*, *19*, 151–167. https://doi.org/10.1007/s10784-019-09431-0

Blomfield, M. (2015). Geoengineering in a climate of uncertainty. In J. Moss (Ed.), *Climate Change and Justice* (pp. 39–58). Cambridge University Press. https://doi.org/10.1017/CBO9781316145340.003

Bloor, D. (1976). *Knowledge and Social Imagery*. Routledge and Kegan Paul.

Boettcher, M., & Schäfer, S. (2017). Reflecting upon 10 years of geoengineering research: Introduction to the Crutzen + 10 special issue. *Earth's Future*, *5*(3), 266–277. https://doi.org/10.1002/2016EF000521

Bogner, A., Littig, B., & Menz, W. (2014). *Interviews mit Experten: Eine praxisorientierte Einführung*. Springer.

Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology Analysis & Strategic Management*, *18*(3–4), 285–298. https://doi.org/10.1080/09537320600777002

Braun, V., & Clarke, V. (2022). Toward good practice in thematic analysis: Avoiding common problems and be(com)ing a knowing researcher. *International Journal of Transgender Health*, *24*(1), 1–6. https://doi.org/10.1080/26895269.2022.2129597

Bucchi, M., & Neresini, F. (2008). Science and Public Participation. In E. J. Hackett, O. Amsterdamska, M. E. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies* (3rd ed., pp. 449–472). MIT Press. https://mitpress.mit.edu/9780262083645/the-handbook-of-science-and-technology-studies/

Buck, H. J. (2022, January 26). We can't afford to stop solar geoengineering research. *MIT Technology Review*. https://www.technologyreview.com/2022/01/26/1044226/we-cant-afford-to-stop-solar-geoengineering-research/

Caldeira, K., & Bala, G. (2017). Reflecting on 50 years of geoengineering research. *Earth's Future*, *5*(1), 10–17. https://doi.org/10.1002/2016EF000454

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. In J. Law (Ed.), *Power, Action and Belief: A new Sociology of Knowledge?* Routledge and Kegan Paul.

Chen, S. (2017). Helping Hand or Hubris? *APSNews*, *26*(9). http://www.aps.org/publications/apsnews/201710/hand-hubris.cfm

Clarke, A. E. (2016). Situating STS and Thinking Ahead. *Engaging Science, Technology, and Society*, 2, 157–179. https://doi.org/10.17351/ests2016.64

Climate Action Tracker. (2023, April). *Countries*. https://climateactiontracker.org/countries/

Cooper, G., Foster, J., Galbraith, L., Jain, S., Neukermans, A., & Ormond, B. (2014). Preliminary results for salt aerosol production intended for marine cloud

brightening, using effervescent spray atomization. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372*(2031), 20140055. https://doi.org/10.1098/rsta.2014.0055

Cressey, D. (2012). Geoengineering experiment cancelled amid patent row. *Nature*. https://doi.org/10.1038/nature.2012.10645

Crutzen, P. J. (2006). Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma? *Climatic Change*, *77*, 211–219. https://doi.org/10.1007/s10584-006-9101-y

Cziczo, D. J., Wolf, M. J., Gasparini, B., Münch, S., & Lohmann, U. (2019). Unanticipated Side Effects of Stratospheric Albedo Modification Proposals Due to Aerosol Composition and Phase. *Scientific Reports*, *9*(1), 18825. https://doi.org/10.1038/s41598-019-53595-3

Davies, S. R. (2014). Knowing and loving: Public engagement beyond discourse. *Science and Technology Studies*, *27*(3), 90–110.

de Laet, M., & Mol, A. (2000). The Zimbabwe Bush Pump: Mechanics of a Fluid Technology. *Social Studies of Science*, *30*(2), 225–263. https://doi.org/10.1177/030631200030002002

Delgado, A., Kjølberg, K. L., & Wickson, F. (2011). Public engagement coming of age: From theory to practice in STS encounters with nanotechnology. *Public Understanding of Science*, *20*(6), 826–845. https://doi.org/10.1177/0963662510363054

Doughty, C. E., Field, C. B., & McMillan, A. M. S. (2011). Can crop albedo be increased through the modification of leaf trichomes, and could this cool regional climate? *Climatic Change*, *104*(2), 379–387. https://doi.org/10.1007/s10584-010-9936-0

Doughty, J. (2018). Past forays into SRM field research and implications for future governance. In J. J. Blackstock & S. Low (Eds.), *Geoengineering our Climate?* Routledge.

Dykema, J., Keith, D., Anderson, J. G., & Weisenstein, D. (2014). Stratospheric controlled perturbation experiment (SCoPEx): A small-scale experiment to improve understanding of the risks of solar geoengineering. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372*, 20140059. https://doi.org/10.1098/rsta.2014.0059

Engels, A., Marotzke, J., Gresse, E., López-Rivera, A., Pagnone, A., & Wilkens, J. (2023). *Hamburg Climate Futures Outlook: The plausibility of a 1.5°C limit to*

global warming - social drivers and physical processes. https://doi.org/10.25592/uhhfdm.11230

Epstein, S. (1995). The Construction of Lay Expertise: AIDS Activism and the Forging of Credibility in the Reform of Clinical Trials. *Science, Technology, & Human Values*, *20*(4), 408–437. https://doi.org/10.1177/016224399502000402

ETC Group. (2011, September 25). *Open letter about SPICE geoengineering test*. https://www.etcgroup.org/content/open-letter-about-spice-geoengineering-test

ETC Group (Director). (2021, June 9). *Solar Geoengineering: Warnings from Scientists, Indigenous Peoples and Climate Activists*. https://www.youtube.com/watch?v=OVs8juLCYyQ

European Commission. (2021). *Forging a climate-resilient Europe—The new EU Strategy on Adaptation to Climate Change*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN

Felt, U. (2015). Keeping technologies out: Sociotechnical imaginaries and the formation of Austria's technopolitical identity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power* (pp. 103–125). The University of Chicago Press.

Flegal, J. A., & Gupta, A. (2018). Evoking equity as a rationale for solar geoengineering research? Scrutinizing emerging expert visions of equity. *International Environmental Agreements: Politics, Law and Economics*, *18*(1), 45–61. https://doi.org/10.1007/s10784-017-9377-6

Frumhoff, P. C., & Stephens, J. C. (2018). Towards legitimacy of the solar geoengineering research enterprise. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2119), 20160459. https://doi.org/10.1098/rsta.2016.0459

Galbraith, J. (2021). Values in early-stage climate engineering: The ethical implications of "doing the research." *Studies in History and Philosophy of Science Part A*, *86*, 103–113. https://doi.org/10.1016/j.shpsa.2021.01.009

Garrison, C. (2023, March 27). How two weather balloons led Mexico to ban solar geoengineering. *Reuters*. https://www.reuters.com/business/environment/how-two-weather-balloons-led-mexico-ban-solar-geoengineering-2023-03-27/

Geoengineering Monitor. (2020, December 22). *SCoPEx in Sweden: First step down the slippery slope of risky solar geoengineering experiments*.

https://www.geoengineeringmonitor.org/2020/12/scopex-in-sweden-first-step-down-the-slippery-slope-of-risky-solar-geoengineering-experiments/

Golja, C. M., Chew, L. W., Dykema, J. A., & Keith, D. W. (2021). Aerosol Dynamics in the Near Field of the SCoPEx Stratospheric Balloon Experiment. *Journal of Geophysical Research: Atmospheres*, *126*(4), e2020JD033438. https://doi.org/10.1029/2020JD033438

Gunderson, R., Petersen, B., & Stuart, D. (2018). A Critical Examination of Geoengineering: Economic and Technological Rationality in Social Context. *Sustainability*, *10*(1), 269. https://doi.org/10.3390/su10010269

Hale, B. (2012). The World That Would Have Been: Moral Hazard Arguments Against Geoengineering. In C. J. Preston (Ed.), *Engineering the Climate: The Ethics of Solar Radiation Managment* (pp. 113–131). Lexington Books.

Hands off Mother Earth! Manifesto against Geoengineering. (2018). https://www.geoengineeringmonitor.org/wp-content/uploads/2018/10/home-new-EN-feb6.pdf

Harding, S. (2009). Postcolonial and feminist philosophies of science and technology: Convergences and dissonances. *Postcolonial Studies*, *12*(4), 401–421. https://doi.org/10.1080/13688790903350658

Harvard University. (2022). *Harvard's Solar Geoengineering Research Program*. https://geoengineering.environment.harvard.edu/home

Henriksen, C., Sandahl, J., Sundström, M., & Wronski, I. (2021, February 24). *Regarding SCoPEx plans for test flights at the Swedish Space Corporation in Kiruna*. https://www.saamicouncil.net/news-archive/open-letter-requesting-cancellation-of-plans-for-geoengineering

Heyen, D., Horton, J., & Moreno-Cruz, J. (2019). Strategic implications of counter-geoengineering: Clash or cooperation? *Journal of Environmental Economics and Management*, *95*, 153–177. https://doi.org/10.1016/j.jeem.2019.03.005

Hicks, D. J. (2017). Genetically Modified Crops, Inclusion, and Democracy. *Perspectives on Science*, *25*(4), 488–520. https://doi.org/10.1162/POSC_a_00251

Horton, J. B., & Keith, D. W. (2016). Solar Geoengineering and Obligations to the Global Poor. In C. J. Preston, *Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene* (pp. 79–92). Rowman & Littlefield International.

Hourdequin, M. (2018). Climate Change, Climate Engineering, and the 'Global Poor': What Does Justice Require? *Ethics, Policy & Environment*, *21*(3), 270–288. https://doi.org/10.1080/21550085.2018.1562525

Hulme, M. (2014). *Can Science Fix Climate Change? A Case Against Climate Engineering*. Polity.

IPCC. (1990). *Climate Change: The IPCC Response Strategies*. https://www.ipcc.ch/report/ar1/wg3/

IPCC. (2021). *Climate Change in Data: The Physical Science Basis*. https://www.ipcc.ch/report/ar6/wg1/resources/climate-change-in-data

IPCC. (2018). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Cambridge University Press. https://doi.org/10.1017/9781009157940.001

IPCC. (2022). Summary for Policymakers. In P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas., R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Jinnah, S., & Nicholson, S. (2019). Introduction to the Symposium on 'Geoengineering: Governing Solar Radiation Management'. *Environmental Politics*, *28*(3), 385–396. https://doi.org/10.1080/09644016.2019.1558515

Jinnah, S., Nicholson, S., Morrow, D. R., Dove, Z., Wapner, P., Valdivia, W., Thiele, L. P., McKinnon, C., Light, A., Lahsen, M., Kashwan, P., Gupta, A., Gillespie, A., Falk, R., Conca, K., Chong, D., & Chhetri, N. (2019). Governing Climate Engineering: A Proposal for Immediate Governance of Solar Radiation Management. *Sustainability*, *11*(14), 3954. https://doi.org/10.3390/su11143954

Keck, M., & Sakdapolrak, P. (2013). What Is Social Resilience? Lessons Learned and Ways Forward. *Erdkunde*, *67*(1), 5–19.

Keith, D. W. (2000). Geoengineering the Climate: History and Prospect. *Annual Review of Energy and the Environment*, *25*(1), 245–284. https://doi.org/10.1146/annurev.energy.25.1.245

Keith, D. W. (2021). Toward constructive disagreement about geoengineering. *Science*, *374*(6569), 812–815. https://doi.org/10.1126/science.abj1587

Keith, D. W., & Hulme, M. (2013, November 29). Climate science: Can geoengineering save the world? *The Guardian*. https://www.theguardian.com/sustainable-business/blog/climate-science-geoengineering-save-world

Kessler, G. (2021, November 10). Robert Moses and the saga of the racist parkway bridges. *Washington Post*. https://www.washingtonpost.com/politics/2021/11/10/robert-moses-saga-racist-parkway-bridges/

Keutsch Group at Harvard. (n.d.). *SCoPEx: Stratospheric Controlled Perturbation Experiment*. Retrieved August 13, 2021, from https://www.keutschgroup.com/scopex

Keutsch Group at Harvard. (2020). *SCoPEx Statements*. https://www.keutschgroup.com/scopex/statements

Kravitz, B., MacMartin, D. G., Robock, A., Rasch, P. J., Ricke, K. L., Cole, J. N. S., Curry, C. L., Irvine, P. J., Ji, D., Keith, D. W., Kristjánsson, J. E., Moore, J. C., Muri, H., Singh, B., Tilmes, S., Watanabe, S., Yang, S., & Yoon, J.-H. (2014). A multi-model assessment of regional climate disparities caused by solar geoengineering. *Environmental Research Letters*, *9*(7), 074013. https://doi.org/10.1088/1748-9326/9/7/074013

Kuo, K. (2011, October 28). Geo-engineering: Why research something we never want to use? *The Conversation*. http://theconversation.com/geo-engineering-why-research-something-we-never-want-to-use-3684

Kurzgesagt – In a Nutshell (Director). (2020, October 27). *Geoengineering: A Horrible Idea We Might Have to Do*. https://www.youtube.com/watch?v=dSu5sXmsur4

Latour, B. (1996). Der Berliner Schlüssel. In B. Latour, *Der Berliner Schlüssel. Erkundungen eines Liebhabers der Wissenschaften* (pp. 37–52). Akademie Verlag.

Laurent, B. (2017). Mobilizing against, Mobilizing with Nanotechnology. In *Democratic Experiments: Problematizing Nanotechnology and Democracy in Europe and the United States* (pp. 151–204). MIT Press.

Law, J., & Lin, W. (2017). Provincializing Sts: Postcoloniality, Symmetry, and Method. *East Asian Science, Technology and Society: An International Journal*, *11*(2), 211–227. https://doi.org/10.1215/18752160-3823859

Lawrence, M. G., & Crutzen, P. J. (2017). Was breaking the taboo on research on climate engineering via albedo modification a moral hazard, or a moral imperative? *Earth's Future*, *5*(2), 136–143. https://doi.org/10.1002/2016EF000463

Lin, A. C. (2013). Does Geoengineering Present a Moral Hazard? *Ecology Law Quarterly*, *40*(3), 673–712.

Low, S., Baum, C. M., & Sovacool, B. K. (2022). Taking it outside: Exploring social opposition to 21 early-stage experiments in radical climate interventions. *Energy Research & Social Science*, *90*, 102594. https://doi.org/10.1016/j.erss.2022.102594

Low, S., & Buck, H. J. (2020). The practice of responsible research and innovation in "climate engineering." *WIREs Climate Change*, *11*(3), e644. https://doi.org/10.1002/wcc.644

Lyall, C., & Tait, J. (2019). Beyond the limits to governance: New rules of engagement for the tentative governance of the life sciences. *Research Policy*, *48*(5), 1128–1137. Scopus. https://doi.org/10.1016/j.respol.2019.01.009

MacKenzie, D., & Wajcman, J. (1999). Introductory essay: The social shaping of technology. In D. MacKenzie & J. Wajcman (Eds.), *The Social Shaping of Technology* (2nd ed.). Open University Press.

MacMynowski, D. G., Keith, D. W., Caldeira, K., & Shin, H.-J. (2011). Can we test geoengineering? *Energy & Environmental Science*, *4*(12), 5044–5052. https://doi.org/10.1039/C1EE01256H

Make Sunsets. (2023). *Make Sunsets*. https://makesunsets.com

Markusson, N., Ginn, F., Singh Ghaleigh, N., & Scott, V. (2014). 'In case of emergency press here': Framing geoengineering as a response to dangerous climate change. *WIREs Climate Change*, *5*(2), 281–290. https://doi.org/10.1002/wcc.263

McCusker, K. E., Armour, K. C., Bitz, C. M., & Battisti, D. S. (2014). Rapid and extensive warming following cessation of solar radiation management. *Environmental Research Letters*, *9*(2), 024005. https://doi.org/10.1088/1748-9326/9/2/024005

McKinnon, C. (2019). Sleepwalking into lock-in? Avoiding wrongs to future people in the governance of solar radiation management research. *Environmental Politics*, *28*(3), 441–459. https://doi.org/10.1080/09644016.2018.1450344

McLaren, D. (2016). Mitigation deterrence and the "moral hazard" of solar radiation management. *Earth's Future*, *4*(12), 596–602. https://doi.org/10.1002/2016EF000445

McNeil, M. (2013). Between a Rock and a Hard Place: The Deficit Model, the Diffusion Model and Publics in STS. *Science as Culture*, *22*(4), 589–608. Scopus. https://doi.org/10.1080/14636778.2013.764068

Merk, C., Pönitzsch, G., & Rehdanz, K. (2016). Knowledge about aerosol injection does not reduce individual mitigation efforts. *Environmental Research Letters*, *11*(5), 054009. https://doi.org/10.1088/1748-9326/11/5/054009

Mettiäinen, I., Buck, H. J., MacMartin, D. G., & Ricke, K. L. (2022). `Bog here, marshland there': Tensions in co-producing scientific knowledge on solar geoengineering in the Arctic. *Environmental Research Letters*, *17*(4), 045001. https://doi.org/10.1088/1748-9326/ac5715

Michael, M. (2009). Publics performing publics: Of PiGs, PiPs and politics. *Public Understanding of Science*, *18*(5), 617–631. https://doi.org/10.1177/0963662508098581

Millard-Ball, A. (2012). The Tuvalu Syndrome. *Climatic Change*, *110*(3), 1047–1066. https://doi.org/10.1007/s10584-011-0102-0

Miller, B. (2021). Is Technology Value-Neutral? *Science, Technology, & Human Values*, *46*(1), 53–80. https://doi.org/10.1177/0162243919900965

Muri, H., Kristjánsson, J. E., Storelvmo, T., & Pfeffer, M. A. (2014). The climatic effects of modifying cirrus clouds in a climate engineering framework. *Journal of Geophysical Research: Atmospheres*, *119*(7), 4174–4191. https://doi.org/10.1002/2013JD021063

National Academies of Sciences, Engineering, and Medicine. (2021). *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*.

National Co-ordinating Centre for Public Engagement. (2020). *What is public engagement?* https://www.publicengagement.ac.uk/about-engagement/what-public-engagement

Nature. (2021). Give research into solar geoengineering a chance. *Nature*, *593*(7858), 167. https://doi.org/10.1038/d41586-021-01243-0

Nelkin, D. (1979). *Controversy: The politics of technical decisions*. Sage.

Nordmann, A. (2014). Responsible innovation, the art and craft of anticipation. *Journal of Responsible Innovation*, *1*(1), 87–98. https://doi.org/10.1080/23299460.2014.882064

O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature*, *260*(5552). https://doi.org/10.1038/260566a0

Ober, K., & Sakdapolrak, P. (2020). Whose climate change adaptation 'barriers'? Exploring the coloniality of climate change adaptation policy assemblages in Thailand and beyond. *Singapore Journal of Tropical Geography*, 41(1), 86–104. https://doi.org/10.1111/sjtg.12309

Osaka, S. (2021, April 8). *Why a landmark experiment into dimming the sun got canceled: Who gets to decide if we research solar geoengineering?* Grist. https://grist.org/science/who-gets-to-decide-if-we-study-solar-geoengineering-after-the-scopex-project-canceled/

Oschlies, A., Held, H., Keller, D., Keller, K., Mengis, N., Quaas, M., Rickels, W., & Schmidt, H. (2017). Indicators and metrics for the assessment of climate engineering. *Earth's Future*, *5*(1), 49–58. https://doi.org/10.1002/2016EF000449

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible Research and Innovation: From Science in Society to Science for Society, with Society. *Science and Public Policy*, *39*, 751–760. https://doi.org/10.1093/scipol/scs093

Parker, A., & Irvine, P. J. (2018). The Risk of Termination Shock From Solar Geoengineering. *Earth's Future*, *6*(3), 456–467. https://doi.org/10.1002/2017EF000735

Parson, E. A., & Reynolds, J. L. (2021). Solar geoengineering governance: Insights from a scenario exercise. *Futures*, *132*, 102805. https://doi.org/10.1016/j.futures.2021.102805

Pasztor, J. (2021). Solar geoengineering research needs formal global debate. *Nature*, *595*(7868), 494–494. https://doi.org/10.1038/d41586-021-01957-1

Pierrehumbert, R. (2019). There is no Plan B for dealing with the climate crisis. *Bulletin of the Atomic Scientists*, *75*(5), 215–221. https://doi.org/10.1080/00963402.2019.1654255

Pierrehumbert, R., & Mann, M. (2021, April 22). Some say we can 'solar-engineer' ourselves out of the climate crisis. Don't buy it. *The Guardian*. http://www.theguardian.com/commentisfree/2021/apr/22/climate-crisis-emergency-earth-day

Pinch, T. J., & Bijker, W. E. (1984). The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science*, *14*(3), 399–441.

Proctor, J., Hsiang, S., Burney, J., Burke, M., & Schlenker, W. (2018). Estimating global agricultural effects of geoengineering using volcanic eruptions. *Nature*, *560*(7719), 480–483. https://doi.org/10.1038/s41586-018-0417-3

Rahman, A. A., Artaxo, P., Asrat, A., & Parker, A. (2018). Developing countries must lead on solar geoengineering research. *Nature*, *556*(7699), 22–24. https://doi.org/10.1038/d41586-018-03917-8

Ravetz, J. (1986). Usable knowledge, usable ignorance: Incomplete science with policy implications. In W. C. Clark & R. E. Munn, *Sustainable development of the biosphere* (pp. 415–432). Cambridge University Press.

Reynolds, J. L. (2022). Linking solar geoengineering and emissions reductions: Strategically resolving an international climate change policy dilemma. *Climate Policy*, *22*(3), 285–300. https://doi.org/10.1080/14693062.2021.1993125

Reynolds, J. L., & Wagner, G. (2020). Highly decentralized solar geoengineering. *Environmental Politics*, *29*(5), 917–933. https://doi.org/10.1080/09644016.2019.1648169

Ricke, K. L., Morgan, M. G., & Allen, M. R. (2010). Regional climate response to solar-radiation management. *Nature Geoscience*, *3*(8), 537–541. https://doi.org/10.1038/ngeo915

Rip, A., Misa, T. J., & Schot, J. (Eds.). (1995). *Managing Technology in Society: The Approach of Constructive Technology Assessment*. Thomson Learning.

Rivas, C. (2017). Finding themes in qualitative data. In C. Seale (Ed.), *Researching Society and Culture* (pp. 431–453). Sage.

Robock, A. (2008). 20 Reasons Why Geoengineering May Be a Bad Idea. *Bulletin of the Atomic Scientists*, *64*(2), 14–18. https://doi.org/10.2968/064002006

Robock, A. (2016). Albedo enhancement by stratospheric sulfur injections: More research needed. *Earth's Future*, *4*(12), 644–648. https://doi.org/10.1002/2016EF000407

Robock, A., Bunzl, M., Kravitz, B., & Stenchikov, G. L. (2010). A Test for Geoengineering? *Science*, *327*(5965), 530–531. https://doi.org/10.1126/science.1186237

Roy, K. (2022). The solar shield concept: Current status and future possibilities. *Acta Astronautica*, *197*, 368–374. https://doi.org/10.1016/j.actaastro.2022.02.022

Ruser, A., & Machin, A. (2016). Technology Can Save Us, Cant It? The Emergence of the 'Technofix' Narrative in Climate Politics. *Proceedings of the International Conference "Technology+ Society= Future*, 437–447.

Sandahl, J., Vänner, J., Swedish Society for Nature Conservation, ETC Group, Biofuelwatch, Center for International Environmental Law, Friend of the Earth International, Heinrich Böll Foundation, Indigenous Environmental Network, & WhatNext? (2021, February 8). *Letter to Swedish Government on planned SCoPEx test flight*. https://www.geoengineeringmonitor.org/wp-content/uploads/2021/02/Letter-re-SCoPEx-to-Swedish-government.pdf

Schmidt, H., Alterskjær, K., Bou Karam, D., Boucher, O., Jones, A., Kristjánsson, J. E., Niemeier, U., Schulz, M., Aaheim, A., Benduhn, F., Lawrence, M., & Timmreck, C. (2012). Solar irradiance reduction to counteract radiative forcing from a quadrupling of CO_2: Climate responses simulated by four earth system models. *Earth System Dynamics*, *3*(1), 63–78. https://doi.org/10.5194/esd-3-63-2012

Schneider, L. (2019). Fixing the Climate? How Geoengineering Threatens to Undermine the SDGs and Climate Justice. *Development*, *62*, 29–36. https://doi.org/10.1057/s41301-019-00211-6

SCoPex Advisory Committee. (n.d.). *Mission and Values*. Retrieved November 12, 2022, from https://scopexac.com/advisory-committee-mission-and-values/

SCoPex Advisory Committee. (2021). *March 31, 2021*. https://scopexac.com/march-31-2021/

Scott, D. (2023). Diversifying the Deliberative Turn: Toward an Agonistic RRI. *Science Technology and Human Values*, *48*(2), 295–318. Scopus. https://doi.org/10.1177/01622439211067268

Secretaría de Medio Ambiente y Recursos Naturales. (2023, January 13). *La experimentación con geoingeniería solar no será permitida en México*. http://www.gob.mx/semarnat/prensa/la-experimentacion-con-geoingenieria-solar-no-sera-permitida-en-mexico

Seth, S. (2017). Colonial History and Postcolonial Science Studies. *Radical History Review*, *2017*(127), 63–85. https://doi.org/10.1215/01636545-3690882

Shepherd, J. (2009). *Geoengineering the climate: Science, governance and uncertainty*. The Royal Society.

Simis, M. J., Madden, H., Cacciatore, M. A., & Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication? *Public Understanding of Science*, *25*(4), 400–414. https://doi.org/10.1177/0963662516629749

Solar Geoengineering Non-Use Agreement. (2021). *Non-Use Agreement*. https://www.solargeoeng.org/non-use-agreement/

SPICE. (2023a). *Aims and Background*. http://www.spice.ac.uk/about-us/aims-and-background/

SPICE. (2023b). *Climate and Environmental Modelling*. http://www.spice.ac.uk/project/climate-and-environmental-modelling/

SPICE. (2023c). *Delivery Systems*. http://www.spice.ac.uk/project/delivery-systems/

SPICE. (2023d). *Evaluating Candidate Particles*. http://www.spice.ac.uk/project/evaluating-candidate-particles/

Stephens, J. C., & Surprise, K. (2020). The hidden injustices of advancing solar geoengineering research. *Global Sustainability*, *3*. https://doi.org/10.1017/sus.2019.28

Stephenson, N. (2021). *Termination Shock*. The Borough Press.

Stilgoe, J. (2015). *Experiment Earth: Responsible innovation in geoengineering*. Routledge.

Stilgoe, J. (2016). Geoengineering as Collective Experimentation. *Science and Engineering Ethics*, *22*(3), 851–869. https://doi.org/10.1007/s11948-015-9646-0

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, *42*(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Strauss, A. L., & Corbin, J. (1999). *Grounded Theory: Grundlagen qualitativer Sozialforschung*. Beltz, PsychologieVerlagsUnion.

Subramaniam, B., Foster, L., Harding, S., Roy, D., & TallBear, K. (2017). Feminism, Postcolonialism, Technoscience. In U. Felt, R. Fouche, C. A. Miller, & L. Smith-

Doerr (Eds.), *The Handbook of Science and Technology Studies* (4th ed.). MIT Press.

Suldovsky, B. (2016). In science communication, why does the idea of the public deficit always return? Exploring key influences. *Public Understanding of Science*, *25*(4), 415–426. https://doi.org/10.1177/0963662516629750

Táíwò, O. O., & Talati, S. (2021). Who Are the Engineers? Solar Geoengineering Research and Justice. *Global Environmental Politics*, *22*(1), 12–18. https://doi.org/10.1162/glep_a_00620

Temple, J. (2017, March 24). Harvard Scientists Moving Ahead on Plans for Atmospheric Geoengineering Experiments. *MIT Technology Review*. https://www.technologyreview.com/2017/03/24/153028/harvard-scientists-moving-ahead-on-plans-for-atmospheric-geoengineering-experiments/

Temple, J. (2021, February 19). A first-of-its-kind geoengineering experiment is about to take its first step. *MIT Technology Review*. https://www.technologyreview.com/2021/02/19/1018813/harvard-first-geoengineering-experiments-in-stratosphere-sweden/

Temple, J. (2023, March 1). Researchers launched a solar geoengineering test flight in the UK last fall. *MIT Technology Review*. https://www.technologyreview.com/2023/03/01/1069283/researchers-launched-a-solar-geoengineering-test-flight-in-the-uk-last-fall/

The DEGREES Initiative. (2023, March 3). *The DEGREES Initiative*. https://www.degrees.ngo/

The Economist. (2010, November 4). Lift-off. *The Economist*. https://www.economist.com/science-and-technology/2010/11/04/lift-off

The Royal Society of London. (1985). *The Public Understanding of Science*. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/1985/10700.pdf

Tilmes, S., Fasullo, J., Lamarque, J.-F., Marsh, D. R., Mills, M., Alterskjær, K., Muri, H., Kristjánsson, J. E., Boucher, O., Schulz, M., Cole, J. N. S., Curry, C. L., Jones, A., Haywood, J., Irvine, P. J., Ji, D., Moore, J. C., Karam, D. B., Kravitz, B., … Watanabe, S. (2013). The hydrological impact of geoengineering in the Geoengineering Model Intercomparison Project (GeoMIP). *Journal of Geophysical Research: Atmospheres*, *118*(19), 11,036-11,058. https://doi.org/10.1002/jgrd.50868

Trench, B. (2008). Towards an Analytical Framework of Science Communication Models. In D. Cheng, M. Claessens, T. Gascoigne, J. Metcalfe, B. Schiele, & S. Shi (Eds.), *Communicating Science in Social Contexts: New models, new practices* (pp. 119–135). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8598-7_7

United Nations. (2015). *The Paris Agreement*. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations Climate Change. (n.d.). *Introduction*. Retrieved April 20, 2023, from https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction

United Nations Environment Programme. (2023). *One Atmosphere: An Independent Expert Review on Solar Radiation Modification Research and Deployment*. https://wedocs.unep.org/20.500.11822/41903

United Nations Environment Programme. (2022, October 27). *World headed for climate catastrophe without urgent action: UN Secretary-General.* http://www.unep.org/news-and-stories/story/world-headed-climate-catastrophe-without-urgent-action-un-secretary-general

von Schomberg, R. (2011). Introduction: Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields. In R. von Schomberg (Ed.), *Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields* (pp. 7–15). Publications Office of the European Union.

Weisenstein, D. K., Visioni, D., Franke, H., Niemeier, U., Vattioni, S., Chiodo, G., Peter, T., & Keith, D. W. (2022). An interactive stratospheric aerosol model intercomparison of solar geoengineering by stratospheric injection of SO_2 or accumulation-mode sulfuric acid aerosols. *Atmospheric Chemistry and Physics*, *22*(5), 2955–2973. https://doi.org/10.5194/acp-22-2955-2022

Wibeck, V., Hansson, A., & Anshelm, J. (2015). Questioning the technological fix to climate change – Lay sense-making of geoengineering in Sweden. *Energy Research & Social Science*, *7*, 23–30. https://doi.org/10.1016/j.erss.2015.03.001

Wigley, T. M. L. (2006). A Combined Mitigation/Geoengineering Approach to Climate Stabilization. *Science*, *314*(5798), 452–454. https://doi.org/10.1126/science.1131728

Wilsdon, J., & Willis, R. (2004). *See-through Science: Why public engagement needs to move upstream*. Demos. https://doi.org/10.13140/RG.2.1.3844.3681

Winickoff, D. E., Flegal, J. A., & Asrat, A. (2015). Engaging the Global South on climate engineering research. *Nature Climate Change*, *5*(7), 627–634. https://doi.org/10.1038/nclimate2632

Winner, L. (1986). Do Artifacts have Politics? In *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (pp. 19–39). University of Chicago Press.

Winsberg, E. (2021). A Modest Defense of Geoengineering Research: A Case Study in the Cost of Learning. *Philosophy & Technology*, *34*, 1109–1134. https://doi.org/10.1007/s13347-021-00452-9

Wolff, J. (2020). Fighting risk with risk: Solar radiation management, regulatory drift, and minimal justice. *Critical Review of International Social and Political Philosophy*, *23*(5), 564–583. https://doi.org/10.1080/13698230.2020.1694214

Wyatt, S. (2008). Technological Determinism is Dead; Long Live Technological Determinism. In E. J. Hackett, O. Amsterdamska, M. E. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies* (3rd ed., pp. 165–180). MIT Press.

Wynne, B. (2007). Public Participation in Science and Technology: Performing and Obscuring a Political–conceptual Category Mistake. *East Asian Science, Technology and Society: An International Journal*, *1*(1), 99–110. https://doi.org/10.1215/s12280-007-9004-7

Zarnetske, P. L., Gurevitch, J., Franklin, J., Groffman, P. M., Harrison, C. S., Hellmann, J. J., Hoffman, F. M., Kothari, S., Robock, A., Tilmes, S., Visioni, D., Wu, J., Xia, L., & Yang, C.-E. (2021). Potential ecological impacts of climate intervention by reflecting sunlight to cool Earth. *Proceedings of the National Academy of Sciences*, *118*(15), e1921854118. https://doi.org/10.1073/pnas.1921854118

8.3. SCoPEx Advisory Committee Members

Name	Background Information
Louise Bedsworth *Member of the leadership committee*	**Profession**: Director of the Land Use Program at the Center for Law, Energy, and the Environment (CLEE) at Berkeley Law School where she also serves as a Senior Advisor to the California-China Climate Institute. **Based in**: USA **Education**: B.S. in Earth, Atmospheric, and Planetary Sciences from the Massachusetts Institute of Technology and an M.S. in Environmental Engineering and Ph.D. in Energy and Resources, both from the University of California at Berkeley. **Research & Work experience**: Before joining CLEE, Louise spent nearly a decade working for the State of California, most recently as the Executive Director of the Strategic Growth Council
Sikina Jinnah *Member of the leadership committee*	**Profession**: Professor of Environmental Studies at University of California at Santa Cruz, and a 2017 Andrew Carnegie Fellow. **Based in**: USA **Education**: PhD from UC Berkeley in Environmental Science, Policy and Management. **Research & Work experience**: Her research focuses on global environmental governance, in particular in the areas of climate change, climate engineering, and the nexus between international trade and environmental politics.

Name	Background Information
Shuchi Talati *Member of the leadership committee*	**Profession**: Scholar in Residence at the Forum for Climate Engineering Assessment at American University. **Based in**: USA **Education**: BS in environmental engineering from Northwestern University, an MA in climate and society from Columbia University, and PhD from Carnegie Mellon in engineering and public policy **Research & Work experience**: She was most recently the Chief of Staff of the Office of Fossil Energy & Carbon Management at the U.S. Department of Energy in the Biden-Harris Administration. She was also previously the UCS Fellow on solar geoengineering research governance and public engagement with the Climate & Energy program at the Union of Concerned Scientists. **Additional Information:** Dr. Talati stepped away from the Committee for government service from April of 2021 to April of 2022.
Michael B. Girrard	**Profession**: Professor of Professional Practice at Columbia Law School, teaches courses on environmental law, climate change law, and energy regulation, founded and directs the Sabin Center for Climate Change Law and chaired the Earth Institute **Based in**: USA **Education**: B.A. in Political Science at Columbia University; J.D. at New York University School of Law **Research & Work experience**: Before joining the Columbia faculty in 2009, he practiced environmental law in New York for 30 years, most recently as partner in charge of the New York office of Arnold & Porter.

Name	Background Information
Michael Kleeman	**Profession**: Senior Fellow at the University of California San Diego affiliated with the School of Global Policy and Institute on Global Conflict and Cooperation **Based in**: USA **Education**: B.S. from Syracuse University and M.A. from Claremont Graduate School **Research & Work experience**: His research focuses on critical infrastructure, public health, and community resilience. He is a senior advisor at BSR (formerly Business for Social Responsibility) and the Boston Consulting Group and serves on the Board Institute for the Future.
Robert Lempert	**Profession**: Principal researcher at the RAND Corporation and Director of the Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition. **Based in**: USA **Education**: Ph.D. in applied physics from Harvard University **Research & Work experience**: His research focuses on risk management and decision-making under conditions of deep uncertainty. He is a Fellow of the American Physical Society, a member of the Council on Foreign Relations, and a convening lead author for Working Group II of the United Nation's Intergovernmental Panel on Climate Change Sixth Assessment Report

Name	Background Information
Katharine Mach	**Profession**: Professor at the University of Miami Rosenstiel School of Marine, Atmospheric, and Earth Science and the UM Abess Center, focused on environmental science and policy. **Based in**: USA **Education**: PhD in Biological Sciences from Stanford University and AB in Biology from Harvard College. **Research & Work experience**: Mach's research assesses climate change risks and response options to address increased flooding, extreme heat, wildfire, and other hazards … She is a chapter lead for the US Fifth National Climate Assessment and was a lead author for the IPCC Sixth Assessment Report.
Leonard Nurse	**Profession**: Former Director, Coastal Zone Management Unit, and Permanent Secretary, Ministry of the Environment, Barbados and a retired Professor in the Centre for Resources Management and Environmental Studies (CERMES), UWI, Cave Hill **Based in**: Barbados **Education**: Graduate of the University of the West Indies, Memorial University, and McGill University **Research & Work experience**: Nurse has been a researcher with the United Nations Intergovernmental Panel on Climate Change (IPCC), and was a Member of the Scientific and Technical Advisory Panel of the Global Environmental Facility of the World Bank.

Name	Background Information
Hosea Olayiwola Patrick	**Profession**: Research fellow in the School of Built Environment and Development Studies, University of KwaZulu-Natal, South Africa. **Based in**: South Africa **Education**: Ph.D. in Political science from the University of KwaZulu Natal (South Africa), an M.Sc. in International relations (University of Ibadan, Nigeria), and a BSc in International Studies (Ahmadu Bello University, Nigeria). **Research & Work experience**: He has published articles on geoengineering, climate change, social cohesion, conflict and cooperation, and public policy, among others.

Most information in the *Background*-column within the table was quoted directly from AC-Document 44[126]. Some additional information (such as education) was retrieved from the personal websites/CVs of AC-members.

[126] SCoPEx Advisory Committee. (n.d.). *Advisory Committee Members*. https://scopexac.com/advisory-committee-members