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Legitimacy and Contestation of Marine Cloud Brightening Field Tests: Lessons from the Great Barrier Reef

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Abstract

Marine cloud brightening is referred to as the injection of small aerosol particles into marine clouds, is a solar geoengineering technology that might be effective in mitigating the effects of climate change. The regional applications of marine cloud brightening are gaining traction in the scientific field, and the technology is currently being explored by the Australian Reef Restoration and Adaptation Project (RRAP) in a bid to protect the Great Barrier Reef from coral bleaching. In March 2020, a first field testing of the technological equipment took place, which demonstrated the effectiveness of the technology to be used. While this is not the first marine cloud brightening research proposal, the few field experiments that have been proposed in the past have all been postponed, or definitively cancelled due to contestation. This study analyses how technology legitimacy is performed by RRAP and argues that the alignment between the RRAP program and important elements of regulative, procedural and normative legitimacy have resulted in relatively low levels of public contestation. In terms of regulative legitimacy, it is argued that the historical regulatory framework Australian states offer for a weather modification simi lar to cloud brightening, *cloud seeding*, might provide a basis for marine cloud brightening to build on. Moreover, taking up the term *geoengineering* in the permit application process, the Great Barrier Reef Marine Park Authority taking significant steps towards regulation. RRAP researchers have paid much attention to studying and designing engagement mechanisms, contributing to the procedural legitimacy of the program. A specialized engagement and involvement program for traditional owners has been set up, which has been met with very positive responses. The most important finding from the analysis on normative legitimacy has been that the narrative of *saving* the Great Barrier Reef through marine cloud brightening is strongly welcomed and supported. Perhaps so much so, that the high-reward that is expected from high-risk technologies like marine cloud brightening seems to be worth the risks for engaged stakeholders. In addition to these empirical results, this study has offered combined a suite of relevant theoretical concepts into a new framework for analyzing legitimacy and contestation in relation to marine cloud brightening field experiments. Nevertheless, this study should be seen as a first attempt at doing so, as more cases of both cancelled and executed field tests should be examined in order to strengthen its dimensions, indicators and their mutual relationships.

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Chapter 1 – Introduction

1.1 Problem statement

The most recent report by the Intergovernmental Panel on Climate Change urges policy makers, scientists and the public to face the facts: "*many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level*" (IPCC, 2021a, p. 41). As human life is significantly dependent on these waters and the ecosystems they support (Panday et al., 2021), taking action to sustain them is of critical importance. The severity and urgency of the current situation has led some scientists to call for drastic measures that go beyond the current pace of GHG emission reductions (NRC, 2015; NASEM, 2021).

Several emerging technologies to deliberately engineer the earth's greenhouse system are now being considered to mitigate and adapt to the effects of anthropogenic climate change. Under the umbrella term 'geoengineering', these technologies can be roughly divided into two main categories: carbon dioxide removal (CDR) and solar radiation management (SRM). CDR comprises several techniques with which carbon dioxide can be captured and removed from the atmosphere on a relatively large scale and thus has the capacity to address anthropogenic causes of climate change. SRM techniques, on the other hand, rather aim to nullify the greenhouse effect of GHG emissions by extending the planets radiation budget (IPCC, 2021b).

The different objectives of SRM and CDR might also explain the anticipated differences in their implementation. SRM technologies are expected to act fast and would be able to produce a detectable climate effect within months, whereas CDR systems would arguably take decades to make a significant impact on CO2-concentrations (Horton, 2015). Moreover, compared to the extremely costly interventions that would be needed to deploy CDR on a large scale, SRM strategies would be fairly cheap (Horton, 2015).

Engagement with SRM is controversial, especially because of the magnitude of uncertainties and risks related to its deployment: its novel and unpredictable nature could potentially create unanticipated, undesirable and perhaps irreversible consequences, whereas CDR generally involves more familiar technologies (Horton, 2015) and thus enjoys a – perhaps false – perception of safety. Despite their prospected effectiveness, neither of these approaches should be viewed as silver bullets: there exists a broad consensus that other actions, including curbing global GHG emissions and further adaptation measures should all be part of a broad package of responses to the climate crisis, and geoengineering might just disincentivize investments in decarbonization (e.g. Biermann et al., 2022). Nevertheless, as the voice of some geoengineering proponents is becoming more influential in international climate governance (Stephens et al., 2021), it is worthwhile to study this debate and its policy implications.

One SRM technique that has been put forward as particularly promising to sustain marine ecosystems and landscapes is marine cloud brightening, first postulated by the late climate physicist John Latham (1990, 2002). In his letter to *Nature*, titled *Control of global warming?*, Latham theorized that it should indeed be feasible to introduce small particles in natural, low-level clouds in a controlled way, in order to change the clouds' characteristics and thereby neutralize global warming. This technique would involve the injection of small aerosol particles, for example vaporized sea salt, into marine stratocumulus clouds (clouds with a maximum height of 2.5 kilometers) (Latham, 2012). The injection of the sea salt increases the number of cloud condensation nuclei: particles that attract water vapor

and cause it to condense. The increased concentration causes the clouds to be brighter, enhancing their albedo-effect and thereby allowing for local cooling of the earth's surface, sufficient to offset the warming effect of a doubled CO2-concentration. This technique would be especially useful at sea, where the number of cloud condensation nuclei is half of the concentration over land (Latham, 1990; 2002).

More recently, the idea of marine cloud brightening was taken up by other authors, investigating its engineering requirements (e.g. Connolly et al., 2014; Cooper et al., 2013) and possible climate impacts (e.g. Ahlm et al., 2017; Parks et al., 2015). It has been found that the unique characteristic of MCB – its ability to be deployed on a local or regional scale relatively easily – could open up a range of applications (Latham et al., 2014; McDonald et al., 2019), varying from polar sea-ice maintenance or restoration, to hurricane weakening and the prevention of coral bleaching episodes (Latham et al., 2014; Harrison et al., 2020; Latham et al., 2012, 2013, 2014; Salter, 2014; Keller, 2018; McDonald et al., 2019). Authors promoting this approach see considerable benefits to using MCB to regionally offset oceanic warming, such as the relative low cost of using the technology and the short amount of time it takes to reach significant results (Morgan & Ricke, 2010; Carnegie Climate Governance Initiative, 2021). Modelling studies predict that within the three regions identified as suitable for marine cloud brightening - the North East Pacific, the South East Pacific and the South East Atlantic - MCB could restore the sea surface temperatures to near the control values (Diamond et al., 2020). Moreover, it was found that when MCB was implemented along current emission rates, coral bleaching events cloud almost entirely be eliminated in all three regions (Latham et al., 2013).

Although regional marine cloud brightening thus provides a compelling case in the search for climate adaptation and ecosystem conservation methods, the scholarly work on climate engineering research and the governance thereof is largely internationally oriented (e.g. Brent et al., 2021; Gupta et al., 2020; Jinnah et al, 2019). While there is certainly relevance and urgency for such studies, Hester (2013) argues that existing multinational treaties that are being put forward as possible governance mechanisms for climate engineering, such as the United Nations Framework Convention on Climate Change (UNFCCC), the London Protocol and Convention and the Convention on Biological Diversity (CBD), might not be able to adjust to the scale and speed at which regional climate efforts are developing. More concretely, nations and private parties increasingly possess the technical know-how and financial means to undertake a climate engineering project in relatively little time, whereas decision-making under the treaties typically requires years of deliberation and effort prior to any collective approval (Hester, 2013). Moreover, Morgan et al. (2010) emphasize that not all regions are equally well-suited for solar radiation management, let alone marine cloud brightening. The consequent diversity in responses could make international consensus about the optimal level of interventions difficult or even impossible (Morgan et al., 2010). In short, the lack of international governance combined with rapid technological development and an increasing sense of urgency pave way for an empirically relevant movement in the direction of regional - or even local - applications of SRM, making adherent governance issues an interesting issue to explore.

Now that regions have been identified as a relevant scope for further research with regard to the governance of MCB experiments, it is still unclear which mode of governance is able to navigate the risks and uncertainties related to MCB, while enabling scientists and experts to gain a better understanding of the technology's effects on cloud-aerosol interaction and the magnitude of its consequences. Current risks mainly revolve around unanticipated – and possibly transboundary –

climatic effects, such as altered precipitation patterns (Latham et al., 2012). In an effort to curb such consequences, the United Nations Convention on Biological Diversity decided during its tenth Conference of the Parties (COP 10), to hold on to the precautionary approach and prohibit geoengineering field experiments (UN CBD, 2010). Although not legally binding, the recommendation by the CBD is widely referenced and recognized as having normative value (Gupta et al., 2020). The CBDs decision X/33 reads as follows:

> (*w) Ensure,* […] *in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering,* […]*, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention* […]; *"* (CBD, 2010, p. 5)

While the COP10's decision has been interpreted as a *de facto* moratorium on field testing by those opposing (solar) geo-engineering (Gupta et al., 2020), those who see the use of SRM techniques as inevitable in dealing with climate change use its non-legal basis to advance their research (Gupta et al., 2020; Grisé et al., 2021). Yet, there is no scientific consensus on the need for, or the desirability of SRM research. In addition, many technological and societal risks uncertainties remain, such as the lack of understanding of cloud-aerosol dynamics, the effects of marine cloud brightening on the (regional) climate, ecosystem and biodiversity, as well as societal and geopolitical impacts (Diamond et al., 2022). Despite the significant concerns from international political organizations, scientists from disciplines, environmental organizations and the broader public, there have been several manifestations of scientists calling for an end to the 'deadlock' on geo-engineering research in the years that followed the CBD decision (e.g. Parson & Keith, 2013; Morgan & Ricke, 2010; Long et al., 2015; Andersen, 2017). Moreover, when carried out on a small-scale, field experiments are being endorsed in highly influential assessments (Gupta & Möller, 2019) by the National Academy of Sciences (NRC, 2015; NASEM, 2021) and the Royal Society (Shepherd., 2012).

Despite the strong endorsement of field experiments by some influential actors, little is known about what would constitute a 'legitimate' field experiment in the eyes of relevant stakeholders, let alone how such projects should be governed (Florin et al., 2020). Morgan & Ricke (2010) have mentioned the need for an "allowed zone" for regional experiments, to be defined using several variables, such as the expected amount of *radiative forcing* (see: paragraph 2.1) that will result from the intervention, its duration, and the impact that the experiment might have on the regional environment and climate. The authors emphasize such an allowed zone would need to be informally audited within the scientific community working on geoengineering. Afterwards, while experiments may still be contingent on the regulatory framework within the country funding or hosting them, studies scoped within this zone should be able to proceed without approval of any international body, provided that the studies' requirements as publicly announced are complied with and results are made available transparently. The idea of setting boundaries has been endorsed by other authors (e.g. Wood & Ackerman, 2012; Haraguchi et al., 2015; Parson & Keith, 2013), but none have attempted to set them. Morgan & Ricke's proposal does however raise questions about the legitimacy of the scientific community to set such boundaries: how would a diverse community of geoengineering scholars be ensured, both in terms of

background and their positionality regarding (scalable) field research, and why would only scientists be eligible to audit boundaries of field testing? In addition, legitimacy is performative. It is not defined by one actors' actions, but rather *attributed* to by the perceptions of others (Yuille, 2020).

What's more, is that this "allowed zone" would merely address climate-physical concerns, brought up by a group of experts, leaving the mode of research governance and further enabling conditions of such an experiment out of the question. Indeed, the governance mechanism applied, combined with other contextual factors such as the strategic framing and the regulatory framework in place are seen as vital in enabling or hindering the implementation of emerging technologies (Ryan, 2015). Importantly, the three factors beneath all influence each other. For example, both stakeholder involvement and regulatory approval contribute to determining a project's acceptability (WHO, 2021), public perceptions about inadequate regulatory supervision of the technology can limit or speed up its development (Mandel, 2015) and strategic framing of a certain technology may result in regulatory and legal restrictions or incentives (Rejeb, 2020). The following sections briefly explain the relevance of each of these factors for enabling or obstructing marine cloud brightening experiments.

Over the past decade or so, social scientific research has started to explore public perceptions and acceptance of geoengineering technologies and, more recently, a growing interest in the governance of scientific research and technical experimentation has emerged (Bellamy et al., 2017). Governance here is defined using the definition from the literature on Responsible Research and Innovation, which will be elaborated upon later in this thesis (Chapter 3): a transparent and interactive process "*by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products.*" (von Schomberg, 2014, p. 39). Several important factors regarding ethical acceptability or legitimacy of geoengineering projects have been identified through workshops and public consultation, such as transparency in research funding decisions, open publication of project results and new regulatory structures (Pidgeon et al., 2013; Moore et al., 2015; Blackstock et al., 2015). Furthermore, focus groups and public engagement events have found that public concerns lie mostly with the controllability of geoengineering options, the possibilities to predict and reverse unintended effects, the cost-effectiveness of the deployed technology and the availability and capacity of democratic institutions to govern such projects (Macnaghten & Szerszynski, 2013; NERC, 2010). Finally, public consultation rounds have been able to produce three criteria for good geoengineering governance: "*greater reflexivity in the articulation of geoengineered futures, the prioritization of broadly "robust" options and decisions over narrowly "optimal" ones and the need to satisfactorily engage concerned publics before declaring geoengineering a legitimate object of scientific governance*" (Bellamy et al., 2017, p. 195; Bellamy, 2016).

Next to public perceptions, strategic framing is another essential element in the enabling or obstruction of experimentation with emerging technologies like marine cloud brightening. The strategic framing perspective recognizes that "*institutions, organizations, and actors attempt to establish their positions and values in a discourse on generally controversial topics and defend them against competing frames*" (Siebert et al., 2021, p.3). Framing is thus used as a mechanism to shape reality, question or criticize a situation and through this, achieve a certain reaction on or perception of the respective topic by other actors. Strategic framing can be carried out by selecting aspects of the perceived situation, and highlighting them when communicating in spoken or written text, thereby promoting a specific definition, causal interpretation, evaluation or recommendation for the topic at

hand (Entman, 1993). The strategic frame is deemed 'successful' if it resonates with the beliefs or opinions of the actor receiving the spoken or written text, and can in that way continuously reinforce certain beliefs about, in this case, marine cloud brightening. It is important to research the strategic frames used in the context of marine cloud brightening experiments, as they can (partly) offer an understanding of how a political or societal debate unfolds and how different orientations within the debate have emerged (Siebert et al., 2021).

Finally, the regulatory framework in the region constitutes a major factor in enabling or obstructing field experiments with technologies like marine cloud brightening. The relevance of the regulatory framework in place has been illustrated in earlier cases where the implementation of emerging, controversial technologies was at stake, such as the introduction of genetically modified organisms in the USA (Mandel, 2015). New technologies, especially as revolutionary as bio- or nanotechnology, disrupt the regulatory systems that are designed to handle existing concerns about a technology and its deployment. However, as emerging technologies are characterized by unknown types and magnitudes of risk, this creates a substantial challenge for its management, from which we should conclude that the traditional command-and-control regulation will not suffice (Mandel, 2015). Nevertheless, the regulatory framework in place remains relevant as it can allow room or restrict the development of marine cloud brightening field experiments.

Solar geoengineering and field experiments: a history of contestation

Up to this point, this introduction has contextualized marine cloud brightening research and experimentation, explained the relevance of regional applications of this technology and the significance of the governance structure, strategic framing and the regulatory framework for marine cloud brightening experiments. It logically follows that this thesis is centered on determining which regional, context-specific conditions enable or hinder the realization of small-scale MCB field trials. In an effort to uncover such underlying conditions, it is necessary to study an actual small-scale MCB field trial as a case. Recently, the first field trial explicitly using the term marine cloud brightening has been executed. The trial took place in March 2020 on the Great Barrier Reef in Queensland, Australia, and showed that the technological devices developed were indeed able to bolster the reflectivity of existing clouds above the reef (SIMS, 2020; Brent et al., 2020).

Similar experiments explicitly labelled as solar geoengineering field trials have been proposed over the years, but all have resulted in severe contestation eventually causing cancellation or postponement. A major example is the Stratospheric Particle Injection for Climate Engineering (SPICE) project, a collaboration among multiple UK universities and a British Aerospace company (Pidgeon et al., 2013; SPICE, 2022). The SPICE project aimed at investigating the possibility of stratospheric injections to mitigate global warming effects (SPICE, 2022). Ultimately, the experiment would involve testing the particles' effectiveness by pumping around 150 liters of water into the atmosphere by attaching a thousand meter long hosepipe attached to a zeppelin-like balloon (Pidgeon et al., 2013) (see Figure 1). According to Matthew Watson, the principal investigator of SPICE, an important factor in the cancellation of the project was "*the lack of rules governing* […] *geoengineering experiments*" (Cressey, 2012, p.1). Another mediating factor were questions surrounding the patent application for the transporting and dispersing technology the research would use. This application for intellectual property represented a possible conflict of interest, especially to the funding partners, in case revenues were to be made. Hence, the SPICE team decided not to proceed with the experiment, even though stakeholder consultation work and other preparations already were taking place.

A second highly controversial solar geoengineering experiment (Fountain & Flavelle, 2021) was scheduled to take place in 2021, in Kiruna, Sweden, as part of Harvard's SCoPEx project. With this project, heavily backed by private research funders, Harvard researchers intended to carry out a Stratospheric Controlled Pertubation Experiment (SCoPEx). This would include an equipment test and eventually, the local injection of aerosols into the upper atmosphere. Initially, the project was scheduled to take place in the USA, but was eventually moved to Sweden *"because of contractor issues."* (Fountain & Flavelle, 2021). In addition, US indigenous peoples protested against the experiment, stating that the testing would *"violate the sacred relationship between Mother Earth and Father Sky"* (UNHRC, 2022). Even though the National Academies' report uses SCoPEx as a positive example of public engagement for solar geoengineering decision-making (NASEM report, 2021, p.180), the indigenous community living in Kiruna, the Saami people, have explicitly opposed the field experiment (Saami Council, 2021), together with other environmentalists, such as research group What Next (Fountain & Flavelle, 2021). Ultimately, the public controversy around the project led to the postponement of the trial, until it "*can make a final recommendation about those flights based on a robust and inclusive public engagement in Sweden*", said the SCoPEx advisory committee (Fountain & Flavelle, 2021, p. 1). Not only did this reveal the sentiment of resistance regarding solar geoengineering within Indigenous communities globally, it also demonstrates how the deployment of public consultation processes *after* having already planned the full research program can backfire (Stephens et al., 2021; Frumhoff & Stephens, 2018).

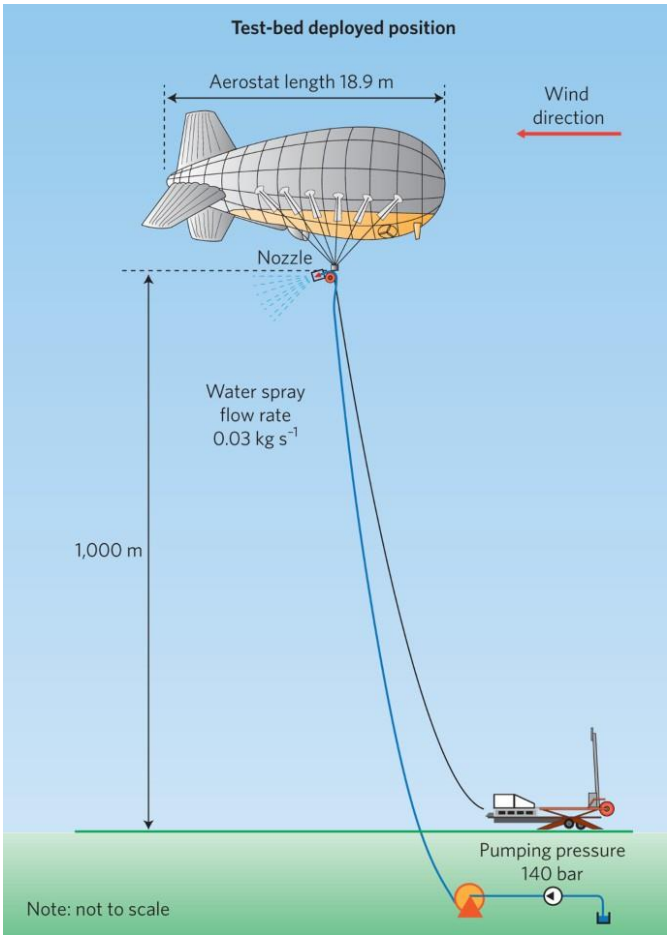

Figure 1 – Schematic overview of the SPICE test-bed proposal. Figure courtesy of Kirsty Kuo, Cambridge University, Engineering Department. Source: Pidgeon et al. (2013)

The third and final solar geoengineering project that should be mentioned here, is the Marine Cloud Brightening Project (or The MCB Project) that included field testing scheduled to take place in 2018 near Monterey Bay, California (USA). This multi-institutional research collaboration within the Atmospheric Intervention Research (AIR) Program at the University of Washington intends to *"develop a framework and associated technology that will allow the scientific community to conduct experiments to understand cloud processes with a much greater degree of control than has previously been possible."* (MCB Project, 2022). However, the project – financially backed by the Gates Foundation – received much backlash since its launch in 2010. Especially the Canadian environmental campaigners from the ETC Group and the Carnegie Climate Governance Initiative have been vocal about halting such unilateral marine cloud brightening experiments, with the ETC Group going as far as calling out "*Bill Gates and his cloud-wrenching cronies*" (Guardian Environment Network, 2010). Not

only environmental advocacy groups, but MPs from the Federal Science and Technology Committee criticized the project proposal, stating that unilateral action on geoengineering should be preceded by UN consultation, a lack of funding and technical challenges, the field test portion on the project has been postponed until further notice (Guardian Environment Network, 2010).

Concluding, while there are multiple (groups of) scientists calling for small-scale, regional experiments with MCB for over a decade, solely the Reef Restoration and Adaptation Project in Queensland, Australia has been practically realized so far, whereas – amongst others – the SPICE project, SCoPEx and The MCB Project have all been unable to. This indicates a unique context in the Australian case, leading to lower levels of contestation. In this thesis, I hope to contribute to a greater understanding of how such contextual factors, such as the governance approach, strategic framing and regulatory framework in place – influence the legitimacy of a project, consequently enabling or obstructing their realization. During a stakeholder consultation round by Stilgoe et al. (2013b) to gain insights on the role of public engagement in geoengineering governance, one participant noted: *"In geoengineering research, context is everything."* (p.5), further emphasizing the need to investigate MCB projects in their own entity in order to understand the factors that 'make or break' them.

Lastly, the broader relevance of this thesis needs to be touched upon. Considering that a multitude of potential topics of research in environmental governance currently exist in the aftermath of the sixth IPCC report, why focus on regional applications for marine cloud brightening specifically? First and foremost, marine cloud brightening is surprisingly under-researched. Although a small body of literature has focused on technical aspects of the technology and its applications, a thorough exploration of when and how marine cloud brightening field experiments have emerged in different contexts is not accessible as of mid-2022. Given that interest in solar radiation management for climate change solutions is growing as the climate crisis continues, now seems like the time for an analysis of the nascence of these experiments and the environments in which they can (or cannot) be born in. Moreover, as already shortly touched upon, there is a large likelihood that marine cloud brightening technologies will be implemented on a regional or national level by individuals or small groups of actors. This tendency underlines the urgency for studying the few cases there are of this phenomenon in order to better anticipate the roll-out of future experiments.

1.2 Aim and research questions

The overarching research aim of this thesis is as follows:

> *To determine in what ways performed regulatory, procedural and normative legitimacy have contributed to the relatively low levels of public contestation in the face of small-scale experimentation with marine cloud brightening on the Australian Great Barrier Reef.*

This overarching aim will be achieved by applying a theoretical approach informed by the literature on responsible research and innovation and anticipatory governance and technology legitimacy onto relevant data from primary and secondary sources.

Following this aim, the overarching research question that this thesis aims to answers to is as follows:

> *In what ways has the Reef Restoration and Adaptation Program performed regulatory, procedural and normative legitimacy and how has this performance contributed to the relatively low levels of public contestation of the small-scale experimentation with marine cloud brightening on the Great Barrier Reef?*

I intend to answer this main research question by breaking down the three types of legitimacy that are vital in enabling or obstructing field experimentation with marine cloud brightening technology: the procedural legitimacy, the regulatory legitimacy and the normative legitimacy. This leads to the following three sub-questions:

1. *In what ways was regulatory legitimacy performed by the Reef Restoration and Adaptation Project and how does this relate to levels of public contestation in the face of small-scale experimentation with marine cloud brightening on the Australian Great Barrier Reef;*
2. *In what ways was procedural legitimacy performed by the Reef Restoration and Adaptation Project and how does this relate to levels of public contestation in the face of small-scale experimentation with marine cloud brightening on the Australian Great Barrier Reef;*
3. *In what ways was normative legitimacy performed by the Reef Restoration and Adaptation Project and how does this relate to levels of public contestation in the face of small-scale experimentation with marine cloud brightening on the Australian Great Barrier Reef.*

1.3 Outline of the thesis

This thesis is divided into nine chapters. Chapter 1 has introduced the thesis, its aims and research questions. The remaining chapters are as follows:

Chapter 2 – Contextualizing Marine Cloud Brightening

In Chapter 2, a more detailed background of marine cloud brightening is presented. Building on the problem statement provided in the first chapter, it provides deeper and more technical information to the technology itself as well as its current technological as well as societal risks and uncertainties. Building on that information, this chapter also introduces the RRAP marine cloud brightening as a case by providing essential background information about the Program.

Chapter 3 – Conceptual Framework

Chapter 3 discusses the theoretical perspectives that are adopted throughout this thesis to analyze the governance of marine cloud brightening experiments. First, an overview of Collingridge's (1980) Dilemma of Social Control is presented, that describes the difficulties associated with adopting new technologies in society. Next, the chapter zooms in on a possible way out of this dilemma: responsible research and innovation (RRI) and discusses how this concept has been applied to geoengineering. The chapter then links this to another dominant concept in the field of governing emerging technologies: anticipatory governance, which is very similar to RRI but has some important nuances that offer some more clarity when performing the study's analysis. Finally, a section is added in which the shortcomings of both concepts are exposed. This section suggest to complement the core of the anticipatory governance framework with both a normative component and the regulatory environment to analyze levels of contestation surrounding marine cloud brightening projects.

Chapter 4 – Study design & methodology

In Chapter 4, the study's ontological and epistemological stances are discussed, followed by the methods and methodology adopted. Starting from the single, non-exemplary case study design, the chapter continues to describe the primary and data collected, as well as the collection process. The corresponding documents are listed in Annex I, II and III. The data analysis was carried out by performing a content analysis through deductive coding, which are both described and justified in the Chapter.

Chapter 5 – Regulative Legitimacy
The analytical portion of this study starts in Chapter 5, where the findings related to regulative legitimacy are presented. First, Australia's history with cloud seeding, a weather modification technique similar to marine cloud brightening, is described, followed by the current relevant regulatory framework. The Chapter continues to describe ways that the current regulative framework – or rather lack thereof – could be futureproofed to become fit for purpose in the face of upcoming cloud brightening experiments and eventual deployment.

Chapter 6 – Procedural Legitimacy
In Chapter 6, findings related to the procedural legitimacy performed by RRAP are discussed. First, existing engagement mechanisms are presented, including recommendations made by RRAP to update these structures to become suitable for future marine cloud brightening experimentation and deployment. Findings show that the RRAP researches attach great value to the engagement of and collaboration with a broad range of stakeholders, which is also reflected in the news articles analyzed. A particularly interesting topic is the engagement and involvement of Traditional Owners – the indigenous peoples of the Great Barrier Reef. This has proven to be an insurmountable challenge in the earlier SCoPEx experiment, where Swedish Saami Council strongly opposed field testing the equipment, partly because of procedural concerns.

Chapter 7 – Performed Normative Legitimacy
Chapter 7 provides an insight in the extent to which RRAPs mission aligns with Australian public norms. By analyzing news articles and combining codes with observations from RRAPs own engagement studies, several interesting observations have been made. First, the widely-used narrative of 'saving' the Great Barrier Reef and its moral appeal are explored. In addition, the specific way with which risks and uncertainties are portrayed is discussed, as well as the emphasis on the programs innovative character. Building on this, it was found that the marine cloud brightening is portrayed as a prestige project, arguably appealing to the Australian public as this aligns with historical aspirations as well as its current policy priorities. Finally, the (fragmented) criticism that was found in some articles is presented.

Chapter 8 – Discussion
In Chapter 8, the focus of the thesis shifts towards potential implications of the findings in the previous chapters for the broader politics and governance of geoengineering. Moreover, a more critical perspective is adopted, based on the findings, in order to shed light on the future of marine cloud brightening experiments. The chapter finishes with a discussion regarding the study's validity and limitations.

Chapter 9 – Conclusion
To conclude this study, Chapter 9 serves as a summary of the findings of the analysis performed in chapters 5, 6, and 7. Here, I offer some final thoughts and provide recommendations related to further research on the governance of marine cloud brightening field experiments.

Chapter 2 – Contextualizing Marine Cloud Brightening

This chapter is intended to contextualize marine cloud brightening technology in order to inform the rest of the chapters in this thesis, which require a basic understanding of marine cloud brightening technology, its promises, uncertainties and (political) implications. The chapter then continues to introduce the case that is studied in this thesis: the Reef Restoration and Adaptation Project (RRAP) in Queensland, Australia.

2.1 Solar radiation management

As introduced in the previous chapter, solar radiation management (SRM) or solar geoengineering can be broadly defined as a set of interventions that *"seek to reflect a small fraction of sunlight back into space or increase the amount of solar radiation the escapes back into space to cool the planet."* (Harvard University Center for the Environment, 2022). These interventions have the potential to offer high-impact options for managing the risks of climate change, of which the most discussed within the academic literature are stratospheric injection, marine cloud brightening, cirrus cloud thinning, as well as space-based techniques. The table below provides a short overview of these techniques, their cooling potential, based on preliminary climate modelling from Lenton and Vaughan (2009) and Ming et al. (2014). When ranked by *radiative forcing* (RF in table), defined as "*any imbalance in Earth's radiation budget caused by human or natural interventions in the climate system*" (Lenton & Vaughan, 2009, p. 5540). After such an intervention, the recovering of energy by the climate system can be observed through temperature change (Lenton & Vaughan, 2009). When expressed in radiative forcing, marine cloud brightening is expected to have a large cooling potential in comparison to other SRM techniques.

SRM technique	**RF**	**Description**
Stratospheric aerosol injection (SAI)	3.71	The injection of the stratosphere (6 – 20 km above surface) with aerosols like sulfur dioxide, alumina, or calcium carbonate that act as reflective agents, thereby enhancing the albedo-effect (Grieger et al., 2019).
Albedo increase of clouds, mechanical (including MCB)	3.71	The injection of small aerosol particles, for example vaporized sea salt, into marine stratocumulus clouds (clouds with a maximum height of 2.5 kilometers) (Latham, 2012).
Albedo increase of deserts	2.12	The laying of highly reflective material across the suitable desert areas (an estimated 2% of the Earth's surface) to enhance surface albedo. Project suggestions include covering 11 million km^2 in reinforced reflective plastic sheets. (Irvine et al., 2011)
Albedo increase of cropland or grassland (or bio- geoengineering, in e.g. Irvine et al., 2011; Singarayer et al., 2009)	0.35-0.55	The growing of (crop) plant varieties with a higher albedo than those that are currently grown. For specific crops at specific latitudes, the albedo is higher than that of natural vegetation, such as European barley. Next to replacing crops, managing plant properties can be also enhance the crop albedo, e.g. by editing leaf wax and the composition of the leaf canopy (Irvine et al., 2011).
Albedo increase by human settlement	0.15	By land conversion for settlement purposes, it is possible to enhance albedo, depending on the composition of settlements and the reflectivity of materials used. This is expected to work best in a context of warm climates (Akbari et al., 2012).
Albedo increase in urban areas	0.047	The increasing the reflectivity of existing surfaces in urban areas, such as rooftops and paved surfaces, albedo is enhanced. This works best in warm climates, where a possible project could be painting residencies in a white (or lighter) color (Akbari et al., 2012).
Albedo increase of clouds, by biological means	0.019	By means of natural phenomena, like volcanic eruptions, the cloud albedo might be enhanced. (Latham, 2012)

Table 1 – Overview of solar geoengineering possibilities, ranked by their radiative forcing or 'cooling potential'.
Source: adapted from Lenton & Vaughan, 2009; Ming et al., 2014)

Particularly, stratospheric aerosols injections has received much scholarly attention over the past decade, in which the risks and uncertainties of the method are often a topic of discussion. MacMartin et al. (2016) provide a reasonable logic for this interest, as they pose that a stratospheric aerosols intervention is "*not binary*": operators are able to decide not only on the amount of aerosols to inject, but also have the power to decide over the place (e.g. latitude), the timing (e.g. season) and the substance (composition of the aerosols). Each option will result in a different climatic effect.

2.2 Marine Cloud Brightening: promises and uncertainties

Marine cloud brightening, as defined by the NASEM report, is *"a strategy for adding particles to the lower atmosphere (near the surface) in order to increase the reflectivity of low-lying clouds over particular regions of the oceans."* (NASEM, 2021). Building on John Latham's theory stemming from the 1990s (see: Chapter 1), the technology has been further studied over the past decades by developing modelling tools (e.g. Korhonen et al., 2010; Jones et al., 2011; Latham et al., 2014) and the technological equipment that would be needed to disperse particles at sea (e.g. Salter et al., 2008). Most of the work on marine cloud brightening has been focused on whether – assuming that the technological puzzle will be solved – significant (global) cloud albedo could be achieved (Latham et al., 2014), which has not (yet) led to a conclusive answer. Multiple modelling studies indicate that the cooling potential of cloud brightening might be sufficient to halt global warming up to at least twice the pre-industrial carbon dioxide levels or *carbon dioxide-doubling* point, while other scholars argue that the cooling potential might unattainable (e.g. Alterskjær & Kristjánsson., 2010) Other work studies the climatic effects of marine cloud brightening through climate modelling, in a quest to predict how precipitation patterns, sea-ice cover and other climatic aspects might be affected (Latham et al., 2014). Although predicted effects are enhanced cloud reflectivity and thus an enhanced albedo, other effects, dependent on aerosol-cloud interactions, should also be considered (NASEM, 2021). Such climatic and surface effects are wide-ranging and dependent on many variables and scales, but could constitute of precipitation increase, changes in the probability of weather extremes, shifts in seasonal timing, agricultural changes, droughts, changes in the ratio of diffuse versus direct light coming from the sun, or effects on photosynthesis (MacMartin et al., 2016; Parkes et al., 2015). On cloud level, it should also be taken into account that the opposite of the theorized effect – decreased cloud reflectivity and albedo decrease in nearby regions through *entrainment* – could be effects of an MCB intervention, too.

Marine cloud brightening is surrounded by a myriad of uncertainties related to its effectiveness, its technological requirements, design strategies for implementation and its governance. On top of that, several implications for further climate action as well as society at large are to be considered. It should be established that the possible effectiveness (measured as radiative forcing) from marine cloud brightening interventions is dependent on time, location, scale, particle type (MacMartin et al., 2016), particle size and the amount of particles injected (Alterskjær & Kristjánsson, 2013). But on top of these variables, there is still a lot unknown when it comes to aerosol-cloud interactions (Wood & Ackerman, 2013), making the effectiveness (if at all) of marine cloud brightening very complex to measure. As current climate models rely on incomplete theoretical cloud formation processes, the accuracy with which climate responses can be predicted is limited (Wood & Ackerman, 2013; NASEM, 2021). In addition, these models also run into scaling issues: the commonly-used global-scale climate models cannot yet render the processes and variability in cloud formation processes, which take place on a micro-scale. Consequently, the model will form clouds at times and places that do not correspond with real-world observations, hampering the validity of its predictions (NASEM, 2021). A similar

shortcoming can be found in current satellite observations, which are able to detect mass-based metrics for aerosols, but tell us little about their composition, particle number and size and suitable monitoring techniques to deploy during and after interventions have yet to be developed (NASEM, 2021). Finally, significant challenges in the design and strategy of cloud brightening interventions are to be considered. MacMartin et al. (2016) lay down key uncertainties that require further scholarly scrutiny. For example, they state that uncertainty remains about the methods for establishing a causal link between climatic effects and the intervention, as well as methods for controlling the effects of interventions across timescales and spatial patterns.

Not only questions regarding MCBs effectiveness (and how to measure it) are prevalent. On the contrary, significant uncertainties regarding its governance and its implications for climate mitigation efforts (e.g. Morton, 2015) pertain. When it comes to the governance of marine cloud brightening, a major question that has yet to be answered is whether different types of interventions (depending on time and spatial scales, research or deployment-driven) require different types or of governance. Some scholars argue that small-scale experiments or projects may not warrant additional dedicated governance (Morgan & Ricke, 2010), or that subsequent risks may be managed by existing substate, domestic and/or international law (Reynolds, 2019), whereas others describe strong opposition to such distinctions, for example by environmental NGOs (Watson, 2014 in: Doughty, 2018). Another pressing question revolves around what a suitable governance framework might look like, what principles should be taken into account and whether or not to constitute a new governing body, or use an existing one (and if so: which one would be the most suitable). Again, perspectives on this vary widely. Two governance proposals stand out in the literature. One of these is the currently standing *de-facto* moratorium on geoengineering field testing and deployment by the Conference on Biological Diversity (CBD) (see: Chapter 1). Another proposal was introduced by a group of academics in 2009 and is referred to as 'the Oxford Principles' and was endorsed by the UK House of Commons and the Asilomar report (ASOC, 2010). Its founders summarize the principles as follows:

> *"Principle 1: Geoengineering to be regulated as a public good.*
> *Principle 2: Public participation in geo-engineering decision-making.*
> *Principle 3: Disclosure of geoengineering research and open publication of results.*
> *Principle 4: Independent assessment of impacts*
> *Principle 5: Governance before deployment."* (Rayner et al., 2013, p. 7-9)

Although the Oxford principles have played a pioneering role in the debate on geoengineering governance, they have also been challenged. For example, Gardiner and Fragnière (2020) argue that the principles are "*largely instrumental and dominated by procedural considerations"* (p. 13). In order to build a more robust framework, the authors argue that more emphasis should be laid on the ethical considerations regarding solar geoengineering, and that a debate on justice, respect and legitimacy is needed. Their Oxford-inspired 'Tollgate Principles" further integrate these values.

A final uncertainty that is worth mentioning in this paragraph relates to the implications of geoengineering. Both experiments and deployment, on small or large-scales, could have far-reaching implications for geopolitical relations, efforts towards climate mitigation and ultimately, more fundamental, moral implications. Although this thesis centers on a solar geoengineering technique with the purpose of mitigating the effects of climate change, these technologies could very well be used in a military context (e.g. Surprise, 2020), which adds a whole new layer to the geoengineering

debate. The impact of solar geoengineering deployment for military use poses such significant risks, leading some scholars to make a case for non-use (Biermann et al., 2022). Next to possible militarization of geoengineering techniques, further experimentation or deployment of solar geoengineering could also have implications for standing and future decarbonization efforts. A prominent view in this regard is that the solar geoengineering could constitute a 'moral hazard', which can be defined as *"the lack of incentive to guard against risk when one is protected from its consequences."* (Wagner & Merk, 2019, p. 135). Nevertheless, it is highly uncertain if and how further research or deployment would actually impact climate mitigation efforts. In their essay *Was breaking the taboo on research on climate engineering via albedo modification a moral hazard, or a moral imperative?* (2006), Lawrence and Crutzen describe how solar geoengineering might pose a moral problem of sorts, but that it also might be a moral problem *not* to discuss solar geoengineering. The verdict is still out.

In short, there are many unknowns revolving around the topic of marine cloud brightening and the wider topic of solar geoengineering. From uncertainties related to possible outcomes and effects, to uncertainty about aerosol-cloud interactions and various governance questions. Among others, Diamond et al. (2022) have tried to derive a possible roadmap for solving the puzzles that still lie ahead – although the fundamental question remains whether any advancement is desirable or not. The authors identified six 'critical science areas' that require answers in order to conclusively tell whether marine cloud brightening could be deemed feasible and effective, most of which relate to the technological gaps, such as the need for generators that are able to deliver appropriately sized particles, knowledge of local cloud response under different weather conditions, and an understanding of circulation and precipitation responses. Furthermore, they argue, the impact on marine ecosystems and coastal communities need to be assessed, where risks should be weighed against the risks of unmitigated global warming. Here, the involvement of scholars from a wide array of fields will be necessary to identify and answer the most pressing questions (Diamond et al., 2022).

2.3 The Case of the Reef Restoration and Adaptation Project

The Reef Restoration and Adaptation Program (RRAP) is a collaboration of Australia's leading experts in biotechnology, environmental engineering and other fields, aiming to create a suite of innovative and targeted measures to help preserve and restore the Great Barrier Reef (Hardisty et al., 2019). Marine cloud brightening is one of the several measures taken up in the program, such as reef shading by fogging, coral seeding by assisted larval movement and (semi)automated aquaculture and reef stabilization by using natural bonding agents (RRAP, 2021). Relevant stakeholders are the Australian Government (donor and client), and partners to the RRAP, the Australian Institute of Marine Science, CSIRO, the Great Barrier Reef Marine Park Authority, the Great Barrier Reef Foundation, The University of Queensland, Queensland University of Technology and James Cook University, augmented by expertise from associated universities (University of Sydney, Southern Cross University, Melbourne University, Griffith University, University of Western Australia), engineering firms (Aurecon, WorleyParsons, Subcon) and international organizations (Mote Marine, NOAA, SECORE, The Nature Conservancy) (Hardisty et al., 2019). The MCB experiment is aimed at cooling and shading the Great Barrier Reef by reducing acute heat and light stress (Hardisty et al., 2019). The technical description involves "*adding nano-sized salt (or other particles) to the lower atmosphere (< 1000m) to change the water droplet size distribution in clouds to enhance the reflectivity of clouds and restrict the amount of light that reaches reefs over distances large enough to also reduce heat*." (Hardisty et al., 2019, p. 65). The MCB experiment will cover 200 or more reefs, up to the whole Great Barrier Reef (Hardisty et al.,

2019), which is approximately 344,400 square kilometers (GBRMPA, 2021) over a timespan of about 10 years (Hardisty et al., 2019).

The MCB intervention is part of the subprogram 'Cooling and Shading'. No costs were provided for the MCB intervention specifically, but the projected costs for the first five years of the whole 'Cooling and shading' program would be 62.3M Australian dollars, followed by another 26.3M Australian dollars in the second five years of the program (Hardisty et al., 2019). The Australian Government funded the $6M RRAP Concept Feasibility Study and allocated a further $100M for reef restoration and adaptation science as part of the $443.3M Reef Trust Partnership (Taylor et al., 2019). Potential benefits from the project amount to $4.5B when combined with other RRAP projects (Hardisty et al., 2019). While there are risks of altered local weather and rainfall patterns, it is uncertain how exactly MCB will affect surrounding regions, i.e. if it would increase, decrease or would have negligible impact (Bay et al., 2019). The first small-scale field experiment was carried out in March 2020 (Brent et al., 2020), demonstrating the effectiveness of the developed technology to disperse sea salt aerosols.

Chapter 3 – Theoretical Framework

This chapter provides an overview of the bodies of research this thesis draws on and combines relevant elements of those into a theoretical framework underpinning the data analysis. First of all, the context of the theoretical framework will be thoroughly discussed by addressing the characteristics of emerging technologies and the dilemma of control they pose when diffused into society. Then, the chapter zooms in on legitimacy, the creation of which is particularly vital to mobilize resources or (regulatory) support for emerging technologies. After discussing the emergence and development of the concept within the body of institutional theory, the chapter moves on to focus on the key types of legitimacy relevant for analyzing the context-specific performed legitimacy of MCB field experiments: *throughput* or *procedural legitimacy*, *normative legitimacy* and *regulative* legitimacy. After introducing these concepts, a theoretical framework for analyzing and assessing the performed legitimacy by MCB field testing projects within the USA and Australia is presented.

3.1 Characterizing emerging technologies

There has been significant attention for emerging technologies within academic research, especially from a policy-making perspective (Rotolo et al., 2015). However, no standard definition exists for what 'emergent' actually signifies: some definitions focus on the potential impact of the technology on the socio-economic system (e.g. Porter et al., 2002), while others emphasize the uncertainties associated with the emergence of the technology (e.g. Boon & Moors, 2008). A specific understanding of 'emergent' is also dependent on the researcher's perspective: while some may believe an technology is emergent because of its anticipated impacts, others may see the same technology as a mere extension of a pre-existing one. A review of the literature by Rotolo et al. (2015) has led to an integrated characterization of emerging technologies, noting five essential attributes. First, emerging technologies possess a 'radical novelty', signifying the use of a different basic principle in comparison to what was used before to fulfil the same function. Second, these technologies show a relatively fast growth compared to settled technologies, although this remains difficult to measure. Third, the authors show the technology should possess a certain level of coherence, generating its identity so it stands out from other technologies still in flux. Fourth, emerging technologies are expected to have transformative effects on the socio-economic system by changing relations, interaction patterns and knowledge production processes among societal actors. Finally, emerging technologies are characterized by uncertainty related to effects and applications, and divergent public sentiment towards the technology (Rotolo et al., 2015).

Understandably, these characteristics lead to the particular challenge for scientists, policy makers as well as society at large to develop ethically sound strategies to cope with them (Stilgoe et al., 2013; Moor, 2005). Moor (2005) poses the hypothesis that the number of ethical issues that arise develops along with the technology. In the introduction stage of a technological transformation, there are few users and limited applications of the technology, resulting in a relatively small number of ethical issues that emerge (Moor, 2005). In the second phase, the 'permeation stage', the number of users and applications increases as the technology diffuses into society, thereby also generating more ethical issues. In the final 'power' stage, the technology has become deeply embedded: it has become widely used and has had a significant societal impact, and are expected to generate even more ethical issues as the technology matures and develops further. For example, artificial intelligence technology currently sparks ethical debates almost constantly, from a variety of perspectives and disciplines. This phenomenon can be explained by the transformative character of emerging technologies, housing the

potential to offer numerous applications for which carefully deliberated ethical policies will not have been developed (Moor, 2005). Although geoengineering technologies are mostly still in a conceptual stage of development, ethical issues related to them are likely to develop along this path, as they are driven by the conception of climate malleability: they offer humans the opportunity to 'engineer' the climate, just as genetic technologies offers life malleability, allowing new (forms of) life to be created. Moor argues that technologies offering such fundamental capabilities are very likely to be further developed and have societal impact (Moor, 2005).

As technological progress in some areas is so diffuse and hard to define, there seems to be a general tendency to group them together under 'general labels', such as nanotechnology, synthetic biology or climate engineering, even when actual capabilities, methods and aims may be very distinctive (Parson, 2017; Rotolo et al, 2015). This tendency towards what Parson (2017) calls 'weakly defined technologies' could potentially create a controversy surrounding the respective technology: its general label can 'take on a life of its own' in public and policy discourse and is consequently subjected to polarizing claims about large benefits or extreme harms, and the associated calls for policy and regulatory support or control (Parson, 2017). In the geoengineering debate, too, the umbrella term of geoengineering or 'climate engineering' has become the focal point for conflict over risks, even though there are considerable differences in terms of environmental and security risks between CDR and SRM, as well as differences within these umbrellas. Parsons (2017) argues that this mismatch, ironically, is detrimental to controlling the risks posed by the technology: aggregating terms may hinder a well-informed debate, generating polarization over definitional arguments. In addition, when trying to devise concrete controls in the form of regulation, this misrepresentation may result in over- and under-inclusiveness of regulation, as well as easy-to-evade regulatory systems (Parson, 2017).

3.2 Emerging technologies in society: a Dilemma of Social Control

Emerging technologies present a social and regulatory difficulty, challenging scientists and policy makers to deliver on the technology's anticipated benefits, while shielding from its risks, particularly when these are not well-understood yet (Mandel, 2009). In his book 'The Social Control of Technology', David Collingridge (1980) illustrates this dilemma in detail. Collingridge starts by two major technological revolutions at the time: the Green Revolution, introducing new, highly productive varieties of wheat, maize and rice in developing countries in order to feed the world's poorest, and the American Manhattan Project, which at an unparalleled intensity of research and development produced the world's first atomic bomb. The outcomes of these developments are perceived to be very different: the Manhattan project being a success and the Green Revolution a failure. Collingridge argues that this is because the Green Revolution did not merely have a technological objective, as it has been highly successful from this perspective, but unfortunately failed to fulfil its societal goals. The program seemed to have a complete lack of understanding of how its technical products would interact with the societal system using them. As this is the case for many technological advances, Collingridge concludes that while the technology thus often performs in the intended way, innovations also prove to have unintended social consequences, fueling a growing hostility towards technological development.

Thinking about how to better *control* technology so as to avoid such undesired effects, Collingridge poses the dilemma of social control: in order to avoid harmful social consequences, it must be known the technology poses such harmful effects and one must be able to change the technology to eliminate their causes. However, in the early stages of technology development, not enough knowledge has been

gathered to install an appropriate management regime with regards to risks towards society, the economy and perhaps the environment. Simply put: in this stage, not enough is known about possible hazardous elements. When detrimental effects surface after introducing the technology in society, the technology might have already become embedded in its structure, making it far more difficult to change than during the development phase. On the other hand, however, controlling innovation in an extremely risk-adverse manner could lead to a moratorium on development, thereby withholding societal and economic progress from the governing party's constituency. It should be stated that 'control' in this dilemma is multi-faceted and that controllability can be directed to a variety of concerns, such as uncertainty of experimental outcomes and the reversibility of impacts (Bellamy et al., 2017).

Collingridge defined the complex relation between anticipation and resilience in such a crisp manner, that his hypothesis of the dilemma of social gained a lot of attention (Parson, 2017). Since the dilemma was first articulated, it has been a reference point for many scholars within the field of science and technology studies, particularly those involved in studying the sociology of knowledge (e.g. Johnston, 1984; Ravetz, 1987; Smithson, 1989; Smit, 1995; van Eijndhoven, 1997). Various scholars have even added to his proposition (e.g. Ludwig et al., 1993; Ribeiro et al., 2018; Nordmann, 2018), for example by emphasizing the tension between knowledge and control in the field of natural resource extraction for human exploitation (Ludwig et al., 1993). However, the experience of the several decades since the formulation of the dilemma of social control shows that the tension is not as disabling as its starkest formulations would suggest (Parson, 2017). As Guston (2018) argues, the dilemma might not even be a true *dilemma* – or at least "*not the soundest of all*" (p. 348) – as there seem to be ways to surmount the dilemma in practice.

Parson (2017) poses two potential responses to the tensions Collingridge describes. He starts by suggesting to open up risk assessments "*to inquiries that are more speculative and explorative […] without giving up disciplined, critical inquiry*" (p. 485) in order to address insufficient knowledge conditions. Secondly, regarding the increasingly uncertain control conditions under which decisions need to be made, Parson suggests a wider range of scope and form of controls, specifically in the earlier, more malleable stages of technology development. Similar contributions have been made by other scholars, resulting in a vocabularies of 'precaution', 'participation' and 'engagement', which have been substituted over time by the language of responsible research and innovation (Owen et al., 2012, 2013, Stilgoe et al., 2013b; Von Schomberg, 2013).

3.3 Dealing with the Dilemma: Responsible Research and Innovation

Responsible Research and Innovation (hereafter: RRI) recognizes the complex knowledge and control conditions relevant when new technologies are introduced to society and aims to investigate new courses of action to deal with these challenges (Stelzer, 2020). There are multiple definitions of RRI, and according to Burget et al. (2017), the meaning of RRI is still under construction. However, there are several often-cited definitions in the literature by Stilgoe et al. (2013b) and von Schomberg (2014). Stilgoe's definition provides a broad, general idea of what RRI is: "*taking care of the future through collective stewardship of science and innovation in the present.*" (p. 1570), while von Schomberg provides a more detailed explanation and focusses on RRI as a transparent and interactive process "*by which societal actors and innovators become mutually responsive to each other with a view to 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)." (2014, p. 39).

The concept's roots stem from uneasiness over the technological 'lock in' (Collingridge, 1980), questions over growing uncertainty and ignorance in knowledge production, concerns about the societal relevance and impact of science, as well as the role of public participation in the scientific process (Owen et al., 2012). The term 'responsible innovation' can be traced back to the beginning of this century (e.g. Hellstrom, 2003). Paralleled with critiques on scientific research regarding its purpose, ethics, social acceptability and governance (Owen et al., 2021), interest in the concept heightened, especially when RRI was adopted within the European Commission's Science in Society program in 2011 (EC, 2011; Owen et al., 2012; de Saille, 2015). RRI recognizes the limits of ordinary policy processes when trying to manage emerging technologies surrounded by controversies, such as geoengineering (Owen et al., 2012). A notable example of these shortcomings can be illustrated through the example of the SPICE project (Stratospheric Particle Injection for Climate Engineering), by missing out on insights and concerns that could only have been found through public consultation (Stilgoe et al., 2013b; Stilgoe, 2015). The emergence of ethically controversial technologies like geoengineering have thus prompted an increasing trend at the policy level to rethink the linear models of science *in* society, to science for society, *with* society (Owen et al., 2020). This creates a particular relevance to investigating how geoengineering governance might become more "socially robust" (Stilgoe et al., 2013a). To that end, Owen et al. (2012) suggest four dimensions of RRI, constituting a commitment to be continuously (1) adaptive, (2) reflective, (3) deliberative and (4) responsive.

This initial framework has been adapted to a range of disciplines and was adopted by Parkhill et al. (2012), Stilgoe (2015), Rayner (2017) and Stelzer (2020) to fit the geoengineering context. In his book 'Experiment Earth: Responsible Innovation in Geoengineering', Stilgoe (2015) discusses four, slightly altered dimensions:

1. *Anticipation* implies that scientists and others governing geoengineering projects should think about unknowns, aiming to increase resilience when – not if – facing surprises. Here, the intention is not to make predictions, but rather think over various possibilities or likelihoods, and therefore asks for multiple perspectives to be involved.
2. *Inclusion* emphasizes the need to include a diverse group of non-scientists in geoengineering research and its governance.
3. *Reflexivity* in the context of science and innovation means that both scientists and those governing innovation within the science-policy interface should remain critical of their own "*social, ethical, and political assumptions and being mindful of commitments, aware of the limits of knowledge and conscious that a particular understanding of an issue may not be universal."* (Stilgoe, 2015, p. 37).
4. Finally, responsiveness towards publics questioning the responsibility of science and innovation should be at the core of a future framework for geoengineering research.

Besides Stilgoe's book (2015), several authors studying public perceptions and social acceptability of climate interventions have touched upon one or more of these dimensions within their studies, and have continuously pressed the importance of involving contextual factors and external perspectives (e.g. Bellamy et al., 2017; Stelzer, 2020, Florin et al., 2020). Moreover, principles discussed at the Asilomar Conference (ASOC, 2010) and the Oxford principles for geoengineering governance (Rayner

et al., 2013) include several (modified) dimensions of RRI and provide an initial starting point for discussions regarding responsible research and innovation in practice.

Although the RRI framework seems particularly suitable for the governance of geoengineering, there are some noteworthy shortcomings. The concepts that are put forward by RRI scholars are mainly focused towards the creation of better suited participatory and engagement structures. However, research shown that participatory procedures do not legitimize the development of the technology per se (e.g. Grunwald, 2004). Grunwald (2004) states that if the participatory procedure is intended to contribute to the legitimization of decisions, in this case the decision to perform a regional, small-scale marine cloud brightening experiment, it still needs to fulfill a number of prerequisites in the procedural, substantial, social and evaluative dimension. Thus, the attainment of legitimacy for regional marine cloud brightening experiments through an inclusive, responsive, anticipatory and reflexive process cannot be expected automatically (Grunwald, 2004).

The shortcomings of participatory processes have been previously illustrated in a geoengineering context by the SPICE Project (Stilgoe et al., 2013b), which involved a stakeholder engagement process over a series of months. SPICE used the so-called "stage-gate process", developed and imposed by the project's funders, the UK Research Councils (Stilgoe et al., 2013b). This stage-gate process could be seen as a possible operationalization of the RRI dimensions by Stilgoe (2015) mentioned before (Stilgoe et al., 2013a). Although a participatory process based on RRI dimensions was thus in place, the SPICE project was eventually cancelled before deployment, showing the limits of RRI governance (Stilgoe et al., 2013a). Stilgoe et al. (2013a) mention the need for proper regulation on geoengineering research in order to continue field testing and Stilgoe et al. (2013b) show the importance of *intent* or *purpose* in public and policy support for experimentation with stratospheric aerosol injections. And thus begs the question: what else is needed for a geoengineering experiment to be perceived as legitimate?

3.4 The Role of Legitimacy

The concept of legitimacy first emerged in the literature on institutional theory and has become one of the theory's central concepts (Deephouse & Suchman, 2008). In his influential article, Suchman (1995) conceptualized legitimacy as "*a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.*" (p. 574). This broad conception entails two key characteristics shaping legitimacy. First, legitimacy is a *perception or assumption*, and thus represents the way actors from outside of the organization experience, view or react to the organization. This creates an interesting tension: while legitimacy can, in theory, be possessed objectively by, for example, an organization or government, the process of creation is subjective (Suchman, 1995). Second, legitimacy is socially constructed by the dynamics between the behaviour of the (un)legitimate actor and the shared values and beliefs of a societal group. It is therefore dependent on the public, but independent of individual perceptions: although certain behaviour may not match individual norms and values, it may still hold its legitimacy if this 'mismatch' does not spread onto the wider public (Suchman, 1995).

So why seek legitimacy in the first place? For governments and other types of organizations, there are multiple motivations to obtain legitimacy. However, motivations always relate to some extent to the factors: *persistence, credibility* and *support* (Suchman, 1995). Legitimacy both enhances the stability and the comprehensibility of activities performed by an actor, and they enhance each other. On one hand, legitimacy increases stability or persistence, because publics are more likely to supply resources

and support to organizations that appear to be desirable and appropriate (Suchman, 1995). Simultaneously, legitimacy influences not only people's attitude towards organizations, but also the way they perceive and understand them. In the eyes of the public, a legitimate organization is therefore not only more worthy of their resources, but more meaningful, predictable and trustworthy than others (Suchman, 1995). Another motivation to seek legitimacy centers on the need for support, either active or passive. If an organization simply wants a particular audience to accept its existence and thus support it 'passively', the threshold of legitimation may be quite low. On the other hand, if the organization desires its audience to intervene in any kind of way, for example by choosing the organization at hand over its competitors, legitimacy demands rise (Suchman, 1995).

So far, the section above broadly discussed the concept of legitimacy, applying an institutional perspective. However, legitimacy can also be attributed to different entities, such as individuals, business models, industries and – of particular relevance for this thesis – technologies (Aldrich and Fiol, 1994). Legitimacy in relation to technologies becomes especially salient when discussing novel, emerging technologies that are radically different from others, as they are highly dependent to mobilize *credibility*, resources and regulatory or financial *support* (Aldrich and Fiol, 1994; Zimmerman & Zeitz, 2002), factors corresponding with the key motivations to seek legitimacy. Legitimacy for an emerging technology can be constructed, again, in a collective process of social interaction, and involves a varied set of actors and organizations (Bergek et al., 2008). Here, it should be noted that a certain technological paradigm is not legitimate (or illegitimate) in itself, but always consists of higher and lower scores on the various aspects of legitimacy, which will be discussed in the next section of this chapter.

3.5 Theoretical Framework: The influence of Legitimacy on Contestation of Small-scale Solar Geoengineering Experiments

Over time, scholars have distinguished different types of legitimacy that have been deemed relevant for assessing overall technology legitimacy: cognitive, normative, regulatory and pragmatic legitimacy (e.g. Aldrich & Fiol, 1994; Suchman, 1995, Jansma et al., 2020). Cognitive legitimacy relates to the comprehensibility of the technology, the extent to which it is known, understood and, when integrated into society, taken for granted. Normative legitimacy refers to the extent to which the technology conforms with societal values, norms and beliefs. Regulative legitimacy is logically related to the formal rules, laws and regulations that apply to the context in which a technology operates, and tests the compliance of the technology to the regulatory context. Finally, where normative legitimacy relates to the technology's applications for society, pragmatic legitimacy is focused on the utility of the technology's developers and its direct audiences, "*'what is in it for me'*" (Walker et al., 2014, p. 198). Although the distinction between different types of legitimacy above is clear and well-established, "*possible pathways for establishing solar geoengineering field research as legitimate are less clear*." (Frumhoff & Stephens, 2018, p. 3). Nevertheless, the marine cloud brightening experiment carried out in Australia and the seeming absence of contestation in the public discourse, may offer new insights into what a legitimate regional marine cloud brightening experiment may entail.

The literature shows that three factors are considered to be of essential importance in the obstruction or enabling of an emerging, high-risk technology's implementation into society: the project's governance arrangements and levels of engagement and participation (as illustrated by the literature on RRI), its compliance and compatibility with existing regulations on the technology, as well as the dominant frames used to describe the technological development, resulting in a dominant public

discourse (e.g. Williarty, 2013). Moreover, these three factors influence each other, as framing and communication have implications for the public demand for regulation and governance (Tingley, 2019) and on the public support for further funding of the technology (Scheufele & Leeuwenstein, 2005). On the other hand, public trust in institutions and regulations in place is paramount in shaping the public perception on the technology (Hofmann et al., 2020). These three factors, essential to the obstruction or enabling of experimentation with or implementation of emerging technologies, have a strong link with three types of legitimacy, two of which were briefly described above: Cognitive and pragmatic legitimacy, seem unsuitable to apply to the context of marine cloud brightening, as the technology is still emerging, there is very little knowledge about its benefits, risks and implications, and therefore it would be hard to measure how the added value ("what's in it for me") is understood by the public. To conclude, in order to understand the technology legitimacy of marine cloud brightening as proposed by RRAP, I will be assessing in what way(s) these types of legitimacy were present in these cases could indicate the alignment of the technology with its context, as Markard et al. (2016) phrased it.

3.5.1 Regulative legitimacy

This study takes the approach of regulative legitimacy as a condition which reflects *how well something is perceived to adhere to certain quasi-legal rules or laws* (Johnson et al., 2006; Kaganer et al., 2010; Ahn et al., 2013). Regulative legitimacy thus flows from what institutions in power define as legally acceptable (Johnson et al., 20056; King et al, 2004), where organizations (and technologies) operating in accordance with those rules possess high legitimacy, whereas those that require regulative changes appear less legitimate (Binz et al., 2016). Regulative legitimacy is particularly salient in technological fields in which societal concerns (such as human or environmental safety)are predominant, as they often require significant oversight of the technological development. For geoengineering and the execution of field experiments with marine cloud brightening more specifically, that is certainly the case, making this dimension important to explore. Particularly in the light of the previously cancelled SPICE experiment (Chapter 1), the regulatory environment governing geoengineering experiments could be one of the 'make or break'-factors for the realization of field testing plans. In the context of organizations planning field tests with emerging technologies, achieving this kind of legitimacy can be tricky, as the existing laws are often not (yet) specific about which technology and which procedures are legitimate – and which are not (Väyrynen & Lanamäki, 2020). In these cases, regulative legitimacy could be achieved by aligning new practices with existing rules, laws and regulations (Zimmerman & Zeitz, 2002; Hargadon & Douglas, 2001) or modifying institutional arrangements to improve acceptance of the innovation (Mokyr, 2016). Other scholars, such as Kaganer et al. (2010), state that communication aspect is important, too: it should be strongly emphasized that the technology conforms to the effective laws regulating the technology.

3.5.2 Procedural or 'throughput' legitimacy

Throughput legitimacy may be defined as a *"procedural criterion with the quality of governance processes, as judged by the accountability of the policy-makers and the transparency, inclusiveness and openness of governance processes"* (Schmidt & Wood, 2019, p. 728). Especially in highly complex modern environments, bodies of power have sought new ways of legitimating their authority. One of these has been the broader move to secure better throughput legitimacy through participatory initiatives designed to include affected citizens and civil society actors in the process of policy formulation. Before, creating legitimacy in governance processes often focused on 'input' legitimacy, or "*the extent to which the regulations are perceived as justified*" (Mena & Palazzo, 2012, p. 1) and/or 'output' legitimacy, or "extent to which the rules effectively solve the issues" (Mena & Palazzo, 2012,

p. 1) . The participatory processes that are part of throughput legitimacy however, prioritize openness and inclusiveness of the process of decision-making itself, rather than focusing on the substantive outcome of the process (e.g. Nabatchi, 2010). Throughput legitimacy offers distinctive normative criteria - accountability, transparency, inclusiveness and openness - and points towards substantive institutional reforms, just like theory often linked to the governance of geoengineering (experiments): responsible research and innovation and anticipatory governance. In the context of the legitimation of geoengineering field testing, it is therefore vital to consider the influence of throughput legitimacy.

3.5.3 Normative legitimacy

The normative pillar of legitimacy relates to a deeper, moral basis of legitimacy and involves judgements about whether something – e.g. a technology, an intervention – contributes positively to society (Suchman, 1995). Such judgements are based on sets of shared norms and values that have been socially constructed over time. Values, according to Scott (2013), are *"conceptions of the preferred or desirable, together with the construction of standards to which existing structures or behaviors can be compared and assessed"* (p. 64), while norms specify legitimate ways what and how something should be developed. Ultimately, when normative legitimacy is achieved in its highest form, these judgements are perceived as objective and natural by the actors. The emphasis of the normative pillar is on promoting broad pro-social logics of justice and welfare (Suchman 1995). Legitimate organizations, technologies or experiments, then follow the moral obligations of a given place and/or culture. New ideas that conflict with the existing normative order, are often seen as less legitimate and are thus more likely to face public contestation (Binz et al., 2016). In the context of geoengineering and field experiments, arguments on both sides of the spectrum are often partly emotional or moralizing, focusing on climate justice or the desirability of techno-fixes for global warming (e.g. Heyward, 2019). This indicates the clear presence of a normative pillar when legitimizing geoengineering experiments. In the context of geoengineering, scholars have already hinted at the importance of *purposes*, but so far the direct link to normative legitimacy has not been drawn. For example, Stilgoe et al. (2013a) wrote that *"geoengineering is defined by its intent, its statement of purpose* (p. xxx), acknowledging that the discussion and governance of purposes will be difficult.

3.6 Operationalization

In order to effectively answer the research questions posed in Chapter 1, three key concepts need operationalization: performed regulative legitimacy, performed procedural legitimacy, and performed normative legitimacy. The theories described earlier in this chapter provide a backbone for this operationalization, and to that end they are brought together in a theoretical framework. In Figure 2, the theoretical framework for this study is visualized. Here, the Dilemma of Social Control provides the background against which weakly-defined technologies emerge, (the legality of) their experimentation and deployment dependent on decision-makers. Previous experiments have shown that contestation can provide a hurdle to technology deployment (Pidgeon et al., 2013; Fountain & Flavelle, 2021), whether protest is coming from the public at large, the scientific community or effective lobbying by policymakers or industries. It could be argued that the way *legitimacy* is performed by the initiators of the field testing experiment plays a large role in the emergence of contestation around a certain experiment, consequently also influencing the decision on its deployment. In particular, the performed regulative, procedural and normative legitimacy are likely to influence contestation levels.

In this study, contestation is defined as a variety of actions to be taken by any stakeholder involved in or affected by the field experiment in order to obstruct, delay or cancel the experiment taking place.

This could be through formal communication channels, such as by writing letters to officials with a decision-making mandate over the field test, by influencing the public sentiment through media coverage, or by organizing public protests. Contestation thus has no single definition and can be expressed in many different ways. As some form of contestation is likely to take place, regardless of the specific intervention, the consequences of contestation provide a scale by which to interpret the level of contestation. For example, a low level of contestation could be a situation in which when the actions taken by those contesting the experiment – e.g. stakeholders involved in or affected, or others – do not significantly alter the planning and execution of the field test. The level of contestation would be high when, due to any form of contestation, the experiment would be obstructed, delayed or, ultimately, permanently cancelled.

In relation to the three legitimacy dimensions, no predefined indicators are set out. This will allow for a more holistic interpretation of the findings. Nevertheless, a few examples can be defined beforehand. For regulative legitimacy, the precense of legislation, directives or guidelines designed for or directly incorporating marine cloud brightening, are a sign of regulative alignment. For procedural legitimacy, the existence of engagement mechanisms, as well as the extent to which they allow a large spectrum of stakeholders to engage, participate and/or co-design could be indicators of a legitimate procedure. Here, special attention should be paid to indigenous communities (Mettiäinen et al., 2022). For normative legitimacy, indicators are even more 'open', but the alignment between public norms and the *purpose* or intent of the project should be aligned. Examples of such a norm could be e.g. the importance of climate action, or the sense of urgency to act on climate change. Figure 2 brings together the theoretical concepts introduced in this chapter in, expressing how, in a context determined by the Dilemma of Social Control, the performance of regulative, procedural and normative legitimacy influence the contestation of field testing emerging technologies, such as marine cloud brightening.

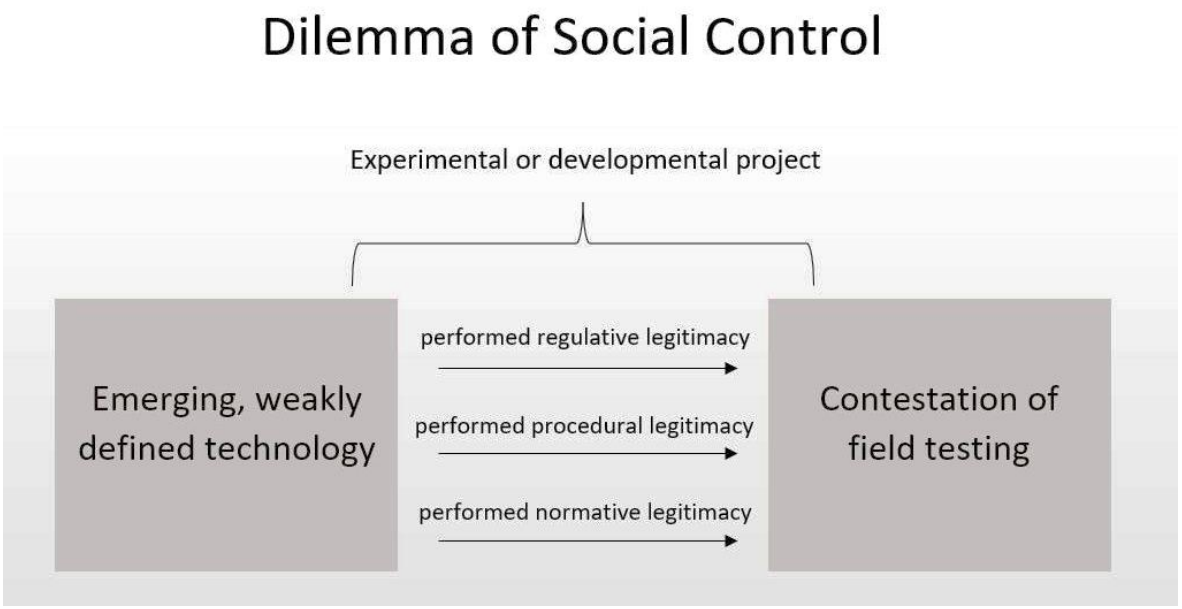

Figure 2 – Framework for analyzing the theorized relationship between emerging technologies and the legitimacy of small-scale field research

Chapter 4 – Study design

This chapter discusses the methodology adopted to carry out the empirical analysis and the underlying assumptions that have informed this approach. The chapter starts by exploring the philosophical background of the study design in order to set the stage for the rest of the methodology. This will be followed by an explanation of the data collection method, including a justification for the sampling strategy and an overview of all collected materials. Consequently, the specific methods for the analysis of the data are introduced, justified and elaborated on in detail.

4.1 Research Paradigm

This study is deeply rooted in constructivism, a theoretical paradigm that can be broadly characterized by its regard of reality as *'socially constructed'* by the actors present in the research process and this complex world is best studied through the lived experiences of those living it (Mertens, 2015). The key ontological, epistemological and methodological assumptions of the constructivist paradigm will be discussed below, making the rationale behind the particular research approach chosen for this study as explicit as possible.

Ontology is the study concerned with what constitutes reality (Lee, 2012). In the constructivist paradigm, reality is assumed to be constructed in social interaction by the actors in the research process, resulting in different versions of reality among those actively constructing it (Lee, 2012) This research assumes that no true or 'correct' reality exists, and therefore adheres to the tradition of relative ontology (Lee, 2012). This implies that the study performed is merely a depiction of the researcher's own reality. Nevertheless, this is not to say that this study considers all versions of reality to be equally valid in all contexts (Manning, 1997). Although there are endless options choosing from (sometimes competing) frames and interpretations of reality to base the arguments presented in this thesis on, some of these interpretations may be more credible than others given the context and aim of the study (Manning, 1997).

With regard to *epistemology*, or the study of how knowledge is created, obtained and transferred (Cohen et al., 2007), this study adheres to the notion of 'subjectivist epistemology'. This epistemological stance answers the question of how knowledge is created by stating the impossibility to separate the inquirer of knowledge from the actor who's knowledge is inquired into (Manning, 1997). This position stems from the fundamental belief that the interaction between the researcher and the researched-into – whether this is actors or objects- creates, through interpretation, the information relevant to the research. As such, the knowledge gained in this thesis is seen to be shaped by a dynamic inquiry process, whereby my own questions, observations and comments shape the knowledge interpreted from the interviews and documents, while these sources themselves simultaneously influence the meanings I ascribe to them (Manning, 1997).

4.1 Case Study Design

This thesis aims to discover how different types of legitimacy performed in RRAP's marine cloud brightening proposal on the Australian Great Barrier Reef have influenced the relatively low levels of public contestation regarding the project. To be able to uncover those practices, a case study design was adopted with RRAP's proposed marine cloud brightening intervention as a selected case. A case study design was deemed most suitable, as it allows for a holistic insight and understanding of a phenomenon (Kumar, 2011). A case study approach can be adopted when the focus is laid on either a

very representative or extremely atypical case (Kumar, 2011), where the case of the RRAP marine cloud brightening proposal can be seen as 'extremely atypical' because of the low levels of public contestation the proposal has received in comparison to other solar geoengineering projects or field tests. The atypical character of the RRAP proposal might therefore inform the existing literature on how legitimacy aspects of marine cloud brightening projects may influence public contestation. This would be a valuable contribution in the light of the discussion around solar geoengineering governance, especially as the scholarly work on the governance of technology-specific interventions is marginal. It is well-understood that a case study of this nature cannot claim to make any generalizations beyond the case that was selected (Kumar, 2011), and that future unique cases may very well possess unique attributes that could vary from the RRAP case.

Although it would have certainly been very insightful and valuable to have compared the RRAP marine cloud brightening proposal with previously cancelled or postponed experiments, the reason for opting for a single case study is twofold. First of all, there is a very small pool of projects that would be suitable for comparison, since the technology is still in a developmental phase. Although there is relatively much written about the SPICE experiment, proposals for the stratospheric particle injection did involve a large array of candidate particles (SPICE, 2022b), whereas the cloud brightening project solely focuses on salt particles. Moreover, marine cloud brightening takes place on the oceans and stratospheric particle injection. There considerable differences could impact the validity of any of the conclusions coming from a comparative analysis. Therefore, I opted to move along with a single case study. Secondly, a lack of data, time and resources further constrained the possibilities of carrying out a comparative study. Although the US-based MCB Project would make for a comparable case in terms of solar geoengineering technique, as well as the technological equipment used, a lack of available data about the project and the unresponsiveness of affiliated researchers towards interview requests made The MCB Project unsuitable for case selection.

4.2 Data Collection Strategy: secondary data sources

In order to answer the research questions, several types of secondary data were needed. First, international, federal as well as state regulatory documents that could indicate to what extent relevant regulatory mechanisms could accommodate for an intervention like marine cloud brightening. Secondly, the recommendation reports as well as the technical reports made publicly available by RRAP would constitute an important source in laying out the specifics of (planned) engagement projects and regulatory status, following their engagement studies, social media sentiment analysis and the mapping of the regulatory environment. Third, in order to assess whether RRAP's self-portrayal would align with public perceptions of the project, the selection of media releases and news articles RRAP has made available on their website was gathered, mainly to assess their normative elements. Purposefully communicated textual sources are collected and analyzed as communication by RRAP that could be seen as representative of bearing the elements intended to be communicated, including frames about the (purpose of) the project. This thesis partly aims to uncover the *normative legitimacy* of MCB experiments, the extent to which the project aligns with societal values, norms and beliefs, which is heavily influenced by the perception of the project's communicated intent or purpose. It is likely that this intent will be disseminated through RRAPs communications, which thus provide a rich data source. As I was not able to conduct direct data analysis from the Australian public, online news(paper) articles were used as substitute to compare RRAPs self-portrayal with external views and writings thereof.

From reviewing the literature used to provide detailed background information about marine cloud brightening and the RRAP case this study has selected (see: Chapter 2 – Background information), relevant criteria came to the fore for the selection of relevant texts to include as data. The following criteria were defined for the texts shared by RRAP as well as the external, online news(paper) articles:

- Written between 2018 - when RRAP plans were first published – and 2022, **and**
- Explicitly discuss marine cloud brightening in relation to RRAPs proposed intervention, **and**
- Distributed via local, regional or (inter)national (online) news channels, **or**
- Purposefully distributed on the RRAP website or social media accounts, **or**
- Containing *any* information related to the legal or regulatory environment, the purpose and positioning of the project, and/or processes of inclusion, public participation and accountability.

Duplicates were filtered out, as well as articles that were inaccessible due to paywalls or broken links. After applying these criteria and filters, 28 documents shared by RRAP were selected, together with 30 external news articles. Annex I and II provide an overview of the articles analyzed, including the type of document and a description of the publisher: media release co-written by RRAP, RRAP partners and international, national or state news outlets, some specialized in e.g. technological news or news related to indigenous people.

Regulatory documents were consulted and obtained via the internet, as they are publicly available sources. The following relevant international agreements, state and federal regulations and other regulatory documents were consulted:

Scale	***Year***	***Title***
International	1975	World Heritage Convention
	1992	Convention on Biological Diversity
	1982	United Nations Convention on the Law of the Sea
	1996	London Convention and Protocol
Federal	1975	Great Barrier Reef Marine Park Act
	1999	Environment Protection and Biodiversity Conservation Act
	2003	Great Barrier Marine Park Zoning Plan
	2019	Great Barrier Reef Marine Park Regulations
	2018	Joint Guidelines Permit Applications for Reef Restoration and Adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park
State	1984	Aboriginal and Torres Strait Islander Heritage Protection Act
	1994	Environmental Protection Act
	1995	Coastal Protection and Management Act
	2004	Marine Parks Zoning Plan
	2004	Marnie Parks Act
	2006	Marine Parks (Declaration) Regulation
	2017	Marine Parks Regulation

Table 2 – Collected regulatory documents

4.3 Data collection Strategy: primary data sources

To supplement the secondary data sources, a small number of experts interviews were conducted to check, extend and deepen the understanding of the above. Initially, I contacted 15 experts who were either directly involved in RRAPs organization, were involved in one of RRAPs partner organizations or who were government officials involved in decision-making over the Program. In the end, two

researchers from the RRAP team were interviewed between December 2021 and January 2022: Dr Stewart Lockie (James Cook University, Queensland), leader of the subprogram Stakeholder and Traditional Owner Engagement, and Dr Pedro Fidelman (University of Queensland), leader of the subprogram on Regulations. Expert interviews may be used for exploratory, systematizing and theory-generating purposes (Bogner & Menz, 2009). This study applies the systematizing approach, which can be defined as *"oriented towards gaining access to excusive knowledge possessed by the expert* […] [in] *an attempt to obtain systematic and complete information"* (Bogner & Menz, 2009, p. 46). Indeed, as the Reef Restoration and Adaptation Program in Australia has only recently begun their operations, expert interviews could provide an insightful peak about ongoing processes that are possibly relevant to the research questions, but have not been communicated publicly (yet), or have not been made explicit. Criteria for selecting experts to interview are dependent on the purpose of the expert interviews, as well as the study's adopted notion of who constitutes an 'expert' (Bogner & Menz, 2009). Here, the constructivist approach was adopted, as developed by Meuser and Nagel (1997), in which 'being an expert' is understood through the role ascription of external actors interested in obtaining information or knowledge (Bogner & Menz, 2009). The subsequent criteria for selecting experts are thus based on the researchers assumption they possess relevant, in-depth knowledge and intelligence about RRAP. The following criteria were defined for sampling experts to approach for an interview:

- Direct involvement with the Reef Restoration and Adaptation Program in one of the RRAP R&D teams; **OR**
- Relevant position within a partner organization or institute of Program to provide insights on developments regarding the legal or regulatory environment, the purpose and positioning of the project, and/or processes of inclusion, participation and accountability; **OR**
- Position not attached to the Program nor its partner organizations, but explicit perception of or knowledge about the project. For example, scholars writing about the Program, as well as relevant decision-makers would be eligible here.

In preparation of the semi-structured interviews, an interview guide was developed. An interview guide for semi-structured interviews is typically defined as *"a list of topics, themes or areas to be covered in a semi-structured interview*" (Lewis-Beck et al., 2004, p. 2) and allows for flexibility and smooth transitions in going from topic to topic. The guide is linked to the research questions of the study and aims to generate data to address them. Although an interview guide thus may take a variety of forms, the prepared interview guide consists of a set of guiding questions directly covering the study's main concepts. In addition, other questions may be formulated during the interview to respond to any interesting prompts made by the interviewee. One of the main obstacles with this type of data collection is that the lack of consistency in the way questions are asked might influence the comparability of the answers and may affect the quality of responses from interviewee to interviewee. However, as the interviews are executed in order to gain unique insights from the interviewees' expertise, comparability is not an essential requirement.

The interview guide below provides an overview of the six pre-designed questions based on the study's conceptual framework and links these to the research question they should provide input for. An opening and closing question were listed in order to provide the interviewee with a clear structure. The interviews took 30 minutes and 45 minutes, respectively.

phase	*concept*	*Question*	*RQ*
Start		Introduction by student, explanation of interview procedure and goals.	-
		Asking for informed consent on recording the interview for personal use	
		Explanation of data processing	
Opening question		When did you first get acquainted with the topic of marine cloud brightening?	-
1	Procedural legitimacy	What do you think about the range and diversity of people that are involved with this project?	1
2	Procedural legitimacy	What do you think about the project's preparation with regard to unexpected outcomes?	1
3	Normative legitimacy	What do you think about the communications strategy put forward by the project leaders?	1, 2
4	Normative legitimacy	How would you describe the engagement with the public throughout the project?	1, 2
5	Regulatory legitimacy	What do you think about the regulations in place relevant to the project?	3
6	Regulatory legitimacy	In your view, what is the effect of current law and regulations on the project?	3
Closing		Is there anything else you would like to tell me about?	-

Table 3 – Interview guide for semi-structured expert interviews

4.4 Content analysis through deductive coding

Data gathered from the expert interviews was recorded and transcribed to allow to take the contents of the interview and effectively analyze it. For transcription, a free web-based transcription tool was used. The data stored on the program was protected by a closed account and could not be accessed by third parties, ensuring sufficient data protection. Since the automatic tool does not work perfectly, manual edits were made to correct the transcription. After transcribing the interviews, a content analysis was executed through open, deductive coding. The deductive approach was adopted as the theoretical framework consisting of the three types of legitimacy informed the elements of texts that were coded. Open coding enables the researcher to *"label concepts, defining and developing categories based on their properties and dimensions."* (Khandar, 2022).

After this process, 36 codes were developed for around 400 quotations. The codes represented relevant themes that were discovered which could inform the answers for the three subquestions on regulative, procedural and normative legitimacy. Nevertheless, not all codes and their adjacent quotations were highlighted in the analysis chapter, as the choice was made to focus on the most important and significant findings from the analysis. Table 6 below provides an overview of the codes or 'themes' that were identified.

Code	*N*
Saving the Great Barrier Reef	90
Description of unknowns and risks	52
Description of marine cloud brightening	47
Marine cloud brightening is controversial/drastic	36
Decarbonization vs. geoengineering	36
Marine cloud brightening as a collaborative effort	32
Due to climate emergency/climate crisis, quick action is needed	32
More research is required	31
Decarbonization remains necessary	25
Innovation as key Ingredient	25
Benefits of geoengineering	23
Scale, local vs. global geoengineering	20
Simplification of the technology	19
Public support is necessary	18
Economic Cost/Benefits	17
Geoengineering will provide time	17

Code	*N*
RRAP/MCB as an Australian prestige project	12
Government in support of intervention/RRAP	12
Geoengineering as a solution to global warming	11
Environmental law and geoengineering	8
Geoengineering to increase resilience	8
Importance of transparency	8
Complexity of marine cloud brightening	8
Highlighting 'naturalness'	6
Lack of funding	4
Governance of marine cloud brightening	4
Issues with unilateralism	3
Moral challenges	3
Increase resilience vs. geoengineering	1
Legitimacy of GBRMPA	1
Weather modification and cloud seeding	1
Skepticism about feasibility	1

Table 4 – Codes identified and the number of adjacent quotations (N)

Chapter 5 – Regulative Legitimacy

This chapter provides an overview of the ways regulatory legitimacy was performed by the Reef Restoration and Adaptation Project, in what ways and to what extent regulatory matters seem to be of concern to external parties and how all of this could have impacted the levels of contestation surrounding the Great Barrier Reef cloud brightening experiment. The chapter starts with drawing a parallel to cloud seeding, a weather modification technique Australia has over seventy years' experience with, and which bears many similarities to marine cloud brightening. It is implied that because of the existing regulatory frameworks for cloud seeding, and evaluations thereof, this experience might have increased the regulative legitimacy for marine cloud brightening interventions. The chapter continues by laying out the relevant international, federal and state regulatory frameworks that may impact the governance of marine cloud brightening in any type of way. However, the following paragraph shows that there is no specific regulatory framework for some of RRAPs more disruptive technological interventions yet – including marine cloud brightening. Yet, the recommendations RRAP has made in anticipation of the intervention already provide a basis and direction.

5.1 Stepping stones: Australia's long history with cloud seeding

Australia's history with weather modification may also have contributed to the relatively low levels of contestation surrounding the marine cloud brightening experiment on the Great Barrier Reef. More specifically, Australia has been deploying a technique called 'cloud seeding' for more than 70 years already, which bears many similarities to marine cloud brightening (Simon et al., 2020). Precipitation enhancement by cloud seeding refers to the "*deliberate human intervention in the atmosphere to enhance the volume of rainfall*" (Simon et al., 2020, p. 6). This process, first discovered in 1946, involves adding substances (e.g. dry ice, silver iodide) (Hydro Tasmania, 2022) to certain types of clouds to increase the crystallization and initiate or enhance rainfall (Simon et al., 2020). As the development of the technology furthered, scientists also discovered they could use salt particles to increase the amount of water droplets present in warm clouds, making cloud seeding now suitable for warmer, (semi-)tropical climates (Simon et al., 2022). Hereafter, several national governments had become interested in the possibilities of using cloud seeding interventions to mitigate extreme weather or to increase precipitation during periods of drought to support agricultural production and the generation of hydropower. Australia was among the early adapters, as its government rolled out the first cloud seeding research program in 1947 (Kraus & Squires, 1947). As Australia is one of the driest continents on the globe and has the lowest annual precipitation rates (Simon et al., 2022), the promise of cloud seeding was very attractive. The federal government requested the Commonwealth Scientific and Industrial Research Organization (CSIRO) to be in charge of cloud seeding research and since then, almost every state in Australia has experimented with the technology (Simon et al., 2022). In the first ten years of deployment, many experiments successfully enhanced precipitation. However, the number of CSIRO-programs has decreased over time, as scientists found the Australian clouds too 'warm' to be suitable for seeding. Research programs therefore struggled to conclusively demonstrate the effectiveness of the technology and the amount of funding for research and development outweighed the benefits for the organization (Parliament of Australia, 2004), leading the federal government to take down its cloud seeding research program in 1981 (Bell, 982). Currently, it still is used by some states and agricultural cooperations and is considered to be a 'marginal water management tool' (Simon et al., 2020).

As mentioned above, marine cloud brightening and weather modification, but specifically cloud seeding, bear many similarities. Next to both being intentional human interventions to alter cloud composition and both using vaporized salt particles, both technologies are characterized by significant uncertainty (Simon et al., 2020). Although experiments with cloud seeding have been ongoing for the past seventy years, their effectiveness is often questioned. As atmospheric processes are immensely complex, measuring the impact of cloud seeding interventions is a tricky exercise, where it is often difficult to attribute an increase in precipitation to the intervention. However, with the technological advancement of remote sensing technology and modelling tools, scientists have been able to demonstrate that the intervention, under specific conditions, can indeed lead to increased rainfall (Simon et al., 2020). In addition, over the years there have been concerns raised over the environmental impact over the agents used to seed the clouds with, specifically silver iodide. The use of this chemical may have long-lasting and accumulative environmental effects (e.g. Fajardo et al., 2016), and *"create risks of ecotoxicity for soil biota both in terrestrial and aquatic environments"* (Simon et al., 2016, p. 701). Moreover, the World Meteorological Organization recommends close monitoring of a broad range of environmental impacts (WMO, 2010). What is communicated by the Weather Modification Association, however, poses a stark contrast to this cautious attitude, as they argue the levels of silver iodide used in cloud seeding pose negligible effects to human and environmental health. Other concerns include the risk of longer running cloud seeding programs to alter precipitation patterns over time, as well as interventions impacting nearby regions unintendedly. The latter could pose serious issues between states (in federal systems) or even nation states.

Although cloud seeding takes place on-land, and marine cloud brightening targets marine clouds specifically, the above concerns align perfectly with the questions and uncertainties that have been sticking to marine cloud brightening and in fact, geoengineering technologies at large. This comparison is also made in two news articles, where the difference between geoengineering and weather modification is highlighted: "*he also readily acknowledges trying to avoid getting embroiled in a debate about solar geoengineering, arguing that the project would be more akin to cloud-seeding operations that are designed to promote rain and that are not considered to be geoengineering*."[36] Due to this likeness, it is plausible that Australia's previous experience with cloud seeding could partially explain the relatively low levels of contestation surrounding the GBR marine cloud brightening experiment, for all types of legitimacy discussed within this thesis. After seventy years of experience with cloud seeding research and deployment – mostly for the generation of hydro-electricity – most states that have running cloud seeding programs have developed specific legislation to govern its use. Although the state of Queensland does not have specific laws in place nor a running cloud seeding program, the state-owned Queensland Climate Change Centre of Excellence welcomed international researchers to work with the best-available technologies to conduct the prestigious 'Queensland Cloud Seeding Research Program' (QCSRP) between 2007 and 2009, with the aim to investigate the potential for cloud seeding in the Queensland summer climate (Tessendorf et al., 2012; Simon et al., 2021). Moreover, Queensland recently carried out a public-private cloud seeding experiment with the US-based company *Weather Modification Inc.*

Other states, notably Tasmania, Victoria and New South Wales, have governance structures and specific legislation in place. Simon et al. (2021) assessed their regulatory and participatory frameworks, from which different questions around "*decision-making, scientific uncertainty, public participation, monitoring of operations and liability for damage*"(p. 711) arose. Of particular interest is the fact that none of these states have the formal requirement for public participation, and in practice, no meetings

or consultations proceed the interventions. In Tasmania and New South Wales, there is information available to the public, but new information is not highlighted nor treated as a major event (Simon et al., 2021). Perhaps this low level of attention originates from the perception Australians have about cloud seeding, as it is commonly regarded as a public service, even though the private sector is increasingly involved in cloud seeding operations (Simon et al., 2020). Moreover, after a survey of Australians' opinion on cloud seeding carried out forty years ago by McBoyle (1984), an overall positive attitude dominated the results, despite some concerns about information sharing and participation opportunities. This suggests an alignment between the public's norms and values, and their perception of the use of cloud seeding technology for enhanced precipitation. However, when a similar survey was conducted in 2008, the report revealed an 'information vacuum' and even high levels of distrust related to the interventions, as they were conducted without public notice or participation. Here too, access to information proved very minimal. After recommendations were made, the company executing cloud seeding interventions established community consultations and increased access to information by means of daily updates on their website and radio reports. Although these types of actions resulted in positive attitudes towards enhanced weathering, opposition remained, especially among environmental NGOs, who were concerned about the possibility to carry out interventions without a proper environmental impact assessment. They argue that the costs of these programs outweigh their benefits, and that funding should be allocated towards more effective, less risky interventions.[36, 40]

The similarities between marine cloud brightening and cloud seeding may have implications for the perceived legitimacy of the RRAP experiment. The fact that Queensland as well as wider Australia has a long-standing experience with cloud seeding using salt particles on-land, may increase the normative legitimacy for marine cloud brightening. As the technologies are very similar, the legitimacy ascribed to cloud seeding could be 'transferred' to marine cloud brightening technology. However, it is worth mentioning that theories about the after-effects of cloud seeding are gaining traction, that might also affect future narratives around marine cloud brightening. Over the year 2022, Sydney has had to endure three major floods, where the average precipitation of months came down in just a few days. Many Australians took to social media, where allegations have circulated that the extreme weather is a consequence of the countries' experience with cloud seeding (Silva, 2022). These theories are not novel, as reporters already interviewed Tasmanian citizens after extreme weather in 2016, who expressed concerns about the weather being linked to cloud seeding (Silva, 2022). Although the Australian federal and state governments are refuting such claims by publishing reports, which are backed by scientists (Silva, 2022), it will remain to be seen how the public belief in these theories might influence the legitimacy of technologies like cloud seeding and marine cloud brightening. Moreover, as cloud seeding operations experienced both procedural and regulatory issues, legitimizing the RRAP marine cloud brightening by Australia's previous experience with cloud seeding could come at a risk. First of all, when the existing regulatory and procedural frameworks for cloud seeding would serve as a basis for governance and engagement, the pitfalls regarding access to information, public participation, questions of accountability and liability, as well as the increased involvement of the private sector could persist. Secondly, not distinguishing clearly between the two technologies and their purposes (enhancing the albedo effect vs. enhanced precipitation) could lead the public, stakeholders as well as decision-makers to underestimate the complexity and the risks that characterize marine cloud brightening to date, as opposed to cloud seeding technology that has been experimented with over years (Simon et al., 2022).

5.2 Relevant regulatory environment

In order to assess the level of regulative legitimacy of the RRAP project, it is important to first establish to what extent present the regulatory framework can be applied to marine cloud brightening. As marine cloud brightening field tests, or field testing the technological equipment that might be used for marine cloud brightening purposes, fall under various scales of jurisdictions, they are regulated on the international, federal, state and local level, creating an intricate network of arrangements that can be complex to navigate. On the international level, Australia is a signatory of various international treaties concerning the Reef and interventions in the marine environment, particularly the World Heritage Convention, the Convention on Biological Diversity (hereafter: CBD), CITES, the London Convention and Protocol as well as the UN Sustainable Development Goals (Fidelman et al., 2019). Since the Reef is globally recognized for its outstanding universal value by its inscription on the World Heritage List, the Australian federal government is obliged to inform the World Heritage Committee in case of any developments or intervention that may impact the universal value of the Reef (UNESCO, 1972; Australian Government, 2022). Here, the World Heritage Committee fulfils a role of international oversight and assistance, where it can make recommendations and decisions that could significantly affect the governance of the Area. The above international agreements are given effect through federal and state laws, such as the 1999 Environment Protection and Biodiversity Conservation Act, that implements the CBD. On top of that, the 2019 Great Barrier Reef Marine Park Regulations demand that any relevant international treaty signed by Australia must be taken into consideration during the assessment of permit applications for activities within the marine park area (Australian Government, 2019). It is important to consider the international regulative realm, as there is significant debate in the international community regarding the governance of solar radiation management interventions, one of which is marine cloud brightening, with special caution when it comes to unilateral deployment (e.g. CBD, 2010; London Protocol; 2013).

Federally, the Government of Australia shares responsibility over the Great Barrier Reef under the Department of the Environment and Energy (hereafter: DEE). The Department is in charge of executing the 1999 Environmental Protection and Biodiversity Conservation Act and regulates new developments in the Great Barrier Reef World Heritage Area that might impact the Reef, its 'outstanding universal value' and is responsible for other federal environmental matters, too. Moreover, the DEE is the main federal department responsible for carrying out the Reef 2050 plan, which subscribes guidelines for reef management and protection until 2050. The DEE does not carry primary responsibility over the GBR Marine Park, however, as this duty is taken up by the Great Barrier Reef Marine Park Authority (hereafter: GBRMPA). GBRMPA carries out the daily management of activities taking place within the Park, in close cooperation with the relevant Queensland authorities, and is also responsible for administrating the 1975 Great Barrier Reef Marine Park Act (Queensland Government, 1975), the primary piece of legislation concerning the protection and management of the Reef and is leading in decisions regarding zoning and permits. Principles for the management of the Reef can also be found by the Plans of Management, Traditional Owner Agreements, policies related to tourism, protected species and the environment, and the various strategic visions and position statements the GBRMP has in place (Fidelman, 2019).

The Queensland Government has tasked its Department of Environment and Science with the principle responsibility for the protection and management of the GBR. It administers the 2004 Marine Parks Act, which established the Great Barrier Reef (Coastal) Marine Park, running along the full length of the Federal Marine Park and created to provide protection for Queensland tidal areas. Within the

department, the QPWS has responsibility for managing the Marine Park, and together with the GBRMPA, through a joint field management program, delivers surveillance, compliance and enforcement activities under the 2004 Marine Parks Act (Queensland) and the 1975 Great Barrier Reef Marine Park Act (Commonwealth). Finally, ,the Department of Environment and Science also holds the Office of the Great Barrier Reef, which plays an important role in implementing – together with the federal government – the Reef 2050 Plan. A less prominent, but nevertheless essential, part of the GBR regulatory framework consists of the thirty-nine local governments which have a major role in planning for development, particularly on land. They are responsible for planning schemes, which regulate development (other than mining and petroleum activities) within their local government areas.

Having discussed the relevant regulatory framework in place in the Great Barrier Reef area, it is important to distinguish relevant requirements for marine cloud brightening interventions that might flow from RRAP. The requirements depend primarily on the presence of the intervention *within* the Marine Park/Coastal Marine Park area and the nature and scale of the activity itself, particularly its environmental consequences. For marine cloud brightening interventions specifically, approval is required under the GBRMP Act, as the field testing would place within the Marine Park and includes interventions in the airspace up to 915 meters. An application for the field testing would have to be compliant with the 209 Great Barrier Reef Marine Park Regulations and in order to obtain a permission, the application would have to undergo an assessment process. The Great Barrier Reef Marine Park Zoning Plan and its Plans of Management consequently determine which and where activities are permitted. For example, it is unlikely that *any* intervention would be permitted in a Preservation Zone.

As noted above, GBRMPA has in place various policies, agreements, position statements, strategies and guidelines relating to protection of the Area. For example, intervention in areas where Indigenous Land Use Agreement applies would be subjected to the terms of these agreements. Moreover, under the Native Title Act (1993, Commonwealth), GBRMPA is responsible for notifying native title holders or claimants in relation to the areas that will be affected by proposed permissions (GBRMPA, 2017). Another example is the Guidelines for permit applications for restoration/adaptation projects to improve resilience of habitats in the Marine Park (GBRMPA, 2018), which refer to many of the RRAP interventions, including marine cloud brightening. These guidelines provide an indication of the regulatory requirements and assessment approach to be adopted as part of the permission system for these interventions. Further in assessing permit applications, GBRMPA is required to consider relevant federal and state legislation and international agreements to which Australia is a party (GBRMPA, 2017). Certain interventions – including marine cloud brightening field trials – would require additional assessment and approval under other regulations, for instance when activities may cause a considerable impact on the environment of the Marine Park or other matters of national environmental significance, they are required to be assessed under the EPBC Act. While there are many other Acts that would apply to RRAP interventions in total, only the EPBC Act is the relevant for cloud brightening intervention specifically.

Now that it is established which specific agreements, regulations and guidelines are relevant to marine cloud brightening field testing, one may wonder how the permit for the performed field test was obtained, and why there has not been any tangible contestation surrounding such a permission being granted, either from signatories to international agreements, or from other stakeholders involved or affected by the test. When asked, one of the interviewees directly involved in the RRAP project clearly stated that the permit was solely granted for testing the possible effectiveness of the machinery – e.g.

size of nozzles, size of water particles - to brighten clouds, *not* to experiment with marine cloud brightening as such. Both interviewees confirmed that *"to be able to test effects on clouds, is a few years in the future."* (personal communication, 2021). Reflecting on the paragraphs above, it could be argued that perhaps, given the strong existing framework governing the Great Barrier Reef and all activities that take place within the Marine Park, public concerns about a lack of or improper regulation of MCB activities are less salient.

5.3 Rethinking and future-proofing current frameworks

Although there are many rules, regulations, guidelines and agreements in place concerning interventions the Great Barrier Reef (Coastal) Marine Park, it should be clear that to date, there is no regulatory framework specifically designed for marine cloud brightening on neither local, state, federal or international scale. Dr Fidelman argued: "*Existing frameworks were developed in a different context. They have been very successful in dealing with conventional threats, like fishing and local and regional impacts of rain. But now we are talking about a shift in paradigm, where we are proposing active interventions, which is a complete departure from the traditional management of the Reef, or any other ecosystem, reserve or park."* (personal communication, 2021). Multiple news outlets commented on the inadequacy of current regulatory frameworks to govern field testing the technology, too: "*Current environmental laws do not make special exemptions for scientific research or testing in areas of national environmental significance, such as the Great Barrier Reef. Any geoengineering trial that might have a "significant impact" on those areas is illegal without a permit from the Commonwealth Environment Minister. The Minister is guided by the precautionary principle and World Heritage obligations in issuing such permits*."[31]; *"the current laws do not guarantee robust governance for field testing of these technologies"*[46] and *"Australia currently has no national law or policy governing geoengineering or solar radiation management, or even on how such activities might fit within national climate response strategy"*[46].

It is clear that geoengineering interventions are perceived by both RRAP and GBRMPA as high-risk interventions. What is interesting, is that the Joint Guidelines for Permit Applications for Reef Restoration and Adaptation Projects to Improve Resilience of Habitats in the Great Barrier Reef Marine Park now also include the word *geoengineering*, categorizing any interventions applying for a permit under the high-risk intervention category, which are required to submit a proof of concept and *"must have an initial small-scale pilot study in the GBR."* (GBRMPA, 2018, p.6).

Intervention	*Examples*	*Likely assessment approach*	*Mitigation*
Geo-engineering	Geo-engineering is the deliberate intervention in the Earth's natural systems to counteract climate change. Examples can include: marine cloud whitening, research on the effects of aerosol particles on clouds, temperature and climate.	Tailored assessment/permit and joint risk assessment with interested scientists/government regulators.	Unknown at this stage.

Figure 3 – Geoengineering in the GBRMPA Joint Guidelines for Permit Applications

(directly adapted from GBRMPA, 2018, p.6)

To adapt the existing regulatory frameworks and 'future-proof' them for interventions such as marine cloud brightening, the technical RRAP report states that *"greater integration, adaptation, agility and*

oversight to address a rapidly-changing environment" (Taylor et al., 2019, p. 15) will be required. In order to obtain such results, six key action points are provided. First, it is advised to increase regulatory capacity in order to be able to address innovative and/or controversial interventions like marine cloud brightening. Second, researchers need to be fully aware of the scope of the regulatory environment governing the Great Barrier Reef and the Marine Park in the process of further designing and delivering on the Program. In order to achieve such awareness, guidelines and trainings should be provided (Taylor et al., 2019). Third, the cooperation and coordination between relevant regulators should be enhanced, according to RRAP researchers (Taylor et al., 2019). RRAP proposes a role of facilitation for themselves, providing a space for cooperation between the GBRMPA and other regulators, while providing scientific and technological input regarding the various interventions. Fourth, the current permit system should be improved to accommodate restoration and adaptation interventions, as previous interventions were mainly focused on management and conservation. Fifth, RRAP recommends the *"development of options for regulatory and policy innovation*" (Taylor et al., 2019, p. 15) to further support the development of the technologies proposed. Finally, it is recommended that a *whole-of-government* approach is adopted, referring to joint activities by diverse layers and scales of government to work together towards reef restoration policy development (Taylor et al., 2019).

Chapter 6 – Procedural legitimacy

This chapter provides an overview of the ways procedural legitimacy was performed by the Reef Restoration and Adaptation Project, in what ways and to what extent procedural matters seem to be of concern to external parties and how all of this could have impacted the levels of contestation surrounding the Great Barrier Reef cloud brightening experiment. The chapter begins with an exploration of RRAP's existing engagement mechanisms and the recommendations it has set up moving forward with the program. The chapter continues by drawing attention to the way RRAP has been portrayed in various news outlets, where the collaborative nature of the program is highlighted as an essential element. Finally, the engagement of the indigenous peoples of the Great Barrier Reef – the Torres and Strait Islander Groups or 'Traditional Owners' – is discussed, in particular because the timely and sufficient engagement of indigenous communities has proven to be a major obstacle for experiments in the past (see: SCoPEx, Chapter 1).

6.1 Existing engagement mechanisms

As part of the Reef Restoration and Adaptation Project, Taylor et al. (2019) have identified various opportunities for utilizing existing engagement structures to engage relevant communities, and identified risks and recommendations for future stages of the project. The GBR community has been divided in a four-fold typology: livelihood stakeholders, indigenous and Traditional Owner entities, citizens and civil society and institutional stakeholders. Here, Traditional Owners constitute a special group of stakeholders, as they consist of indigenous peoples from Aboriginal and Straight Torres Island descent, who have obtained particular rights and responsibilities in the management of and decision-making of the Reef (see: paragraph 6.3). Livelihood stakeholders are defined as *"reef- dependent and reef-associated industries, stakeholders and communities in the Great Barrier reef and catchment"* (Taylor et al., 2019b, p. 32), whereas institutional stakeholders consist of *"local, regional, state, national and international governing bodies or organizations with responsibilities and interests in the Great Barrier Reef"* (Taylor et al., 2019b, p. 32). Finally, citizens and civil society consist of the larger public "*and other interests in the Great Barrier Reef from individuals or groups based inside or outside of the Reef and its catchment"* (Taylor et al., 2019b, p. 32). Table 5 below provides a specific overview of included stakeholders per typology, and provides examples (non-exhaustive) of fora and structures that hold rights and interests in RRAP. These structures have been useful in identifying opportunities of utilizing existing engagement structures.

The RRAP study into existing engagement mechanisms found 119 main engagement mechanisms in total, divided over the four stakeholder typologies (Taylor et al., 2019b). For livelihood stakeholders, the engagement mechanisms are characterized by a mix of organizational types and they perform either single or multiple roles (e.g. assisting the GBRMPA and/or promoting the interests of particular stakeholders). In the case of Indigenous and Traditional Owner entities, the mechanisms are particularly geared towards *"facilitating expressions of indigenous legal rights"* (Taylor et al., 2019b, p. 35). For citizens and civil society, organizations are mostly characterized as not-for-profit operated by volunteers, aiming to promote stakeholder interests and to improve community engagement, for example. Finally, the engagement mechanisms for institutional stakeholders mainly concentrate on reef science or reef policy in some way since they mainly exist to enable government to fulfill its mandate. They consequently perform a variety of roles, such as advising institutions and facilitating stakeholder action (Taylor et al., 2019b).

Stakeholder typology	*Organizations, fora and structures that hold rights and interests*
Livelihood stakeholders	- **Coastal Communities** (e.g. GBRMPA Local Marine Advisory Committees) - **Industry and Business Groups** (e.g. Queensland Farmers Federation, Chambers of Commerce, Queensland Tourism Industry Council) - **Voluntary programs** (e.g. Reef Guardian Fishers Program) - **Commercial Fishing** (e.g. Queensland Seafood Industry Association) and **Recreational Fishing** (e.g. Mackay Recreational Fishing Alliance)
Indigenous and Traditional Owner entities	- (e.g.) Torres Strait Regional Authority (TSRA), Indigenous Reef Advisory Committee, Traditional Use of Marine Resources Agreements and Land Use Agreements, Land and Sea Country Ranger programs, Commonwealth Indigenous Advisory Committee,
Citizens and civil society	- **Regional arrangements** (e.g. Rivers to Reef Report Card Partnership) - **Schools** (e.g. Marine Teacher Association, Reef Guardian Schools) - **Business community** (e.g. multiple Rotaries) - **Conservation** and **citizen science** (e.g. WWF, Greenpeace, UNESCO, IUCN, GBR Citizen Science Alliance and local/regional/national conservation organizations)
Institutional stakeholders	- **Science community** (e.g. Australian Institute of Marine Science) - **Local government** (e.g. Queensland Regional Organizations of Councils, Local Government Association Queensland) - **Queensland government** (e.g. Department of National Parks, Sports and Racing, Department of Environment and Science) - **Australian Government** (e.g. Department of Agriculture and Water Resources, Department of Environment and Energy)

Table 5 – overview of groups, fora and structures for groups that hold rights and interests in RRAP, per stakeholder typology. Adapted from Taylor et al. (2019b), p. 33-34.

After assessing these mechanisms for RRAP science engagement, it was concluded that the existing mechanisms are generally well-structured and offer a suitable basis for RRAP engagement practices. In short, they are expected to be useful for e.g. *"seeking expressions of stakeholder interests, rights, knowledge and perspectives to restoration and adaptation during the design, testing and deployment of interventions options", "tapping into well-established networks already in place and with a history of discussing and advising on reef science and policy for timely engagement"* and *"framing social benefit and social value narratives of technology deployment for specific stakeholder rights and interests"* (Taylor et al., 2019, p. 36-37). Nevertheless, the complex environmental, social and institutional Reef landscape also raises uncertainties about how these existing mechanisms could be effectively used for RRAP engagement. For example, it remains unclear to what extent the existing engagement mechanisms are suitable for the objective reef restoration, or the highly innovative, sometimes controversial technologies that are being proposed. As these mechanism are based on existing government mandates and agreements on science, governance and policy, RRAP recommends further exploring to what extent existing frameworks are 'fit for purpose' and where they might need additional support or changes (Taylor et al., 2019a). In addition, questions surrounding the capacity to facilitate the engagement have emerged, as some mechanisms will need technical and financial support in order to adequately identify stakeholder perceptions and desires, and how these relate to the interventions proposed, to explore various trade-offs and to function as a communication network. Finally, it is recommended that the program further studies the matching of the engagement mechanisms to the different engagement objectives, as different stages in the program may require different types of involvement and engagement (Taylor et al., 2019a).

RRAP researchers have thus put forward several recommendations for the engagement component of the further rollout of the RRAP R&D program, based on literature research of models for managing the social dimensions of ecological restoration projects and the social acceptability of new technologies. Regarding the existing engagement mechanisms, they comment that although it is generally suitable for accessing the target groups, to engage them and to further work on aligning project goals with stakeholder interests, norms and values, some of the more challenging aspects of the program require tailored engagement activities. For example, it is recommended that for the deliberation on specific technologies, representation in RRAP decision-making, co-design of the interventions, as well as the exploration of trade-offs and uncertainties, special fit-for-purpose activities should be designed. Another recommendation relates to the role of the Traditional Owners. RRAP researchers have found opportunity for 'improved coordination' when it comes to the empowerment of the indigenous groups to exercise their rights and responsibilities. It is therefore recommended that special approaches are being developed regarding co-research and education and accreditation opportunities, among others. The third and final engagement recommendation relates to the complexity and innovative character of the project. RRAP researchers argue that "*social scientists, and engagement specialists with expertise in designing, facilitating and evaluating transdisciplinary research (…) that support responsible innovation*" (Taylor et al., 2019a, p. 14) should be involved throughout the project to strengthen its governance model.

6.2 Interventions as 'a collaborative effort'

In the texts analyzed, the importance of collaboration in a program as complex as RRAP is often stressed by words such as *partnership, open engagement* with *key stakeholders* and *social license*. Although the term 'social license' is mentioned, it is not explained in any of the media releases, while it is a central concept to RRAP's engagement strategy. In their technical report, Taylor et al. (2019) define social license as *"the broad approval or acceptance that communities, the general public, and other stakeholders afford to the development and management of natural resources* (p. 7). The term is most commonly used to investigate the social acceptance of natural resource extraction, but has recently also been applied to conservation activities (Taylor et al., 2019) since public attitudes are able to affect the level of contestation or support towards specific technologies and other environmental management interventions. Involving the public at an early state is thus of vital importance to the 'success' of RRAP. This also becomes clear from the documents shared by RRAP as well as media articles, which describe that *"collaboration is critical"* [5] and sometimes highlight the importance of specific stakeholder groups, such as *"ecologists, tourism or fishing industry, Traditional Owners or the general community"*, reef managers and *the Australian community and industry*."[7] What's more, many articles highlight the importance of "*what society wants*"[1] and *"the will and priorities of the people."* [7] While much is being written about the *need* for engagement and collaboration, little is explained about what the collaboration would look like, the planned engagement process, or how interested or affected parties could become involved in the process.

6.3 Engagement and involvement of Traditional Owners

In the Great Barrier Reef area, Traditional Owners make up an important share of residents. 'Traditional Owner' is the umbrella term for a large variety of indigenous peoples, totaling around 70 groups of Aboriginal and Torres Strait Islander groups, who have traditionally been connected to the Reef, hold a native title within the area and are "*entitled to undertake activities under custom or tradition"* (GBRMPA, 2022a). Their presence dates back to over seven thousand years ago, when these peoples lived on what is currently the sea floor, and consequently adapted to the sea level rise and

formation of the Reef (GBRMPA, 2022a). After the Reef had formed, the Aboriginal and Torres Strait Islander groups remained in their 'Sea Country', and the new ecosystem became embedded in islander culture, spirituality and resource use (GBRMPA, 2022a). Over time, the English colonization of Australia and the Reef led to various ecological pressures on the reef, traditional custodianship and displacement of the indigenous groups. Nevertheless, many Traditional Owners stayed connected to their Sea Country and are looking to re-establish their role in its management and policy making. Over the last decade, GBRMPA and the Traditional Owners have collaboratively developed the *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park* and the Indigenous Land and Sea Country Partnerships Program, a $20 million investment to enable continued traditional management of the Reef (GBRMPA, 2022b). To implement the latter, the Traditional Use of Marine Resources Agreements (TUMRAs) were established, describing in detail how Traditional Owner Groups, the Australian and the Queensland Government agencies should cooperate in order to preserve traditional use activities. In total, more than 43% of the Great Barrier Reef Marine Park area is now managed under one of the nine TUMRAs (GBRMPA, 2022b).

Regarding the RRAP project, the Traditional Owner Communities are one of the key stakeholders within the initial engagement studies. In fact, $51.8 million from the Reef Trust and Great Barrier Reef Foundation partnership is dedicated to Traditional Owners, to design key recommendations and best practices for reef management that can be aligned with traditional practices, norms and values.[59] RRAP researchers executed a desktop and expert-informed review of relevant existing literature on known issues, needs and best practices related to Indigenous peoples' engagement, management of the Great Barrier Reef and governance more broadly, including several Traditional Ownership representatives as experts. As a result, a specific program recommendation regarding the engagement of Traditional Owners is made: RRAP needs to recognize the Traditional Owners *"as both governors and managers of the Great Barrier Reef in their own right and translate that recognition into wider RRAP processes. The unique status of Great Barrier Reef Traditional Owners as Australia's First Peoples results in expectations that RRAP should accommodate roles for Traditional Owners that are far more significant than just participants in generalized RRAP stakeholder processes."* (Taylor et al., 2019, p. 14). Professor Stewart Lockie, who is responsible for RRAPs subprogram on Stakeholder and Traditional Owner engagement, specifically highlighted that the subprogram's foundational work should be taken up by all other subprograms on the found: "*public deliberation is particularly important when engaging with traditional owners. If you're a scientist, doing research and intervening in their sea country, you have to talk to them. I am a social researcher and they are happy to talk to me, but that cannot be a substitute for the person who will be doing cloud brightening research. It is really important that the researchers across all programs get out to the community, because they have a different kind of relationship with the Reef, and they don' t want to deal with intermediaries."* (personal communication, 2021).

In general, the Traditional Owners have welcomed the RRAPs ambition to protect the reef and increase its resilience in the face of climate change and other threats. As one Traditional Owner, Ms Prior, said in an interview with the National Indigenous news outlet NITV: *"It's never too late to try and do something. I think it's a good idea, especially from my point of view as a Ngaro Traditional Owner and a Saltwater person."* [59] Another Traditional Owner, Ms Deshong, says: "*It's a good opportunity for the Traditional Owners along the Great Barrier Reef. It gives them the chance to be part of the solution, really looking after the reef. It gives them a great opportunity to work and network with researchers, economic development, everything*." [59] Historically, the Traditional Owners of the Great Barrier have

not always been recognized by governmental institutions, which also surfaced as a social risk of the program during the in-depth interviews carried out by RRAP at the start of the project. However, the RRAP project has directly identified this group as a major stakeholder and – next to continuous engagement - directly involves them in the 'co-design phases', which has been very positively received[59]. When it comes to the specific intervention of marine cloud brightening, the Traditional Owners do not seem to explicitly oppose experiments, but there is neither an account of their explicit approval. Traditional Owners were mainly concerned with ecological risks linked to the coral breeding interventions, as this might create new pest species, change species interaction patterns and impact the food web on the Reef. For the Traditional Owners, this raises significant concerns of cultural acceptability (Taylor et al., 2019). Concerns related to the intervention of marine cloud brightening will be explored in later stages of the RRAP R&D engagement process, of which the outcomes will be leading as to how and which interventions can be conducted, since the Traditional Owners will be involved in the designing of the intervention program.

6.4 Public concerns and distrust

Research focused on trust levels among relevant stakeholders and involved authorities performed by RRAP shows a high level of trust in the science community and the Great Barrier Reef Marine Park Authority (Taylor et al., 2019). Whereas respondents believed that the federal and Queensland Governments' were capable to ensure a healthy future for the Reef, their levels of trust were lower, implying a certain governmental distrust (Taylor et al., 2019). This corresponds with general trends of low levels of trust in governments in Australia, as could be found in similar surveys (e.g. Moffat et al., 2014; Moffat et al., 2017). However, the belief in the capability or 'institutional efficacy' of these governments implies there is generally a positive perception and confidence among Australian citizens. Public concerns and distrust are important when it comes to procedural legitimacy, as involving and engaging stakeholders will be more difficult in situations of distrust, affecting the overall legitimacy of the Program. The lack of public trust has also been found in the analyzed texts, discussing distrust in the Coalition for not taking appropriate climate action and doubting the motives of RRAP since it would allow the Australian government to continue to emit high levels of GHG-emissions[8]. Another article comments on a concern regarding the assessment of risks and the of the GBRMPA: "*It is unclear how the federal environment minister and the Great Barrier Reef Marine Park Authority will evaluate whether the risks of field testing are small enough to justify granting their approval. The position is made more uncertain by the fact that the authority is directly involved in at least one of the projects. This uncertainty risks poor environmental outcomes and erosion of public confidence.*"[31].

Although the Recommendation Report that RRAP published does not elaborate much on dealing with public trust and procedural legitimacy, it does have the tendency to 'treat' issues regarding the legitimacy of decisions and actions by ensuring "*stakeholder and rights-holders participate in transparent and inclusive decision-making at governance and operational levels."* (Taylor et al., 2019, p. 8). While more and/or enhanced engagement seems like a logical way to increase legitimacy and treat possible issues related to public concerns, this conclusion might prove too straightforward. The role of participation as a means of increasing legitimacy in technological decision-making will therefore be critically discussed in the Discussion of this thesis (Chapter 8).

Chapter 7 – Normative Legitimacy

This chapter provides an overview of the ways normative legitimacy was performed by the Reef Restoration and Adaptation Project and a reflection on how this performance could have impacted the levels of contestation surrounding the Great Barrier Reef cloud brightening experiment. The major narrative that resulted from the analysis are discussed, which related to marine cloud brightening as a technology that could help to "save" the Reef, the importance of innovation as well as the positioning of the experiment and the RRAP project at large as state-of-the-art prestige projects, appealing to historical aspirations and values shared among citizens, and aligning with current public policy priorities. The chapter concludes by discussing observations on the contestation observed throughout the news media articles analyzed.

7.1 'Saving' the Great Barrier Reef

All articles that were analyzed, both from RRAPs own media channels as well as external news articles discussing the experiment, seem to support the narrative that 'ambitious'[32,55] or even 'extreme'[45] measures like marine cloud brightening are deployed in order to "save the great barrier reef". Of course, RRAP as a whole is designed – as the name says – to increase reef resilience and to restore the reef where possible. The wording "*saving the Great Barrier Reef*", however, puts an normative emphasis on the responsibility of reef stakeholders to support the list of possible interventions resulting from RRAPs initial research in order to prevent to Reef from dying off. In this light, a significant share of the articles sketch a situation where decision-makers and scientists have arrived at an *either-or* dilemma: *either* we deploy marine cloud brightening, *or* we lose the Great Barrier Reef. By emphasizing the Reef's international status and its ecosystem services while simultaneously 'simplifying' marine cloud brightening technology, mentioning prospected benefits while neglecting to portray the unknowns, possible risks, regulatory gaps and oppositional voices, it is likely that the scale would tip towards acceptance of marine cloud brightening in order to 'save' the Reef.

Many articles also add the element of time into the mix, emphasizing the need to quickly act in the face of climate change. Sometimes this call for quick action is very explicit, other times it is highlighted by painting a bleak picture of the coming years "*if we don't act*"[56]: increases in the occurrence of mass coral bleaching episodes, a massive decrease of biodiversity in the area and a loss of income for many operators active on the Reef. The way these articles portray the state the Reef is in, and how quickly it will worsen, adds to the sense of urgency when opting for interventions like marine cloud brightening. Marine cloud brightening, among some of the other RRAP suggestions, is said to "*buy the reef time*"[29,31,32,33] as it might "*slow the rate at which ocean warming is bleaching the coral*"[40]. This tone of voice is not always directed at the general public, though. In several articles, the federal Australian government is being criticized for being late or even negligent when it comes to climate action, which has resulted in the need to combine decarbonization measures with more drastic interventions, like marine cloud brightening[35,46,57]. Finally, cloud brightening is also characterized as an intervention that can be effective within a relatively short time period, theoretically bringing "*direct relief to specific regions of the coral reef system*"[36], adding to its attractiveness.

Another recurring element – mainly but not exclusively in the external news articles – is the statement that drastic problems require "*drastic solutions"*[29], "*out-of-the-box thinking"*[45] or "*extreme measures"*[56] and that *"desperate times ask for desperate measures"*[41]. This all comes together in the framing of marine cloud brightening as a 'necessary evil'[55] for the survival of the Great Barrier Reef,

and can be found in various articles discussing the field experiment. By phrasing it this way, writers create the idea of marine cloud brightening experiments as something that can only be legitimized by its purpose. This reaffirms the importance of purpose or intent, as Stilgoe (2013a) already hinted at, and might be one of the defining factors for the low levels of contestation in Australia in comparison to other geoengineering experiments, such as SPICE, SCoPEx and the MCB Project. Where these projects' intent has been to experiment with geoengineering techniques, proving their effectiveness in order to ultimately use them as climate mitigation tools, their purpose was not nearly as concrete – and 'heroic' – as the RRAP cloud brightening intervention.

It is noteworthy that almost all articles from external news sources assume the technology's effectiveness in shading and cooling the Reef, referring to it as a "solution".[40] Some of them even go beyond saving the Reef, and state that this technology could potentially "*stop climate change.*"[49] As one article says: "*If we could do it, it would reduce global warming and all the negative things that come from that. It would keep the extreme storms from coming, it would reduce the rise of sea level, and reduce sea ice melting.*"[55] That statement is factually incorrect: marine cloud brightening it *potentially* able to decrease the intensity of the effects of global warming on a certain scale, but does not contribute to actual decarbonization, as several articles rightly state[35,46]. A few articles interviewing the leader of the experiment, Dr Daniel Harrison, show a more nuanced picture, as the scientist is more cautious in his optimism.[33,34,35,36] Although Dr Harrison acknowledges the possibilities, he admits that there still remain many uncertainties and that the technology needs to be developed further and experimented with in order to be able to actually be of any service to the Reef. This more nuanced picture is also supported by the RRAP technical report (Taylor et al., 2019b), and was confirmed by the interview with Dr Fidelman, who stated that "*this is a few years in the future*. (…) *there's a lot of ground to cover before they will be able to test any sort of effects on the clouds*" (personal communication, 2021).

This narrative also corresponds to the findings of RRAPs public survey, which asked both the general Australian public, Queensland citizens as well as reef stakeholders about their support for the measures included in the RRAP proposal. Overall, respondents indeed perceived the Reef to be facing significant threats and there was a general sentiment on the necessity of preventing further degradation (Taylor et al., 2019b). Among the respondents, 71% was supportive of large-scale restorations (Taylor et al., 2019b), but it should be noted that Great Barrier Reef residents tended to be less supportive overall than other Australians. They argued that combatting direct threats to the Reef, in particular GHG-emissions, should be a more pressing or equally important policy objective compared with restoration (Taylor et al., 2019, p. 48). Regarding the specific technologies, survey respondents were generally accepting or undecided, which implies cautious support for some of the interventions, including marine cloud brightening (Taylor et al., 2019b). Nevertheless, marine cloud brightening is perceived to be riskier than other technologies proposed (Taylor et al., 2019, p. 49). Next to the survey, RRAP also executed twenty-four in-depth interviews with reef stakeholders, among whom local members of government, the tourism industry, non-governmental organizations as well as Traditional Owners. During the interviews, stakeholders expressed more complex attitudes. For example, there was skepticism regarding the government's motives behind restoration-focused investments and the effectiveness of the proposed interventions. Furthermore, they identified various types of risks linked to the program, among which were ecological risks such as changes to the local weather patterns, and they showed "*moral confliction about proposed restoration actions"* (Taylor et

al., 2019b, p. 21)., two concerns particularly characterizing for technologies like marine cloud brightening .

7.2 Risks and uncertainties: considerable, but 'not insurmountable'

The risks and uncertainties of marine cloud brightening or geoengineering at large have been mentioned and sometimes even elaborately discussed in many of the articles, both those from RRAPs own communication channels as well as those externally published. Many of the concerns addressed are focused on the novelty of marine cloud brightening experiments and the fact that there has not been field work on the effectiveness of the technology. It follows that there this raises some questions and concerns. As one article states: "*there is the risk the projects do not work at all, or not as effective as advertised"*[29], especially due to the complexity of atmospheric interactions. In addition, Lynn Russel, an atmospheric chemist specialized in cloud brightening, has questioned the suitability of the clouds at the Great Barrier Reef for the intervention. Dr Harrison, in charge of the shading and cooling portion of RRAP, has indeed acknowledged these worries. Although he is confident that there are low layered clouds present in a certain part of the Reef, he also stresses that it remains unclear *"how much coverage a full-scale cloud-brightening operation could provide across the entirety of the reef."* [36].

Nevertheless, the large majority of risks described was centered on the environmental risks that marine cloud brightening possibly bears, which seems ironic as the measure is considered in order to protect an environmental landmark. The possibility of altering rainfall patterns is often discussed: *"you're changing the balance, changing precipitation, and there is something really, really significant side effects that can go here"* [30], as well as other possible climatic effects: *"every part of the atmosphere is connected, so if you don't balance your warming and cooling very carefully, then you get all sorts of changes in the climate system, some of which are difficult to predict"* [51]. Here, the emphasis is often placed both on the possible irreversibility of consequences and on their scale, arguing that even 'small-scale', 'local' or 'regional' interventions could have unintended effects on a global scale. Another item points out that in the case marine cloud brightening was to be deployed in order to locally 'cool and shade' the Great Barrier Reef, the reverse might actually be achieved, as quitting the brightening operation could lead to *"extremely rapid, catastrophic warming"* [51]. Some articles also zoom in on the transnational consequences of marine cloud brightening, even hinting at warfare as a possible effect of unilateral experimentation with the technology, because "*if one country did something they thought would help them and it was harmful to another country, they might be quite upset*."[55] One article concludes there is a *"very real risk of catastrophe that geoengineering poses, pointing out that there are "hundreds" of potential adverse impacts. Most importantly, there is no "Planet B" if we get it wrong."* [29]

Although descriptions of risk, uncertainty or concern can be found in the large majority of the articles that were analyzed, these uncertainties are often directly countered by the 'Save the Great Barrier Reef'-narrative, where the survival of the Reef is juxtaposed against the possible side-effects of intervention. The situation that is being portrayed shows that scientists are certain the Reef will die off if 'nothing is done', whereas it is uncertain if there will be any side-effects if experiments run at a regional scale, which effects may occur and when they do – how severe they will be. Often, the uncertainties are seen as a reason to actually continue the research in and the development of the technology. After mentioning the unknowns, statements such as "*more measurements, and detailed modelling, are needed to provide answers*" [36] or "*we need to look at if it influences weather patterns, and trials need to occur*" [45] are made. This all fits the idea that in the case that cloud brightening actually

turns out to be a suitable mechanism to counter coral bleaching, the technology should be exploited responsibly, taking into account all possible consequences. However, the consequences will remain unknown until field trials will be executed. This attitude provides almost a textbook depiction of the 'Dilemma of Social Control' as discussed in Chapter 2. It should be noted that the critiques discussed in the previous paragraph, as well as the arguments used to offset such concerns, also apply to the broader concept of solar geoengineering. Criticism regarding the marine cloud brightening proposal might therefore not be directly caused by concerns about the project or technology *per se*, but instead could stem from opposition to solar geoengineering at large.

7.3 Innovation as a Key Ingredient

Another key element in all communications has been the innovative character of the RRAP interventions, but specifically marine cloud brightening and genetically modified corals. Many articles highlighted the innovative quality of the program, or the technology itself, in a positive manner. The interventions are branded as *novel, innovative,* as having more to offer than best-practice conventional management*, cutting-edge*[18]*, promising*[17, 21] and *sophisticated*[4]. That the public seems to respond positively to the novelty of the interventions also surfaced from the social media sentiment analysis performed by RRAP to test the public attitude of Australians as well as Great Barrier Reef residents towards the interventions. One of its major conclusions was that the more innovative an intervention seemed, the higher the support typically was, as approaches like marine cloud brightening were compared to existing (small-scale) interventions were generally perceived as more effective or to be offering greater prospects for the repair or protection of the Reef (Taylor et al., 2019b). By contrast, the language used for these innovations is generally simplified in these articles, specifically those from other sources than RRAP's website. In those texts, the complexity of marine cloud brightening often is lost, referring to the technology as *thickening clouds*[34], *spraying salty droplets*[36] into the atmosphere, or as *a way to block sunlight*[36]. This also happens on social media, where those discussing the interventions used terms like *sun shield* and *cloud seeding* (Taylor et al., 2019b, p. 82). These more informal ways of naming and discussing the technology actually had a positive effect on people's risk perception: the RRAP study shows that when the language about interventions was simple and tangible, people were more prone to have a positive response to the intervention (Taylor et al., 2019b). So, while the innovative aspect of cloud brightening seems to be appealing to the Australian public, the technical details of the innovation were often left out of the information provided, which seems to have had a positive effect on their perception of the technology.

7.4 Marine Cloud Brightening as a State-of-the-Art Prestige Project

It is worth highlighting here that the RRAP, but individual interventions too, were often branded as the pinnacle of Australian research. The emphasis on the nationality of researchers, the Reef as an Australian icon, the role of the Australian government, as well as the position of Australia in the global science community stood out, especially in the articles that were shared on RRAPs website. For example, articles mentioned that *"Australia's marine researchers are leading the way"* [7], *"Australian science can lead the way in developing adaptive technologies to help protect the reef"* [2] and *"The Reef Restoration and Adaptation Program is Australia's opportunity to shine in showing the world how we can support coral reefs to adapt and rebuild"* [2]. This 'patriotic' frame could have impacted the perception of the Australian public vis-à-vis the intervention of marine cloud brightening. Historically, Australia has been a nation that has struggled to reach a prominent international position in knowledge production or to attract high-technology industries (Charles et al., 2021). Nevertheless, there is a strong, ongoing narrative about the need to transition into a *"high value-added economy based on*

science, technology, innovation, entrepreneurship and competition" (Charles et al., 2021, p.55, based on: Australian Department of Industry, Innovation, Energy and Resources, 2015). The idea of a new, 'world-leading program'[2] seems to align very well with this desire and could possibly have impacted the perceived normative legitimacy of RRAP – including the marine cloud brightening intervention – in a positive direction.

Whereas the conception of RRAP as a prestige project mainly occurred in the documents shared by the project itself, externally published sources commented on the political interests behind RRAP. These articles hinted at the upcoming federal elections, where the major parties – Labor and Liberal – aim to win over Queensland citizens, as its swing seats are likely to determine the outcome of the elections. Over the past electoral cycle, there has been a lot of pressure on politicians to come up with concrete climate actions (e.g. Reuters, 2021; [39, 40]), especially after the unprecedented bushfire season of 2020-2021 (Dunne et al., 2020). Although RRAP is not about decarbonization, the narrative of 'saving the Great Barrier Reef' and help 'cooling the earth' might appeal to voters and simultaneously satisfy UNESCO concerns [43]. The Reef thereby has become one of the *"key election fights"* [39] in the region. As one critic phrases it: *"the technology-led utopia that Scott Morrison is dreaming into existence is underpinned by eight years of dis-investment in everything he's now claiming will get us there."* [57].

7.5 Fragmented Criticism

Geoengineering and thus marine cloud brightening experiments have been characterized by critique, opposition and contestation, thus far leading to postponement or even cancellation of scheduled field tests. In the case of RRAP, however, the criticism has become far less apparent. What stood out from analyzing the external materials written about the experiment, has been the fragmentation of criticism and the distance of opponents to the general public. Three main groups of opponents became visible from the analysis, which were international environmental organizations or advocacy groups, others in the scientific community, as well as the federal Green party. Critique of the project and marine cloud brightening more specifically centers around the persisting need for decarbonization policies, naming interventions like cloud brightening '*band-aid solutions*' [35, 57]. The latter is specifically true for the Green party, who feel like the Federal government have neglected to 'walk the talk' when it comes to climate action and struggle with the large budget for adaptation interventions that have not been proven to be effective, yet [35, 46]. Others, like the Massachusetts advocacy group 'Union of Concerned Scientists' also spoke out about their belief that marine cloud brightening cannot substitute decarbonization of the Australian economy: *"Pushing for a technological fix to global warming without moving to aggressively curb greenhouse gases is 'sheer lunacy'"*[36]. Although the need for decarbonization measures is described in many articles, is widely shared by the Australian public and residents of the Great Barrier Reef, and underscored by RRAP in their reports, it does not seem to constitute a reason to oppose the project in itself. For many people, it simply means that RRAP might be necessary to catch up with earlier climate commitments, and might need to co-exist with other mitigation efforts. As Dr Mead says: *"This is a preventative measure ... that needs to go hand-in-hand with climate mitigation work"* [55].

In the international realm, environmentalist and scientists' concerns are more focused towards the opacity of the operation, as they claim RRAP has published very little research on the topic of marine cloud brightening.[36] Finally, environmentalist organizations like the Carnegie Climate Governance Initiative and its director Janos Pasztor, have expressed their worries regarding the unilateral action by Australia. The group claims that RRAP is *"setting the wrong kind of precedent by rebranding a solar*

geoengineering experiment that could have regional impacts as a local adaptation project." [36]. Pastor continues by stating that *"One could say that there should have been some level of consultation with the outside world."* [36] Although there seems to be considerable critique that is being brought into the conversation, two observations stand out. First of all, that the critique is coming from groups that are – apart from the political groups opposing the experiment – physically quite distant from the Reef. In the RRAP case, it is not communities that live off the Reef's services, or that reside in the area that seem to be opposing the experiment, but rather those within the international scientific and environmental community. This distance might partially explain why these voices of opposition are not widely reported on. Secondly, the way the critique or opposition is portrayed in the media makes it seem as if those opposing the experiment or the technology itself are a minority or niches, by highlighting that these groups are non-Australian[36], 'conservationist'[39] and 'environmentalist'[36] while emphasizing the strong support from the Australian government, citizens and even Traditional Owners.

What became apparent throughout the reading of the articles written about the RRAP field test, is that one the one hand, researchers seem hesitant to link the experiment to geoengineering, whereas other articles actually characterize this as a first open-air geoengineering experiment. What's more, is the caution with which the RRAP program uses the term geoengineering. A quote by Dr Harrison in an interview with ABC News reads: *"Geoengineering certainly does carry negative connotations. (…) I just think having the word 'engineering' in it doesn't help*. *Having machines that do stuff, that's engineering, and people don't like the idea of using machines to fix our planet."* [55]. Contrary to most news articles, Dr Harrison brings a rather nuanced view to the table, as he highlights that actual deployment is still years away and that the experiment merely confirmed that the nozzle-technology was in fact able to disperse aerosols into marine stratocumulus clouds. Of course, the test that occurred late March 2020 was indeed geared at testing the technological equipment, not to test the effectiveness of marine cloud brightening in the field. It is however worth it to think about the implications for normative legitimacy here. It is unclear – both from the literature as well as this study – whether public perception is stooled on the idea that an actual geoengineering test has taken place and that it has proven to be effective in brightening clouds, or that the general acceptance of the field testing is based on the fact that this was a test of technological equipment, not of the technology itself. It will thus remain to be seen if and how public norms and values will change once the research and development moves into the stages of marine cloud brightening experiments.

A similar observation was made regarding the scale of the experiment. In some articles that described the technology, a difference was made between solar geoengineering for the purpose of cooling the planet globally, and marine cloud brightening, as this technology would also be suitable for 'small-scale' experiments. For example, one article writes: "*We would not be directly testing marine cloud brightening at any scale that would affect climate*"[40]. Another article mentions that the concerns related to solar radiation management mainly stem from the fact that interventions are designed for large-scale deployment, and directly follows up that statement by arguing that "*cloud brightening has been studied as a potential local intervention.*"[36]. Another statement hints at the reversibility of small-scale testing, where RRAP research & development program director David Mead stresses that *"all of the methods and technologies they're exploring are easily and quickly reversible. This is not a decision to proceed or to deploy."*[55]. It is worth considering how these writings could have influenced the low levels of opposition in Australia and in the Great Barrier Reef Area, specifically. The emphasis on the

‘small-scale’, the ‘locality’ of the intervention as well as the reversibility of consequences could, for example, have altered the public risk-perception of the experiment.

To conclude, strong alignment was found between the narrative of ‘saving’ the Great Barrier Reef and widespread norms and beliefs about climate change and the importance of climate action. Moreover, the marketing of RRAP as a prestige project and the continuous emphasis on its innovative character seemed to appeal to the Australian public, which may be explained through historical ambitions and current public policy priorities of becoming a competitive knowledge-producing country. Using these narratives, the Reef has also become a key fight in the upcoming elections, leading some to question the government’s motivations for initiating the RRAP project in the first place. However, the little contestation around the experiment and the larger RRAP was fragmented, and ‘distant’: there were very little signs of national groups criticizing or protesting against marine cloud brightening. To circle back to the previous chapter, in which normative legitimacy is discussed in relation to the Reef’s Traditional Owners, it is not entirely clear to what extent the technology of marine cloud brightening aligns with their norms, values and traditions. However, RRAPs engagement study has shown no objections either, and reactions from these indigenous people show that RRAPs purpose to support the Reef’s health has been a decisive factor in their support for the project.

Chapter 8 – Discussion

This chapter seeks to summarize and interpret the findings from the analysis of both primary and secondary sources. The chapter starts off with a critical discussion of the findings, and continues to reflect on the theoretical framework adopted throughout this study. Next, possible implications of this study are discussed, where the findings of this study are placed in the larger picture of governing (small-scale) geoengineering experiments. The chapter ends with an assessment of the research process and discusses limitations in the study's validity and reliability.

8.1 The role of legitimacy in contestation of solar geoengineering field tests

This thesis lies a foundational background against which solar geoengineering or marine cloud brightening field experiments might be designed or tested for qualities that have shown – in the compiled theoretical framework and from the analysis of the Australian case – to provide, to some extent, a basis for 'legitimacy'. I however do not want to claim that any geoengineering experiment can be labelled as legitimate, as this is highly dependent on whose perception the research is written from. As the international communities at large, many national governments, the scholarly world and (international) civil society have not been able to decide whether geoengineering in itself is legitimate, it would be wrong to come to such a conclusion in a Masters' thesis. I intended to lay out why and how the Australian case distinguishes itself from cancelled or postponed attempts like we've seen in Sweden, the UK and the United States. In order to do so, I added various notions of legitimacy to already existing scholarly literature on responsible research and innovation in order to arrive at an integral framework. This thesis might be useful in the larger debate about (solar) geoengineering and field experiments, offering key insights from the early stages of the Australian RRAP case.

RRAP has sought to find a way to move forward with cutting-edge technological interventions in a bid to restore – to the extent possible – the natural wonder of the Great Barrier Reef. By doing so, it has displayed various forms of regulative, procedural and normative legitimacy. Across these types of legitimacy, RRAP has shown to stand out from other projects that have previously been proposed but have been postponed, or even cancelled because of contestation. Especially in relation to SCoPEx, the differences are stark. What stands out is the attention RRAPs intervention proposal has for the various aspects of the Program but particularly the engagement and involvement strategies tailored for Traditional Owner groups. SCoPEx has shown how a failure to anticipate backlash and contestation, as well as granting co-design positions and ownership to indigenous peoples, could cancel an experiment that had not even the intention of dispersing agents into the atmosphere. The Saami worldview fundamentally clashes with the idea of solar geoengineering, said the vice president of the Saami Council (Osaka, 2021). Now that the experiment is postponed, it is pending further "societal engagement" with the Saami and the Swedish public. However, such engagement has not been made concrete yet, experts say (Osaka, 2021).

RRAP on the other hand, has – to a large extent – concretized its stakeholders, their importance, the project phases in which they need to be involved. Moreover, they took into account the special role of Traditional Owners and made their unique role and responsibilities a central element of their engagement strategy. Perhaps as important as designing concrete plans for what is known, RRAP also showed anticipation of future engagement risks related to all stakeholder groups. However, I believe it is worth discussing limitations of approaching legitimacy for technological decision-making through participation here. Grunwald (2004) poses that it is not the participatory procedures themselves that

bring about legitimacy for the development of a certain technology. Only under certain preconditions – such as involving the public to make value judgements as early as the stage in which questions are being formulated and the technology is being assessed – can participation be meaningful and grant legitimacy to technological development (Grunwald, 2004). Although it seems that for now – partly because the narratives between RRAPs communication and the public sentiment align – RRAP has succeeded to meaningfully involve selected stakeholders, it thus remains to be seen how the project will develop in the future as it moves from equipment experiments towards small-scale field testing.

Another result that stood out, was the role of RRAPs strong, normatively appealing narrative of 'Saving the Great Barrier Reef'. Not only was this message purposefully communicated in order to increase the Program's public credibility (Taylor et al., 2019) (*"continue to communicate restoration as part of the solution"*), it was spread by almost every article discussing the intervention. In external media articles, the mandate for marine cloud brightening was often even exaggerated, mentioning how deployment of the technology could 'halt climate change'. It seems as if there has been a perfect window of opportunity for the 'saving the great barrier reef frame': the general concern about climate change among Australians, the unique perception Australians have of the Reef as a national natural icon (and, not to forget, a source of income for a considerable population in Queensland), and the sentiment that the federal government should speed up its climate agenda, all seem to have resulted in a perfect alignment of the communicated narrative with commonly shared norms and values. When comparing these findings to earlier projects, RRAP stands out as a unique case in which there is a specific goal *including* a normative element ('saving' something appeals to a person's standards) coupled to the experiment, which are absent in all other projects introduced by this study.

A third interesting finding is the link that has been made between the 'small-scale' geoengineering that RRAP eventually plans to carry out in the Great Barrier Reef Area, and cloud seeding or weather modification. Although Australia's more than 70 years of experience with this technology and the regulatory framework that has been set up for it may have strengthened the regulative, procedural and normative legitimacy of RRAP, having previous experience with cloud seeding does not directly increase public acceptance or decrease the levels of public contestation. Although solar geoengineering projects have been proposed in other countries that have a similar history with weather modification, such as The MCB Project in the US, any legitimacy that could have been 'transferred' onto marine cloud brightening did not stop the projects from being postponed or cancelled. Moreover, recent developments in the wake of extreme weather in Sydney have shown that cloud seeding operations can be contested, which could also have implications for the future acceptance of marine cloud brightening experimentation.

8.2 Theoretical reflections

While the level of performed regulative, procedural and normative legitimacy seem to be – and are perhaps even largely defining – indicators for public contestation, one must be cautious in making this assumption the other way around. Situations where the level public contestation may appear very low, do not automatically indicate high scores on these types of legitimacy. This is where the concept of power plays an important role, because it follows that bodies in charge of the planning and/or execution of the project are vital in shaping the narrative that is subsequently presented to society. This could then influence the information being spread about the technology or the project, but also could oppress voices of concern and critique. The theoretical model that was designed for this thesis

should therefore not be used as a generalized tool, and especially not to inductively conclude that all experiments with low levels of contestation are per definition 'legitimate'.

Furthermore, there might be several other factors that have influenced the low levels of contestation around the RRAP marine cloud brightening proposal. For example, Brent et al. (2020) write that the Australian public may have been too preoccupied to be fully aware of and capable of reacting to the experiment. As the experiment was carried out in March 2020, the public was focused on a major health and economic crisis, with news related to COVID-19 and government response measures dominating all major news outlets. Moreover, the summer before the experiment was characterized by catastrophic bushfires, which environmentalists, policy makers as well as the Australian public were still dealing with at the time. Their thesis is, thus, that the reaction of the public might have been different if it had happened at another time, in which there might have been more coverage of the experiment.

In addition, the role of participation as a means of increasing legitimacy in technological decision-making deserves some critical attention. Many organizations and scholars, including this thesis, (partially) define the legitimacy of a certain intervention according to the extent of the engagement and participatory process that was carried out before, during and after the intervention (Grunwald, 2004). However, Grunwald (2004) argues that participation alone may not be enough to legitimize an intervention. It is therefore essential to review the focus on procedural legitimacy in this study, instead of taking into account input and output legitimacy as well. As Schmidt (2019) argues: "*However high the quality of the governance processes, throughput is considered no substitute for input or output. It cannot make up for bad results or little citizen participation, whereas problematic procedures can throw into question political input and/or policy output*." (p.16). The SCoPEx project signifies a clear example of a project aiming to ensure good procedural legitimacy, but failing to create input legitimacy in the early design phase (Pidgeon et al., 2013). This emphasizes the importance to take this factor in when studying the role of legitimacy in contestation around geoengineering experiments.

Another factor to consider is the fact that RRAP consists of eleven priority interventions and even more interventions in total. Because of this, the project is not always brought in connection directly to some of the more controversial technologies, like marine cloud brightening. Although articles describing the Reef Restoration and Adaptation Program as consisting of a suite of interventions, many articles turned out not to pass the criteria for this study because they did not mention the marine cloud brightening intervention specifically. This also could have played a part in the normative legitimacy ascribed to the project. Moreover, as many articles were written about the corals-related interventions, it should also be taken into account that e.g. the intervention with genetically modified corals could have 'taken over' controversy from the marine cloud brightening experiment. Especially as the genetic modification as a technology is better known within society than marine cloud brightening, other interventions might have triggered public attention over marine cloud brightening.

A final consideration is the question of how the different variables of regulative, procedural and normative legitimacy might influence each other. For example, it stems from this thesis' results that the clearest alignment was found for normative legitimacy, as the public values, concerns and motivations fit very well with the positioning of the RRAP marine cloud brightening proposal as a way to increase reef resilience and halt coral bleaching. On procedural legitimacy, it can be concluded that RRAP developers have studied previous marine cloud brightening experiments and have implemented

(or recommended) best practices, especially when it comes to the engagement and involvement of Traditional Owners. Although there is no regulative framework for marine cloud brightening (yet), there were still low levels of public contestation. This begs the question whether 'performing well' on one or two types of legitimacy might even out a 'poor' performance on the other variable. Or even, whether a certain type of legitimacy might be more important overall.

8.3 Implications of the RRAP marine cloud brightening proposal

The RRAP marine cloud brightening proposal stands out for several reasons, one of which is bringing to life the case for marine cloud brightening as a conservation method. This concept is not new: scholars have tried to model the implications of solar geoengineering for biodiversity and conservation (e.g. Dagon & Schrag, 2017), although possible detrimental effects have also been established (Trisos et al., 2018). For marine cloud brightening in particular, it has been argued before that deployment could contribute to the conservation of Arctic sea ice (Jones et al., 2009, 2010; Rasch et al., 2009, Latham et al., 2014) or the preservation of coral reefs (Latham et al., 2013). The low contestation levels of the RRAP proposal indicate that marine cloud brightening with the purpose of conserving (landmark) ecosystems might have the potential to (partly) de-tangle itself from the geoengineering-debate and instead become a (high-risk) conservation method, perhaps taking away some of the taboo around geoengineering in the mainstream climate change debate. Such mainstreaming could contribute to a broader debate of geoengineering, but also brings along its own set of dangers, as described by Stephens et al. (2021): increasing the likelihood of international conflict, unilateral deployment and further delays in the prioritization of other climate actions. Depending on the perspective, the moral hazard argument (see: Chapter 2) thus still applies: in case decarbonization efforts by the Australian government and the international community are not further intensified and sped up, deploying marine cloud brightening for conservation purposes could be fighting a running battle.

Other implications of RRAPs proposal for marine cloud brightening experimentation should be considered, too. In light of the governance discussion and the current *de facto* moratorium on climate-related geoengineering, it is particularly interesting that the Australian government is planning – and to some extent already executing – field experimentation and eventual deployment of marine cloud brightening within the Great Barrier Reef area. Yet, despite this unilateral action by Australia – which has been party to the CBD since 1993 (CBD, 2022) – no formal commentary has been released by the CBD calling on Australia to suspense any activities related to the marine cloud brightening portion of RRAP (to my knowledge). This begs an array of questions: why has there not been a statement yet, neither by the CBD nor its parties, and what does that tell about the RRAP project and perhaps, the influence of the CBD? Although any commentary, a statement or even a warning can still be expected, as the experiment carried out by Dr Harrison's team has been an initial equipment test, it is worth contemplating what the implications of the CBDs absence could be. A possible consequence could be that – in case the marine cloud brightening intervention indeed proves to halt or slow down coral bleaching – other governments will follow. The risks of unilateral deployment, however, are substantial and might generate consequences that cross borders (Reynolds & Wagner, 2020).

A third implication that should be discussed in this section relates to the broader ethics of geoengineering, and the dilemma of social control. The question that has been opened by RRAPs low levels of public contestation and the broad public support that reported by its researchers during the mapping of public sentiments, would be the following: to what extent does the RRAP marine cloud brightening proposal constitute a precedent for a growing acceptance of (or even support for)

deploying high-risk technologies as the effects of climate change becomes more tangible? It would require more research to even come close to answering such a question, but it might be worthwhile to understand if and how – over time – the broader Australian public might become more susceptible to the idea of marine cloud brightening in the aftermath of the RRAP experiments, and whether such effects might be transferable to other (solar) geoengineering techniques. In case marine cloud brightening indeed turns out to be able to soften the effects of coral bleaching, could it be that the RRAP experiments are a 'stepping stone' to other high-risk interventions, under the narrative of 'high-risk, high rewards'?

8.4 Discussion of limitations

This thesis has attempted to unravel in what ways the RRAP marine cloud brightening proposal has performed regulative, procedural and normative legitimacy, and how performance on those legitimacy dimensions has caused little public contestation over the first field test of the technological equipment. However, the research process has been far from linear which has led to a number of limitations that need to be discussed, especially if future research will build on some of the findings from this study. A first important limitation is the fact that the overwhelming part of the data this thesis has studied comes from secondary sources and the very limited number of expert interviews. Due to time and resource constraints, a limited pool of experts to reach out to and a high rate of negative replies, gathering more data from experts and other stakeholders was not feasible. This mainly has implications for the internal validity of this study: as no stakeholders or experts *outside* of RRAP were interviewed and only two RRAP researchers, the depth with which legitimacy dimensions could be explored was limited, as well as the certainty with which can be claimed that the relatively good performance on the legitimacy dimensions tested indeed caused low levels of controversy. Future research might benefit from studying legitimacy in relation to marine cloud brightening programs using more direct data, where e.g. the alignment between the organization's own efforts and portrayal could be tested against legitimacy scores ascribed to the program by different stakeholder groups.

A second limitation relates to the external validity of the findings. Since I opted for a case study design with a non-exemplary case, the external validity – or transferability of similar conclusions to other cases – is limited. All data used is highly specific and dependent on the context of Australia, its governance structure, its rich history, the unique ecosystem of the Great Barrier Reef region and societal norms, values and challenges. Even though other marine cloud brightening projects, such as the US based MCB Project, might portray similar basic characteristics, the outcomes could be drastically different. The indicators – or *ways* legitimacy was performed as found by this study - that were described should therefore be regarded as a first start. Future research could build on these indicators, supplement them or change them entirely, in order to create a more holistic view of ways in which legitimacy can be performed by marine cloud brightening projects, depending on their broader context. The study's limited external validity does however not undermine the theoretical foundation this study has attempted to lay down: the dimensions of regulative, procedural and normative legitimacy will – to a greater or lesser degree – play a determining role in the emergence of contestation around marine cloud brightening experiments. Of course, these three dimensions can be supplemented based on specific case characteristics, and some dimensions may have a larger impact on the emergence of contestation. In this light, comparative case studies are also recommended in order to discover which elements are context-specific and which elements might be generalized.

Third, this study has used media articles supplemented with RRAPs own stakeholder engagement studies as a source to understand the public sentiment towards the RRAP marine cloud brightening intervention. Here, the assumption was made that although (independent) primary data sources on the public sentiment towards the intervention were not available and it was not feasible to interview members of the public and other stakeholders first-hand, news articles would be a suitable alternative. This assumption rests on the fact that the way events are portrayed in news media can be traced back to the general public opinion (Schulz, 2008). A concrete example can be found in Howse et al. (2022), where a literature review reveals news articles as a regular source for measuring public opinion and acceptability, albeit in the field of health studies. So although it should be clear that media articles *can* in fact be used for the purposes of this study, there are a few pitfalls to this approach that should be addressed. First, it is extremely difficult to tell whether public opinion informs the media, or whether news articles inform public opinion. Schulz (2008) describes this as one of the lasting questions of public opinion research: "*Do news media mould or mirror public opinion?"* (Schulz, 2008, p. 348). Consequently, the positionality of media outlets should be taken into accounts: any relations to or preferences for either proponents or opponents of marine cloud brightening could have influenced the correspondence.

Finally, making inferences about legitimacy by analyzing public opinion limits the study to a particular perspective. The RRAP case could also have been studied with a similar methodology, but instead of defining legitimacy and contestation from the perspective of the broader public, other perspectives could have been adopted. For example, while RRAPs engagement studies show that Australian citizens and Great Barrier Reef residents have a generally positive attitude towards marine cloud brightening deployment, such an outcome could have been very different for a different population, such as international lawmakers, environmental non-governmental organizations, or even scientists.

Chapter 9 – Conclusion

This thesis started with the following two-fold: *In what ways has the Reef Restoration and Adaptation Program performed regulatory, procedural and normative legitimacy and how has this performance contributed to the relatively low levels of public contestation of the small-scale experimentation with marine cloud brightening on the Great Barrier Reef?* By bringing together different strands of literature on the governance of emerging technologies, such as Responsible Research and Innovation (RRI) and anticipatory governance, this thesis proposes a new framework for exploring the role of legitimacy and contestation of marine cloud brightening field experiments. The framework includes three legitimacy dimensions: 1) regulative legitimacy – or the extent to which the intervention is perceived to adhere to the relevant regulatory framework, 2) procedural legitimacy – or the extent to which governance processes are transparent, inclusive and open, and to what extent relevant policy-makers can be held accountable, and 3) normative legitimacy – or to what the intervention is considered to contribute to society. While this theoretical framework provides a preliminary basis for future researchers to expand on, it's application onto the RRAP case has uncovered indicators when studying the legitimacy of cloud brightening field tests.

Analyzing the relevant regulatory framework governing the Great Barrier Reef Marine Park Area, it should be concluded that the Reef is governed by a complex landscape of many laws, regulations and guidelines on international, national and state-level. The current framework is not yet deemed suitable for experimentation with marine cloud brightening, argue RRAP researchers and news media. However, first preparatory steps have been taken. The RRAP technical report has provided extensive recommendations for 'future-proofing' the regulatory environment, and the Great Barrier Reef Marine Park Authority has already taken up 'geoengineering' as a project characteristic to apply for an intervention permit, categorizing such interventions as 'high-risk' and having them subject to more extensive permitting procedures. The dense network of regulations governing the Reef in combination with these first steps towards better alignment, have arguably contributed to the regulative legitimacy performed by RRAP. A second argument in relation to the regulative legitimacy links back to Australia's history with a weather modification with similar characteristics as marine cloud brightening: cloud seeding. Arguably, Australia's longstanding history with cloud seeding and the regulatory framework developed for the execution of cloud seeding programs in most states, including Queensland, has contributed to both its regulative and normative legitimacy. In light of recent developments, however, this contribution might also be questioned. It's complex nature and uncertainties make the technology prone to theories about its side-effects, which could have been observed by social media posts linking extreme weather events in Sydney over the summer of 2022.

In relation to procedural legitimacy, RRAPs engagement studies were analyzed in combination with data from (external) news sources. Many articles covering RRAP and the marine cloud brightening proposal more specifically, highlighted the need for collaboration with and inclusion of a broad variety of stakeholders. The technical report highlighted the same aim, and extensively studied four relevant stakeholder groups (livelihood stakeholders, Indigenous and Traditional Owner entities, citizens and civil society, and institutional stakeholders), the benefits of engaging them, risks and uncertainties for engagement, as well as recommendations on future engagement and involvement in the co-design of the interventions. In relation to the Traditional Owners, special attention has been paid to the *social license* to operate on the Reef, an area that is home to many of the natural resources that have been managed and exploited by the Traditional Owners for years. This particular attention to the Torres and

Strait Islander Groups has been well-received, report both Dr Stewart Lockie and local (indigenous) news sources, although Dr Lockie emphasizes the need to continue engagement and involvement on the ground, in all subprograms of RRAP. This finding stands in contrast with earlier experiments, such as SCoPEx, which is said to have failed to timely engage the Swedish indigenous community.

Normative legitimacy has been performed by the exploitation of different narratives in RRAPs communication that aligned with widely shared public views about climate change, the importance of innovation and the shared ambition for Australia to become an internationally competitive state when it comes to knowledge sharing. The idea of "saving" the Reef through marine cloud brightening was not only adopted by many news sources, but also proved to be essential common ground between the Traditional Owners of the Reef, and RRAPs researchers. In this part of the analysis, some contestation was found, albeit very minimal. The observation was made that the critiques and concerns that were described were the very same concerns sticking to the broader concept of solar geoengineering. Moreover, it was found that contestation was both fragmented and 'distant'. It was fragmented in the sense that there had been no collective efforts by those questioning or opposing the marine cloud brightening proposal to take action through e.g. protesting or by writing letters to decision-makers. Contestation was found to be distant, as the articles writing about it emphasized that this critique either came from non-Australians, or from niche groups in society.

The outcomes of this study provide some key insights into the Australian case, and how its introduction of geoengineering to the regulatory environment, its extensive engagement program and alignment of narratives with widely shared public norms have contributed to low levels of contestation of the experiment conducted in March 2020, to test marine cloud brightening equipment. Nevertheless, it remains to be seen how its performance on these three dimensions of legitimacy will persist the test of time. As the program intends to deploy marine cloud brightening, the first experiments are underway, and it shall be interesting to study how contestation around the proposal – both in Australian and in the international sphere – might change, as soon as the project moves from 'mere' equipment tests to small-scale marine cloud brightening.

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Annex I – Collected documents published by RRAP

Reference	Type	Title	Date	Published by	Description	Link to article
1	Media release	Difficult, complex decisions underpin the future of the world's coral reefs	27-8-2020	RRAP	RRAP	https://tinyurl.com/4c5j9jva
2	Media release	Joint Media Release: $150 million to drive innovations to boost Reef resilience	16-4-2020	RRAP	RRAP	https://tinyurl.com/y4wey4n8
3	Media release	Reef's massive size may be an asset in helping it withstand climate change	19-8-2018	RRAP	RRAP	https://tinyurl.com/4m62v37e
4	Media release	Winning hearts, finding cash, and tough decisions to save the Reef	18-7-2018	RRAP	RRAP	https://tinyurl.com/4f7pwnfx
5	Media release	Sunlight-deflecting clouds and mass-produced baby corals among proposed Reef solutions	17-7-2018	RRAP	RRAP	https://tinyurl.com/yc5v3232
6	Media release	International gathering to help the Great Barrier Reef help itself	15-7-2018	RRAP	RRAP	https://tinyurl.com/mphcbyd8
7	Media release	Helping the Great Barrier Reef: What can we do? What should we do?	1-7-2018	RRAP	RRAP	https://tinyurl.com/2p977mey
8	Media release	Coral reefs around the world are declining but Australia's marine researchers are leading the way in a bid to restore the Great Barrier Reef.	1-6-2018	RRAP	RRAP	https://tinyurl.com/ycyrsvca
9	Media release	Program announcement by the Prime Minister	22-1-2018	RRAP	RRAP	https://tinyurl.com/mrywz2cv
10	News article	The reef is not fine, nor is it dying; truth is in between	15-7-2021	The Australian	News outlet, national	https://tinyurl.com/4dzmkjmx

11	News article	Designing a blueprint for coral reef survival	30-4-2021	Biological Conservation	News outlet, national, specialized	https://tinyurl.com/2p9f2bz2
12	News article	Buying time for the Barrier Reef - shading coral and controlling starfish show promise at large scale	30-4-2021	ECOS	RRAP partner	https://tinyurl.com/yc8nkfwk
13	News article	Life support' measures could buy Great Barrier Reef another two decades, study finds	30-4-2021	The Guardian, Australia edition	News outlet, national	https://tinyurl.com/2p84r4nx
14	News article	The Marine Science Saving Our Backyard	12-4-2021	BD Mag	Magazine, Queensland	https://tinyurl.com/32y3w4az
15	News article	Taronga Media Release: Scientists playing key role in protecting reef	15-2-2021	Taronga Media	News outlet, national, specialized	https://tinyurl.com/mryrjv8y
16	News article	AIMS media release: Genome research brings identification of heat-resilient corals a step closer	17-7-2020	AIMS	RRAP partner	https://tinyurl.com/p2mcyk7p
17	News article	Bulletin of the Atomic Scientists: Literally cooked in hot water - what happened in the latest mass coral bleaching on the Great Barrier Reef	29-6-2020	Bulletin of the Atomic Scientists	News outlet, international, specialized	https://tinyurl.com/5n74k8rb
18	News article	Great Barrier Reef Foundation: Australian-first reef restoration hub for Cairns and Port Douglas	5-6-2020	Great Barrier Reef Foundation: Australian	RRAP partner	https://tinyurl.com/yrn7ej86
19	News article	ECOS: Novel interventions more than a 'cool idea' for the Great Barrier Reef	30-4-2020	ECOS	RRAP partner	https://tinyurl.com/2t25dr2m
20	News article	The Conversation: if we can put a man on the	24-4-2020	The Conversation	News outlet, international, specialized	https://tinyurl.com/ys9fa2nu

		moon, we can save the Great Barrier Reef				
21	News article	EcoWatch: Australia throws Great Barrier Reef a $300M lifeline, but will it cut emissions?	20-4-2020	EcoWatch	News outlet, international, specialized	https://tinyurl.com/nreb2uvc
22	News article	Independent: Snow machines could brighten clouds and halt GBR bleaching	20-4-2020	Independent	News outlet, international	https://tinyurl.com/ymdmp9nv
23	News article	The Guardian: Rebuilt it, shade it, breed it: three tactics to buy time for the Great Barrier Reef	18-4-2020	The Guardian, Australia edition	News outlet, international	https://tinyurl.com/4x7dtb8t
24	News article	ABC Triple J Hack: Australia's moonshot attempt to save the Great Barrier Reef has begun	17-4-2020	ABC Triple J Hack	News outlet, national	https://tinyurl.com/2p8pu7kt
25	News article	The Guardian: Scientists trial cloud brightening equipment to shade and cool the Great Barrier Reef	17-4-2020	The Guardian, Australia edition	News outlet, national	https://tinyurl.com/2p82fpea
26	News article	Yahoo! News: Brightening clouds and coral larvae: study picks best Great Barrier Reef rescue ideas	16-4-2020	Yahoo! News	News outlet, international	https://tinyurl.com/2p9hhyb3
27	News article	9 News: $300M earmarked for new Great Barrier Reef research	16-4-2020	9 News	News outlet, national	https://tinyurl.com/5d66z5j2
28	News article	Mirage News: Southern Cross University joins world-leading RRAP Program to boost reef resilience	16-4-2020	Mirage News	News outlet, national	https://tinyurl.com/3e28mdk3

Annex II – Collected documents from external (online) news outlets

Reference	Type	Title	Date	Published by	Description	Link to article
29	News article	Geoenegineering: The quick, and potentially catastrophic, fix for climate change	4-6-2018	ABC Premium News (Australia)	Media outlet, national	https://tinyurl.com/23eu85h7
30	News article	Climate change means geoengineering under pressure to keep our CO2 budgets under control	7-10-2019	ABC Premium News (Australia)	Media outlet, national	https://tinyurl.com/bdzy7vha
31	News article	Geoengineering the Great Barrier Reef needs strong rules	3-8-2018	The Mandarin	Media outlet, national	https://tinyurl.com/y8v8cfp5
32	News article	Scientists try 'cloud brightening' to protect Great Barrier Reef	17-4-2020	Phys.org	Media outlet, international, specialized	https://tinyurl.com/3w7xrhvr
33	News article	Scientists are Brightening Clouds over The Great Barrier Reef To Protect Dying Coral	20-4-2020	Forbes	Media outlet, international	https://tinyurl.com/3uhr4tnf
34	News article	Little fluffy clouds may help save Australia's Great Barrier Reef	28-9-2021	Reuters	Media outlet, international	https://tinyurl.com/3ppucyyv
35	News article	Coalition backs 'cloud-brightening' trial on Great Barrier Reef to tackle global heating	14-7-2020	The Guardian, Australia edition	Media outlet, national	https://tinyurl.com/yyrkpp9m
36	News article	Can artificially altered clouds save the Great Barrier Reef?	25-8-2021	Nature	Media outlet, international	https://tinyurl.com/yc3v2swp
37	News article	Can This 'Cloud-Brightening' Technique Save the Great Barrier Reef?	26-8-2021	Interesting Engineering	Media outlet, specialized	https://tinyurl.com/yrxbvb7d
38	News article	Artificially altered clouds could help the Great Barrier Reef, Experts say	13-9-2021	The Weather Network	Media outlet, international, specialized	https://tinyurl.com/wcudnenb
39	News article	Morrison government announces $1bn pledge for Great Barrier Reef over the next decade	27-1-2022	The Guardian, Australia edition	Media outlet, national	https://tinyurl.com/yckxahph

40	News article	Scientists Are Tinkering With Clouds to Save the Great Barrier Reef	20-1-2022	Wired UK	Media outlet, international	https://tinyurl.com/274w5k42
41	News article	'Cloud Brightening' Might Save the Great Barrier Reef	16-6-2018	Popular Mechanics	Media outlet, specialized	https://tinyurl.com/2z2jh6fk
42	News article	Budget earmarks $500m to mitigate Great Barrier Reef climate change	28-4-2018	The Guardian, Australia edition	Media outlet, national	https://tinyurl.com/2p88b2kp
43	News article	$1 billion of additional funding will do little for the Great Barrier Reef	1-2-2022	Phys.org	Media outlet, international, specialized	https://tinyurl.com/cwcw8wex
44	News article	How artificial clouds could save the Great Barrier Reef	18-9-2021	Freethink	Media outlet, international	https://tinyurl.com/254exv2x
45	News article	Great Barrier Reef: Outside-the-box thinking needed to fix its many problems, bleeding-edge solutioneers say	17-7-2018	ABC Premium News (Australia)	News outlet, national	https://tinyurl.com/yhum93f3
46	News article	Legal protections urged as science gears up to aid Great Barrier Reef	8-4-2019	Sydney Morning Herald (Australia)	Media outlet, national	https://tinyurl.com/t3df9hvc
47	News article	Interactive: Can the Great Barrier Reef survive climate change?	19-3-2019	Carbon Brief	Media outlet, international, specialized	https://tinyurl.com/bdf8hakz
48	News article	Cloud brightening, 'sun shields' to save Barrier Reef	20-7-2018	Jacaranda FM	Media outlet, national	https://tinyurl.com/4bpys443
49	News article	How artificially brightened clouds could stop climate change	20-2-2019	BBC	Media outlet, international	https://tinyurl.com/aerpxapx
50	News article	PM's claim Coalition saved reef from nonexistent 'endangered list' condemned as 'ridiculous'	12-5-2019	The Guardian, Australia edition	Media outlet, national	https://tinyurl.com/32648kda
51	News article	Cloud spraying and hurricane slaying: how ocean geoengineering became the frontier of the climate crisis	23-6-2021	The Guardian, Australia edition	Media outlet, national	https://tinyurl.com/55zmk93k
52	News article	The desperate race to cool the ocean before it's too late	23-4-2019	MIT Technology Review	Media outlet, international, specialized	https://tinyurl.com/yuxch52f

53	News article	As climate disasters pile up, a radical proposal gains traction	10-11-2020	The New York Times	Media outlet, international	https://tinyurl.com/d37nzxvh
54	News article	Scientists turn to risky plan B as the world fails on climate change	22-8-2021	Sydney Morning Herald	News outlet, national	https://tinyurl.com/u7ucwbaf
55	News article	Saviour or scientific hubris? Geoengineering the planet to counter climate change	26-8-2020	ABC Premium News (Australia)	News outlet, national	https://tinyurl.com/yc3jaux3
56	News article	What happens if we don't act?	21-12-2018	News.com.au	News outlet, national	https://tinyurl.com/4auauuxe
57	News article	Morrison's vision is not about technology, nor taxes. Just lots and lots of gaslighting	12-11-2021	The Shot	News outlet, national	https://tinyurl.com/2cebnshy
58	News article	Great Barrier Reef coral bleaching to be tackled in cloud-brightening experiment	17-4-2020	ABC Premium News (Australia)	Media outlet, national	https://tinyurl.com/yckpavt9
59	News article	Saltwater Traditional Owners welcome further protection of the Great Barrier Reef	18-4-2020	National Indigenous Television (NITV)	Media outlet, national, specialized	https://tinyurl.com/b29dubht