2022-2023
Master's Thesis – Master Sustainable Development

A Discourse Analysis of the Debate on Geoengineering in Japan

Student Information	
Name	Momoka Yabe
Student number	4620488
Thesis Course	45 EC
Supervisor	Prof. dr. Frank Biermann
2nd Reader	Dr. Rakhyun E. Kim
E-mail	m.yabe@students.uu.nl
Starting Date	17/11/2022
Submission Date	26/06/2023
Word Count	14,234 words (excl. Tables and Figures)

Summary

Geoengineering is a set of climate technologies for carbon dioxide removal (CDR) and solar radiation management (SRM) that have emerged in the Global North. Given the limited efforts being made to mitigate climate change to achieve the Paris Goals, geoengineering has gained prominence to complement current climate policies. Geoengineering has also emerged in the scientific community, where numerous studies have been conducted. In particular, given the uncertainties and risks of geoengineering, scholars have been interested in the public discourse surrounding geoengineering issues. Despite considerable attention to the discourses of SRM and CDR in the research field, most of it has focused on English-speaking countries in the Global North. This study explores the discourses and actors surrounding geoengineering and discusses how the narratives are being shaped in Japan. The study analyses 61 documents, including policy papers, reports, news articles and academic articles on SRM and CDR, and 11 interviews with relevant actors through discourse and network analysis using an inductive coding scheme. The analysis shows that the Japanese debate on SRM is still underdeveloped and that only researchers have knowledge about the technology. 11 actors have statements on SRM in terms of governance, concerns, implementation and research and development. On the other hand, the debate on CDR, in particular CCS, is active and government, industry and academic groups are very interested in developing and implementing CCS in terms of economic and climate change objectives. Out of 24 relevant CCS actors, 13 actors indicate their position on CCS, such as governance, concerns, implementation, research and development and business. Several actors belong to international communities that have a transnational influence on the Japanese debate on SRM and CCS, which could affect the narratives and policies. Overall, inadequate and unbalanced power prevents actors from engaging in collective decision-making and agenda-setting on geoengineering. In this context, this study offers four policy recommendations to overcome the challenges surrounding the geoengineering debate in Japan.

KEYWORDS: Geoengineering; SRM; CCS; Discourse; Network; Japan

Preface

Climate change governance has been my academic passion since my undergraduate studies. The first course of the Sustainable Development Programme, 'Foundation of ESG', taught by my supervisor, expanded my academic interests and led me to research geoengineering for my master's thesis.

Given the progress towards the Paris Agreement and climate change mitigation, the debate on a new approach, geoengineering, is more focused than ever. It is of utmost importance that the debate on geoengineering is led by a specific economic group, but encouraged to include all countries and relevant actors.

In this regard, focusing on Japan, my country, for this research has been an exciting and challenging academic project. It was a great honour to conduct the first research on the Japanese debate on geoengineering. I believe that connecting actors' relationships promotes better collective governance, and I hope that this research maps the future direction of the geoengineering debate in Japan.

Utrecht University

Table of Contents

1. Introduction

1.1 Problem Definition

1.1 Geoengineering

"The international community is falling far short of the Paris goals, with no credible pathway to 1.5°C in place" (UNEP, 2022).

The United Nations Environment Programme (UNEP) published the Emissions Gap Report in 2022, which states that the current process of mitigating climate change is far from the goal of the Paris Agreement (UNEP, 2022). Even in the best-case scenario, where all possible efforts could be made by countries, we can only achieve the 1.8-degree scenario. Tackling the climate crisis will require much greater effort and innovative solutions.

International actors such as economies and organisations have committed to tackling the climate crisis through multiple approaches: implementing Nationally Determined Contributions (NDCs), establishing climate laws and net zero targets, and transforming societies for sustainability (UNEP, 2022). However, these efforts have not yielded positive results; we are witnessing an increasingly severe climate crisis around the world. According to the Emergency Events Database, more than 430 climate-related disasters caused about 10,500 deaths and about $252 billion in economic damage worldwide in 2021 (CRED, 2022). Furthermore, the negative impacts of climate change continue to disrupt people, the environment and biodiversity (Fawzy et al., 2020; Abbass et al., 2022).

In recognition of the limitations of current approaches to climate change mitigation, industrial countries have been discussing an alternative idea (cf. Biermann et al., 2022). Geoengineering or climate engineering is one of the innovative climate solutions. Such climate technologies have gained prominence among industrial countries and scientists in the Global North as one of the tools or backup plans for climate change mitigation (Gupta et al., 2020; Sovacool, 2021; Reynolds, 2022).

Geoengineering is a broad term used to describe technological climate interventions to mitigate climate change (Lawrence et al., 2018; Parson & Reynolds, 2021). Carbon dioxide removal (CDR) and solar radiation management (modification) (SRM) are the two key technologies of geoengineering (Caldeira et al., 2013; Gardiner & McKinnon, 2020; Grubb et al., 2022). CDR refers to the approach that removes emitted CO2 from the atmosphere. SRM is intended to reflect the sunlight and to cool down the plant, for example employing aerosol injection. Table 1 and Figure 1 show the relevant technologies for both CDR and SRM to mitigate climate change.

CDR removes CO2 from the atmosphere and stores the carbon in "geological, terrestrial, ocean reservoirs or in products" (Babiker et al., 2022, p. 220). There is a growing consensus in the international community that the CDR is necessary to achieve the Paris Goals (Buylova, 2021). Afforestation-reforestation, direct air carbon capture and sequestration (DACCS), enhanced weathering (EW), bioenergy combined with carbon capture and storage (BECCS) and carbon capture and (utilisation) storage (CC(U)S) are considered the main options for CDR (Babiker et al., 2022; Jaschke & Biermann; 2022).

Governments and industries are particularly interested in CCS and CCUS worldwide. CCS and CCUS are climate geoengineering technologies that enable the long-term capture, transport, storage and use of CO2 in onshore or offshore geological formations (Gough & Mander, 2019). It is an emerging climate mitigation technology that can be applied to energy production and industry, helping to capture carbon emitted by industrialised activities (Babiker et al., 2022).

In contrast, SRM has more uncertainties (Grubb et al., 2022) and is still under theoretical development. SRM has three main approaches to reflecting and blocking sunlight from space and cooling the planet: space, atmosphere and surface (Lawrence et al., 2018). SRM also has different approaches such as space mirrors, stratospheric aerosol injection (SAI), marine sky brightening (MSB) and cirrus cloud thinning (CCT), surface-based brightening (Lawrence et al., 2018).

In particular, SAI has become increasingly prominent in research following MSB and CCT (Lawrence et al., 2018; Patt et al., 2022). SAI involves the injection of sulphate aerosol precursors into the lower stratosphere (Bednarz et al., 2022), inspired by the processes that naturally follow large wildfires and volcanic eruptions (Hueholt et al., 2023). SAI aims to complement the mitigation of climate change by cooling the Earth's surface temperature with the implementation of the global approach to reducing CO2 emissions (Hueholt et al., 2023).

	CDR	SRM
Technologies	Afforestation - Reforestation Direct Air Carbon Capture and Sequestration (DACCS) Enhanced Weathering (EW) Bioenergy Combined with Carbon Capture and Storage (BECCS) Carbon Capture and Storage (CCS) Carbon Capture, Utilisation and Storage (CCUS)	Stratospheric Aerosol Injection (SAI) Marine Sky Brightening (MSB) Cirrus Cloud Thinning (CCT) Space Mirrors Surface-Based Brightening

Table 1: Relevant technologies for CDR and SRM

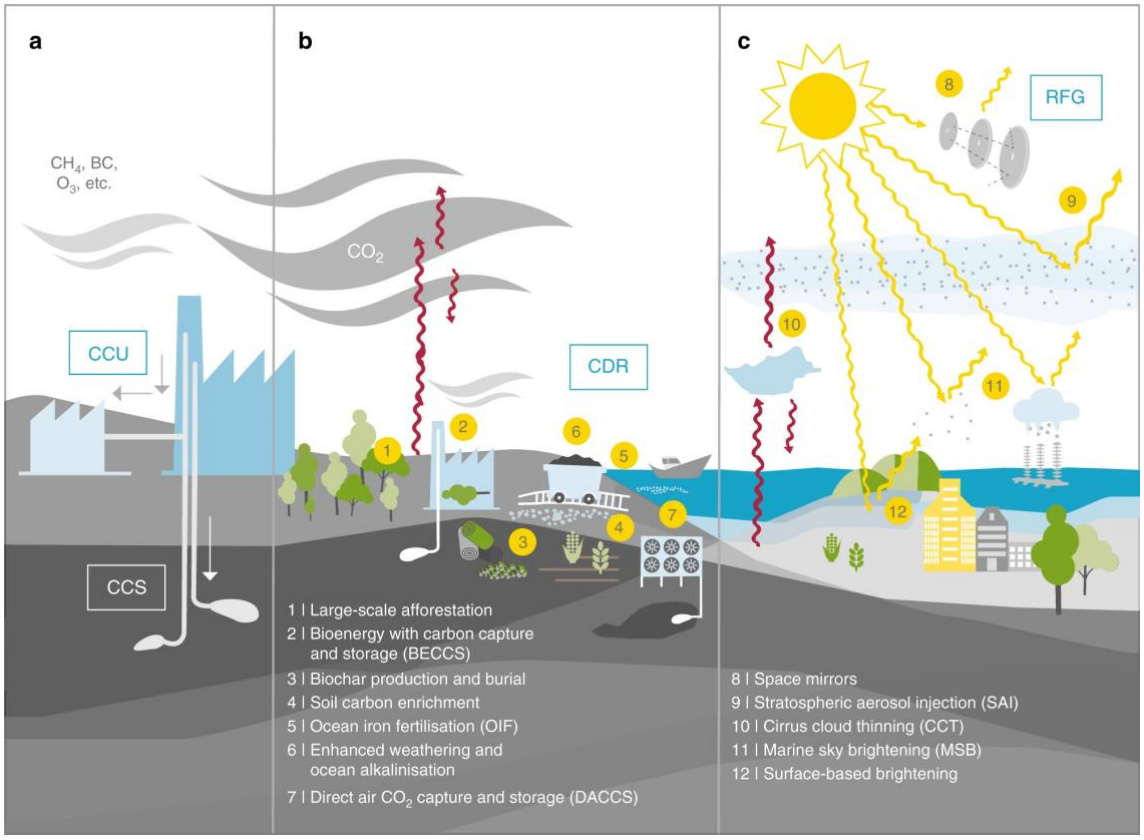

Figure 1: Relevant technologies for CDR and SRM retrieved from Laurence et al. (2018). The picture illustrates how both technologies are embedded in the socio-

ecosystem. (RFG=SRM).

While industrial countries actively discuss CDR and SRM as innovative and necessary solutions to mitigate GHG emissions, many scholars raise the uncertainties and risks of imposing such technologies at the planetary scale (e.g. Jacobson, 2018; Gunderson et al., 2019). For instance, Brack and King (2021) raise the justice issue of land-based CDR, which threatens food security and biodiversity cycles. Furthermore, some studies show that CDR has negative impacts on vulnerable regions and people (Jaschke & Biermann, 2022).

SRM is even more controversial, with a more negative consensus among scientists (Reynolds, 2022). The risk of SRM is strongly linked to ethics because of the intervention in the ecosystem and the risk to future generations (Reynolds, 2022). Furthermore, SRM has more socio-political concerns (e.g. international governance conflicts) and risks to the environment and humanity in terms of justice and ethics (Asayama et al., 2019; Parson & Reynolds, 2021).

Another possible threat of geoengineering in general is that it slows down efforts to reduce emissions, but allows humans to continue emitting CO2. Patt et al. (2022) discuss that the development of CDR and SRM could result in the problem shifting away from addressing emissions reduction and the human footprint.

1.2 The Adoption of Geoengineering in Global

Many industrial countries are engaged in geoengineering research and development. For instance, CDR has gained prominence among policymakers and researchers in industrialised nations as a realistic and critical approach to achieving net zero (Babiker et al., 2022; Riahi et al., 2022). Countries in the Global North have a significant interest in CDR and have predominantly developed CDR (Batres et al., 2021). In particular, the emergence of CCS projects is significant. There are 196 ongoing projects worldwide, including 30 operational facilities as of 2022 (Global CCS Institute, 2022).

Similarly, SRM experiments and projects have been carried out in the Global North (Sovacool, 2021). In particular, wealthy industrialised countries, namely the United States (US) and the United Kingdom (UK), have been interested in the development of SRM and its governance since the early 2000s (McLaren & Corry, 2021). The UK government invests in researching SRM for computer simulation but does not intend to deploy it (Department for Business, Energy & Industrial Strategy, 2020).

In contrast, the US government has a strong interest in SRM research and development, funding and establishing research agendas and projects (Reynolds, 2019; Biermann et al., 2022). In specific, the SCoPEx project, led by Harvard University, has conducted research and tests such as the Stratospheric Controlled Perturbation

Experiment. However, the test was halted due to objections from the local community (Stephens et al., 2020; Biermann et al., 2022).

Despite the growing presence of geoengineering, the current theoretical and political debate has not yet extended beyond the Global North (Delina, 2020; Stephens & Surprise, 2020; Sugiyama et al., 2020; Delina, 2021; Jaschke & Biermann, 2022). In addition, mainstream research on geoengineering is generally conducted in English-speaking countries (Raimi, 2021) and lacks more in-depth regional case study research (Sugiyama et al., 2020). Scholars should therefore enhance research by including perspectives beyond the Global North.

1.3 Geoengineering in Japan

In this regard, this research focuses on Japan. Japan is one of the major economies representing the G7 and ranks 3rd in terms of global GDP. The G7 accounts for about 40% of global greenhouse gas emissions, of which Japan is responsible for 3-5% of emissions (Kameyama, 2021; IEA, 2022). In 2022, the G7 working group published a report discussing geoengineering and its controversy (Warren, 2022). However, neither the Japanese government's position on CDR or SRM, nor research on the geoengineering debate in Japan has been widely explored.

Sugiyama et al. (2017a; 2020) and Sugiyama and Fujiwara (2016) found that Japanese university students are relatively supportive of the development of research on SRM, but cautious about the use of technologies or field experiments. Asayama et al. (2017) and Sugiyama et al. (2017a, p.7) noted that Japanese citizens "cautiously and conditionally" accept SRM research as they are aware of the climate crisis. Furthermore, Sugiyama et al. (2017b) conducted a study to identify the important research agenda on SRM by organising workshops inviting relevant actors from government, industry, academia, and NGOs yet their relationships have not yet been identified.

In short, the preliminary literature review revealed that researchers focus on the discourse of Japanese citizens on SRM, but not on CDR or the overview of the CDR and SRM debate and its related actors in Japan. Therefore, research on the debate on CDR and SRM at the national level and the relationships between the relevant actors in Japan is crucial.

1.2 Research Aim and Question

Based on the knowledge gap in the current literature, - i.e. the lack of theoretical debate and analysis on geoengineering in the context of Japanese climate change governance -, this research aims to identify the ongoing debate on geoengineering in Japan and how they are framed in terms of agenda-settings.

Therefore, the following research question guides this project:

What is the current debate on geoengineering (CDR and SRM) for global climate mitigation in Japan and how are the narratives shaped?

The main research question is complemented by five sub-questions:

1. **What kinds of statements about geoengineering are currently shared in Japanese society?**
    a. Which statements are dominant?
    b. What are the storylines of the geoengineering debate in Japan?

2. **Who are the main actors in the current geoengineering debate in Japan?**
    a. What are their views and interests on global geoengineering in Japan?
    b. How are the actors associated with the identified statements?
    c. To what extent are actors interested in CDR and SRM?

3. **How are the actors' networks structured?**
    a. How does the power balance of the actors involved shape the discourse and influence the discussion?
    b. To what extent does international influence affect the Japanese debate on geoengineering?

4. **What policy recommendations can be derived from the findings of this research?**
    a. What is the role of the Quadruple Helix in developing the dialogue on the future debate on geoengineering in Japan?

For the purposes of this research, the term geoengineering is used in a broad sense, taking into account CDR and SRM.

1.3 Research Framework

Figure 2 illustrates the research framework for this study. The main research question consisted of four sub-questions that guided three phases of research.

Phase one began with data collection to identify statements about geoengineering in Japan as a basis for this research. A synthetic literature review explored dominant opinions and relevant actors of geoengineering in Japan. Documents including journal articles, policy documents, newspaper articles and reports were collected. Sub-questions (SQ) 1 and 2 were addressed in this phase.

In addition, Phase 1 also aimed to understand the views of actors and their level of interest in geoengineering. In this respect, SQ2 was also answered in this phase by conducting interviews. The selection of interviewees was based on the results of the data collection from the documents.

In the second phase, the analysis was carried out. In this phase, the statements on SRM and CDR and their relevant actors were examined. In addition, the relationships and networks of the actors were analysed in order to understand the networks of the actors around geoengineering in Japan. This step was linked to SQ3. First, storylines were developed through discourse analysis by coding the collected data. Subsequently, network analysis was conducted to understand the relationships of relevant actors and their power relations, which provided an overview of the Japanese geoengineering debate.

Finally, the third phase highlighted and discussed the findings, which led to the policy recommendations (SQ4) and future research directions. In the original research proposal, a workshop was planned to provide a discussion workshop for actors to exchange views on both the SRM and CDR and the network. However, due to time constraints, this was not organised within the given timeframe.

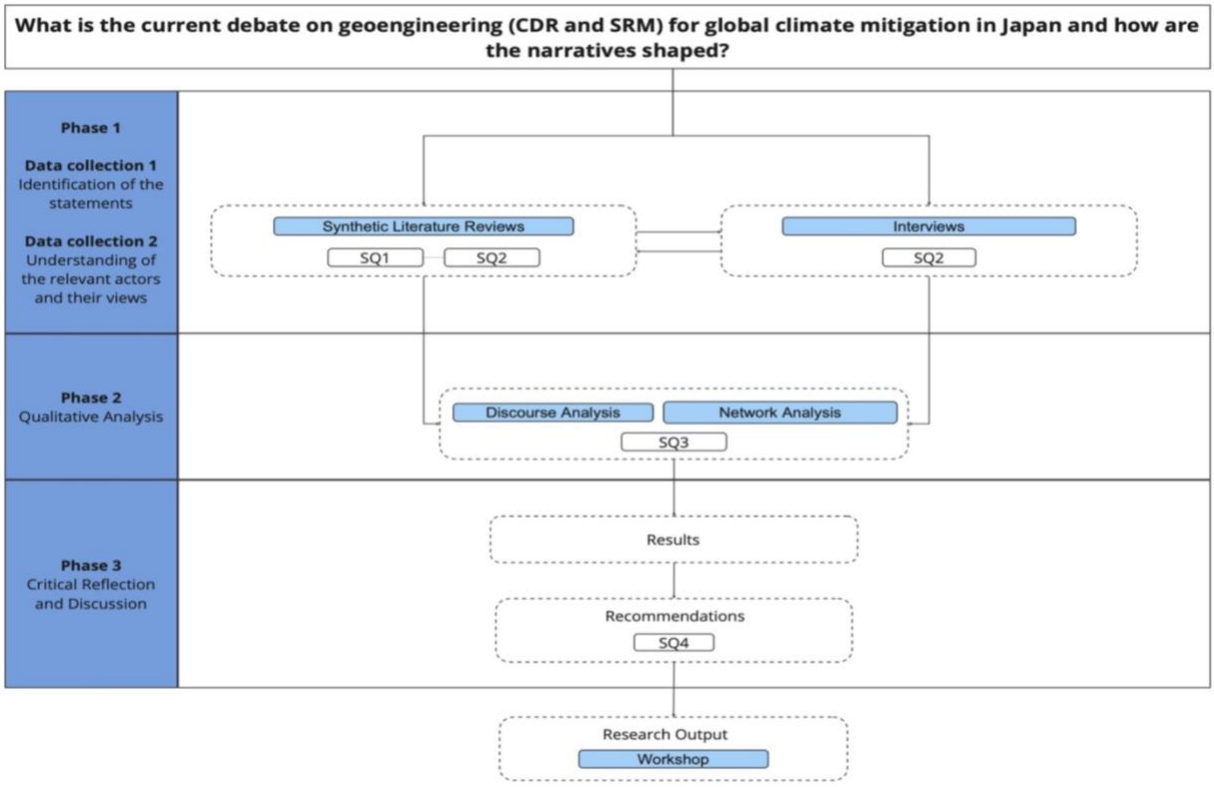

Figure 2: Research Framework

1.4 Scientific and Societal Relevance of the Research

1.4.1 Scientific Relevance

This research contributes to filling the knowledge gap in the growing research of geoengineering. Firstly, given that current geoengineering research focuses on the Global North, specifically the English-speaking countries, research on other regions is vital. For instance, discourse analysis of geoengineering has primarily focused on industrialised countries in the Global North, such as North America, Europe and Australia (Delina, 2021; Jaschke & Biermann, 2022). This suggests that the central narratives of geoengineering are shaped by Western society and culture, which may conflict with views in other regions. Depending on the given social structure and cultural background, the idea of geoengineering could differ from region to region. It is therefore crucial to consider global perspectives, as both geoengineering technologies have global implications, both ethically and physically.

Secondly, some English research has explored both debates and relevant actors of CDR and SRM in Japan. The research was led by Japanese researchers and published in the late 2010s (e.g. Asayama et al. 2017; Sugiyama et al. 2017a). They focus on public discourse and the identification of the research agenda for geoengineering. However, to the best of my knowledge, the relevant actors around the issue of geoengineering and their statements on geoengineering have not been researched. As geoengineering emerges and becomes more prominent on the international agenda, updated studies on geoengineering in Japan are urgently required. In this regard, research on the Japanese debate on geoengineering - CDR and SRM - is essential to improve regional/global understanding of the different perspectives.

Finally, research on the geoengineering debate is of great importance. A large group of scientists propose the need for more research on geoengineering due to growing concerns (e.g. Anshelm & Hansson, 2014). In order to amplify the debate on geoengineering at an international level, it is important to elicit the existing voices of concern and opposition that have not been identified. Therefore, this research contributes to the growing body of literature on geoengineering by providing new insight into an Asian country in English.

1.4.2 Societal Relevance

First, studying the Japanese debate on geoengineering is crucial for future dialogue at the international level, as the urgency of geoengineering has been debated by researchers and policymakers (McLaren & Corry, 2021). Although Japanese economic influence has declined since the late 1990s, Japan's presence in global governance is prominent as a

member of the G7 (Oshiba, 2021). In addition, the Japanese government has been involved in the global environmental debate since the 1980s, when environmental discussion emerged at the international round table (Kameyama, 2021). It is important to identify Japan's position on geoengineering and its relevant actors, who play the primary role in the coming agenda-setting on climate technology. Thus, this research contributes to the global debate on geoengineering by providing Japanese insights in English.

Subsequently, policy recommendations based on the analytical findings can add value to the current Japanese climate change governance. The preliminary research found that the Japanese debate on geoengineering is less active than other countries in the Global North (e.g., Cox et al., 2020; Burnard & Colvin, 2022). Given the emergence of novel climate technologies in the world, the Japanese government could adopt new policies and prepare for knowledge production on geoengineering. Thus, this research highlights the circumstances of the current understanding of geoengineering and who is sharing the knowledge.

Finally, assuming that geoengineering is less prominent in Japan, the study contributes to raising awareness of climate technology in Japan by providing an overview of the Japanese discourse on geoengineering. Scientific findings can promote public debate and policy when they are shared with society (Blanton & Ikizer, 2019). Furthermore, a comprehensive discussion of such controversial issues with relevant actors and the public is essential for the government's policy agenda-setting. Thus, this study can propose new insights to lay the foundation for future geoengineering debates in Japan.

2. Theoretical Research Design

2.1 Agenda-Setting and Multiple Streams Theory

In order to understand how an emerging technology - i.e. a new agenda - is framed and developed in a country, it is crucial to identify how the agenda is adopted. The Multiple streams theory (MSF) proposed by Kingdon (1995) provides useful insights into how the new agenda is framed and set in policy making (Knaggård, 2015). MSF explains how a policy is formulated under conditions of ambiguity (Zahariadis, 2014). The condition of ambiguity is defined as "a state of having many ways of thinking about the same circumstances or phenomena" (Zahariadis, 2019). Therefore, this study adopts MSF as a theoretical framework to discuss the current debate on geoengineering in Japan.

Given the complexity of agenda-setting in the Anthropocene, policymakers are challenged to understand the dynamic issues and find adequate solutions under such conditions of 'ambiguity' and time constraints (Zohlnhöfer et al., 2015). MSF is an appropriate theoretical framework to understand agenda-setting under the complexity and ambiguity of the political situation. Geoengineering is a novel technology that has emerged on the climate and political agenda, requiring technoscientific knowledge and a new political approach to governance. Moreover, there is a limited time frame for addressing climate emergencies. The 'ambiguity' of the politics of geoengineering is thus even more pronounced, and policymakers are called upon to address the issue in the limited time available.

The context of ambiguity exists in the structure of government, understood as 'organised anarchy', which is indicated by "fluid participation, problematic preferences and unclear technologies" (Zahariadis, 2014, p. 22). First, fluid participation describes the mobility of actors in the decision-making process. Actors range from bureaucrats to interest groups such as NGOs. Second, problematic preferences refer to the indecisiveness of decision-makers. Due to time constraints and fluid political issues, decision-makers are often required to develop a policy while failing to prioritise problems. Third, unclear technology includes the lack of organisational structure in policy-making. Actors involved in decision-making are uncertain about their position and responsibilities in the process, which creates ambiguity in the policy-making systems.

MSF consists of three main streams: problem, policy and politics (Figure 3). The three individual streams flow through the political system. When the streams are coupled at critical times, a 'policy window' is opened by 'policy entrepreneurs' (Zahariadis, 2014). This study focuses on the three streams to provide an overview of the geoengineering debate in Japan and how geoengineering is adopted in Japanese society. Understanding that geoengineering is a relatively new agenda, this study does not explore the actual policy development and implementation of geoengineering in Japan.

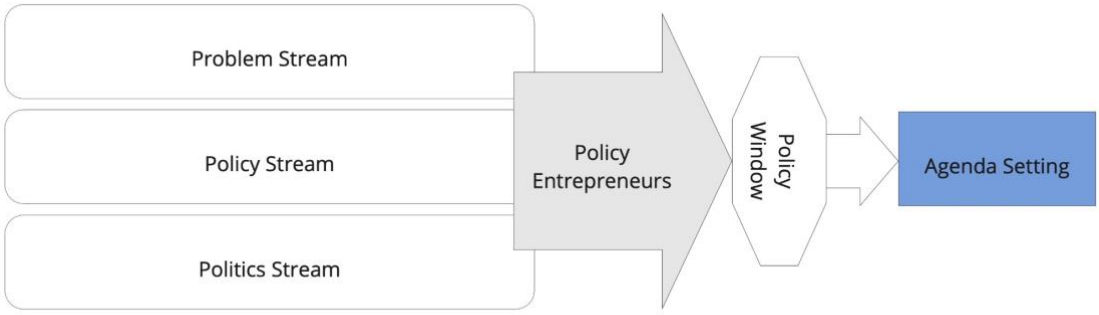

Figure 3: Multiple Streams Framework

The three streams can be explained as follows. The problem stream refers to the critical situation that the country faces, including natural disasters and political system failures (Horton et al., 2023). National problems are dynamic and diverse and require definition and prioritisation. The problem can be defined by the 'problem entrepreneurs' who are the relevant actors in policy-making and seek the attention of the government (Hoefer, 2022). Alternatively, three measurements, namely the change in objective indicators, the occurrence of focusing events and the accumulation of feedback, help to define the problem stream (Fitch-Roy & Fairbrass, 2018).

The policy stream indicates the political idea that intends to solve the problems arising in the country (Horton et al., 2023). The problem-solving idea is invented by the relevant actors, such as experts in a think tank, which accumulates in the 'policy primeval soup' (Hoefer, 2022; Horton et al., 2023). Policymakers carefully select such an idea if it meets the value, technical feasibility and effectiveness (Fitch-Roy & Fairbrass, 2018; Hoefer, 2022; Horton et al., 2023).

The politics stream consists of the political interests and intentions of the political actors, including the government, parties, and interest groups (Zahariadis, 2014; Herweg et al., 2022). The actors, who represent the political process, exert their influence in order to achieve their interests. In this regard, the politics stream includes the different perceptions of political actors who oppose or support the policies and issues (Fitch-Roy & Fairbrass, 2018).

2.1.1 MSF and Japanese Climate Change Mitigation Governance

Geoengineering is considered part of the solution to climate change and is included in climate policy (Sovacool, 2021). Therefore, understanding the context of Japanese climate governance helps to get an overview of the geoengineering debate in Japan. Therefore, this section explores the Japanese governance and decision-making process on climate change mitigation by applying the MSF and its three streams.

Problem Stream

The severe impact of the climate crisis is significant for the livelihoods of people in Japan. For instance, heat waves in summer cause the death of thousands of people and agricultural sectors (Baba et al., 2021; Koppenborg & Hanssen, 2021). Moreover,

devastating typhoons hit during summer have resulted in economic damage and people's life (Nayak & Takemi, 2020; Kameyama, 2021).

While affected by the catastrophic climate crisis, Japan is a highly carbon-driven country in G7 and has been struggling with carbon emission reduction related to the industry (Ju et al., 2021). Especially, after the Great East Earthquake in 2011, the government of Japan has been challenged to find an alternative energy policy to cover the closure of nuclear power plants (Sugiyama et al., 2019). Thus, Japan strives to realise climate and energy policy while reducing CO2 emissions. Additionally, given the climate responsibility and its goals, the Japanese government has received pressure from the international community to improve its unambitious climate policies (Koppenborg & Hanssen, 2021).

The perception of climate change in Japan also frames the problem stream. More than 70 % of the public in Japan perceives climate change as severe impact happening right now around the world (IMF, 2023). However, only about 40% of Japanese citizens consider climate change's impact imminently affects Japan (IMF, 2023). This view also shows the relatively reluctant support toward climate mitigation policies compared to the rest of the countries. IMF (2023) indicates that the Japanese public shows resistance toward the mitigation policies such as carbon pricing, subsidies to renewable energy, and emission reduction policies, which result is prominent in the Asia Pacific. Kameyama (2021) describes this situation as a lack of norm sharing in Japan. Although the norms of the climate crisis are growing in Japan, Japanese citizens have not fully realised the emission reduction responsibility.

Policy Stream

The '2050 Carbon Neutral Declaration' adopted in 2020 steers the current Japanese climate governance. Carbon neutral policy 2050 consists of three main approaches: green innovations, localised approaches, and bilateral and multilateral assistance (Cabinet Office, n.d.). Along with this policy, the revised Act on Promotion of Global Warming Countermeasures enacted in 2021 entails the government's legal commitment to carbon-neutral transformation by 2050 (Ministry of the Environment, 2021a). Moreover, the Japanese government determined that there will be a 46% CO2 reduction (2013 base) by 2013 in 2020, reflected in the latest NDCs submitted to UNFCCC (Ministry of the Environment, 2021b).

The Japanese climate policy aims to pursue carbon neutrality while securing the economic growth of the country (Hasui & Komatsu, 2021). In this context, the Japanese government had historically been reluctant to adopt the ambitious climate policy as they believed that addressing climate change led to economic stagnation (Koppenborg & Hanssen, 2021; Gilson, 2023).

The latest climate mitigation policy, the '2050 Carbon Neutral Declaration' indicates that the government of Japan recognises the opportunity for economic development and reform of industrial structure through climate mitigation policies (Cabinet Office, 2021). Policy 11 'carbon recycling' specifically mentioned CCS indicating the development of CCS. Under the declaration, the government established the Green Innovation Fund to invest two trillion yen in the research and development of innovative technology for carbon neutrality including CCS (METI, 2021). This fund aims to support the industries for the next 10 years by subsidising the research and development to implementation of green technologies (METI, 2021).

Politics Stream

The politics stream can be described by the political influence of actors in climate change policy-making in Japan (Figure 4). First, the legislative organisation within the government influences Japanese climate policy. The Global Warming Prevention Headquarters (GWPH) was established in 1997 under the Act on Promotion of Global Warming Countermeasures to steer Japanese climate policy. The Cabinet Office embeds the office in the structure; the Prime Minister leads the office as head, the Minister of Economy, Trade and Industry (METI) as deputy head and the Minister of the Environment (MOE), and the members consist of other ministers (Cabinet Office, 1997).

Under the GWPH, a triangular network of executives and stakeholders is involved in the decision-making process. Satoh (2014) identifies a 'triangle structure' represented by the government, ministries and industry in the policy-making process of climate change mitigation. This triangular network structure of MOE, METI and the Japan Business Federation (Keidanren) implements Japanese climate policy through interactions. METI works closely with Keidanren as its purpose is to pursue economic growth and energy efficiency, while MOE steers climate policy and environmental protection (Koppenborg & Hanssen, 2021). In this regard, the power balance of the triangle is tilted towards METI and Keidanren, which creates conflicts between MOE and leads to the dysfunction of Japanese climate policies (Satoh, 2014; Kameyama, 2021; Koppenborg & Hanssen, 2021).

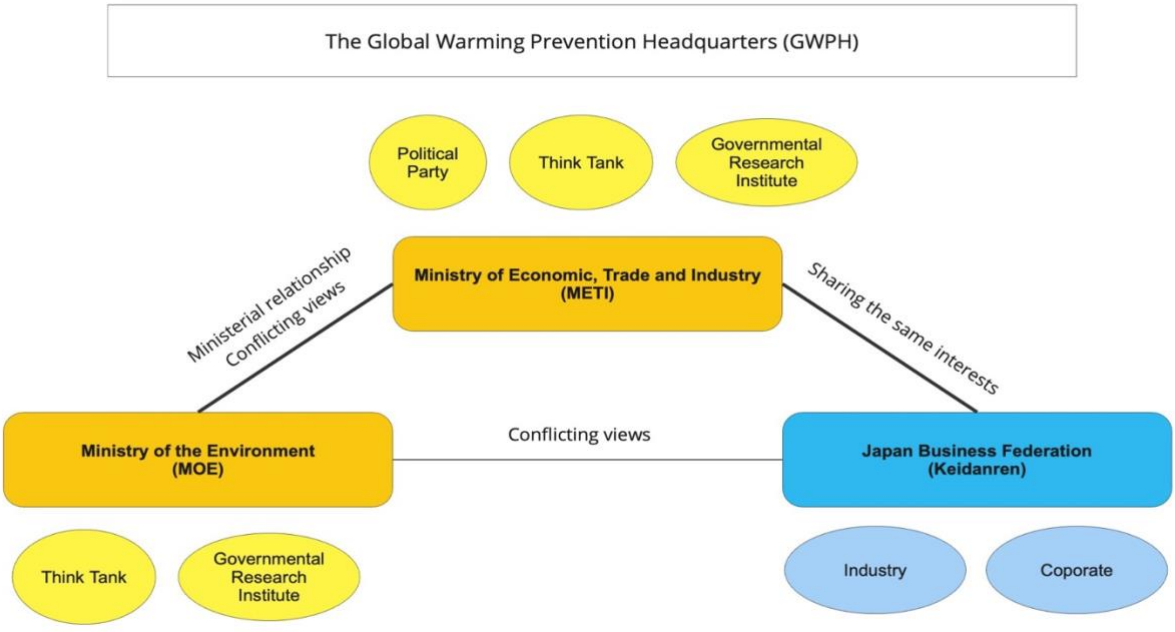

Figure 4: The political influence and structure of Japanese Climate policy (based on Satoh, 2014; Gilson, 2021; Koppenborg & Hanssen, 2021): The thickness of the line between each block indicates the closeness (thick = close; thin = fewer interactions). The circles around the sectors represent the actors linking to each block.

2.2 Technoscientific Innovation and Helix Theory

The MSF helps explain agenda-setting in the political context; however, it focuses only on the political actors (Herweg et al., 2022). This excludes the various actors' involvement and perspectives in the process, resulting in an incomplete understanding of the dynamics and power relations within the policy process. Furthermore, it is also important to understand how a country adopts and develops technoscientific innovations in the light of technological developments.

Geoengineering has emerged from complex environmental and political issues. In this context, technoscientific development requires an interdisciplinary approach as it is a matter of science and governance. Therefore, helix theory helps us to understand the social structure that fosters technoscientific innovation. In this study, innovation is understood not only as technological development, but also as social action to mitigate climate change, such as climate change policy (Fagiewicz et al., 2021).

The Triple Helix is a theory proposed by Etzkowitz and Leydesdorff (1995). The model is derived from innovation research and explains that the Triple Helix promotes "regional economic growth" and "entrepreneurship by understanding the dynamics of interactions between three institutional spheres: university, industry and government" (Cai & Etzkowitz, 2020). Etzkowitz and Leydesdorff (1995) argue that in a knowledge-based society, social and technological innovation is enhanced by close interactions between universities, industry and government, rather than by traditional government-industry linkages.

The dynamic interactions of the three domains have been interpreted and elaborated in various academic fields, including sustainability governance (e.g. climate change governance) (Scalia et al., 2018; Savaino et al., 2019). Figure 5 illustrates the three domains of sustainability governance: environmental, social and economic. The Triple Helix of sustainability governance interprets the interactions of actors, namely government, industry and academia, to influence the three sustainable innovations. (Scalia et al., 2018).

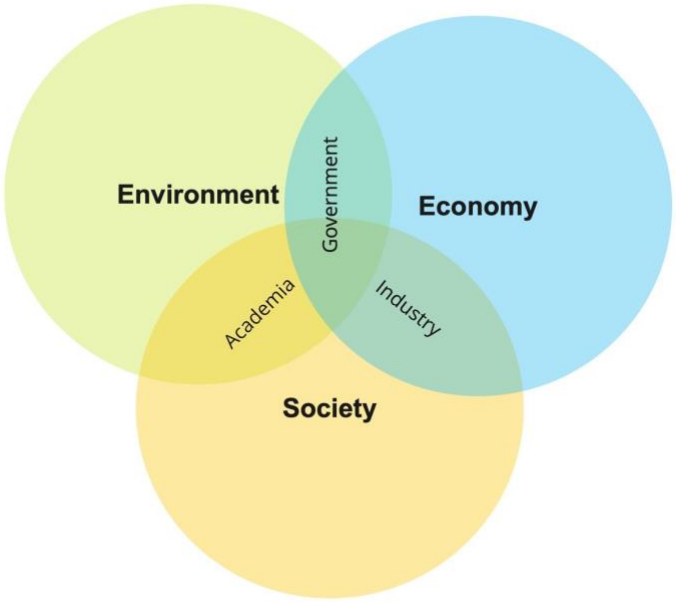

Figure 5: Triple Helix model in sustainability governance (based on Scalia et al., 2018; Savaino et al., 2019): Each circle represents three domains of the Triple Helix in Sustainability: Environment, Economy, and Society, and overlapping parts connect through each actor: Government; Industry; and Academia.

In addition to the original Triple Helix, a new helix has been incorporated into the theory to explain climate change innovation. In climate change governance, non-state actors such as NGOs are crucial as actors representing the voice of citizens (United Nations, 1992; Kythreotis et al., 2019). This Quadruple Helix theory includes NGOs as a fourth actor in addition to the triple helix theory (Carayannis & Campbell, 2021) (Figure 6). This model explains the synergy of interactions between four sectors, namely government, industry, academia and NGOs, that accelerate innovation in sustainable development. The involvement of citizens provides the feedback effect that influences knowledge and technology development (Hakeem et al., 2023). Furthermore, citizen engagement also legitimises and justifies innovation in society (Hakeem et al., 2023).

Overall, helix theory explains the interactions of helices that drive innovation in society. Technological innovation results from the production of knowledge that occurs when the helices are coupled in their interactions. Additionally, climate change mitigation is accelerated by the Quadruple Helix (Fagiewicz et al., 2021). In short, this research assumes that the technoscientific innovation of geoengineering will be adopted under the interactions in the Quadruple Helix.

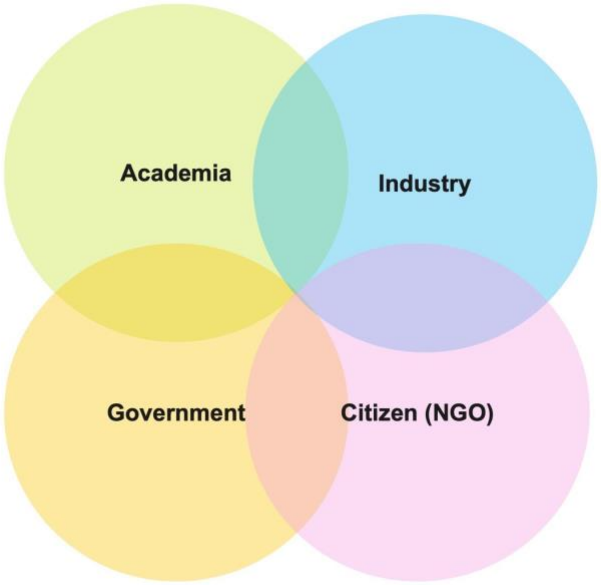

Figure 6: The Quadruple Helix in climate governance (based on GRIP, 2020; Carayannis & Campbell, 2021): Four actors (Government; Industry; Academia; and Citizen/NGO) interact with each other steering sustainability governance.

2.2.1 Helix Theory in Japan

The triple helix is a central element of Japan's overall policy and technological development. The Japanese government often incorporates 'industry-academia-government (産学官: San-gaku-kan)' collaboration into policy (e.g. MAFF, 2022; METI, n.d.). Policymakers in Japan promote the Triple Helix, believing that the cooperation of the helices leads to economic growth through the production of science and technology (CRDS, 2021).

Climate policy (mitigation/adaptation) is no exception (e.g. FSA, 2022). The Government of Japan has implemented the 'Green Growth Strategy' policy as part of the 2050 Climate Neutrality Declaration. The strategy outlines the enhancement of the Triple Helix to achieve precise economic growth and climate change mitigation (Cabinet Office, 2021). Specifically, the Japanese government focuses on technological development, especially for recycling and storing carbon under the Triple Helix (Cabinet Office, 2021).

Yoda and Kuwashima (2020) discuss the history of the Triple Helix in Japan. Historically, the Triple Helix was restricted by regulation after World War II, as the military served as the government helix until the 1970s. After deregulation, the government strengthened the Triple Helix under the Science and Technology Basic Plan. The Japanese government established national research institutes, which later became independent administrative organisations, to promote knowledge production and implement research results. This results in closer interaction between the government and the academic helix, particularly national research institutes.

The Quadruple Helix also influences and represents Japan's innovation and climate policy. In addition to the 'triangle structure' (*see*: 2.1.1), local governments and non-state actors have also increased their influence on Japanese climate policy-making in recent decades (Figure 7). Historically, the Japanese government had not changed its stance on steering drastic climate policies through major events such as the Kyoto Protocol, Fukushima and the Paris Agreement (Kameyama, 2021; Koppenborg & Hanssen, 2021; Gilson, 2023). However, following the adoption of the Paris Agreement, non-state actors such as NGOs, industry and local governments have become more inclined to set their own climate action plans. This movement is influencing policy-making, with governments committing to developing climate mitigation policies at the national level (Kameyama, 2021).

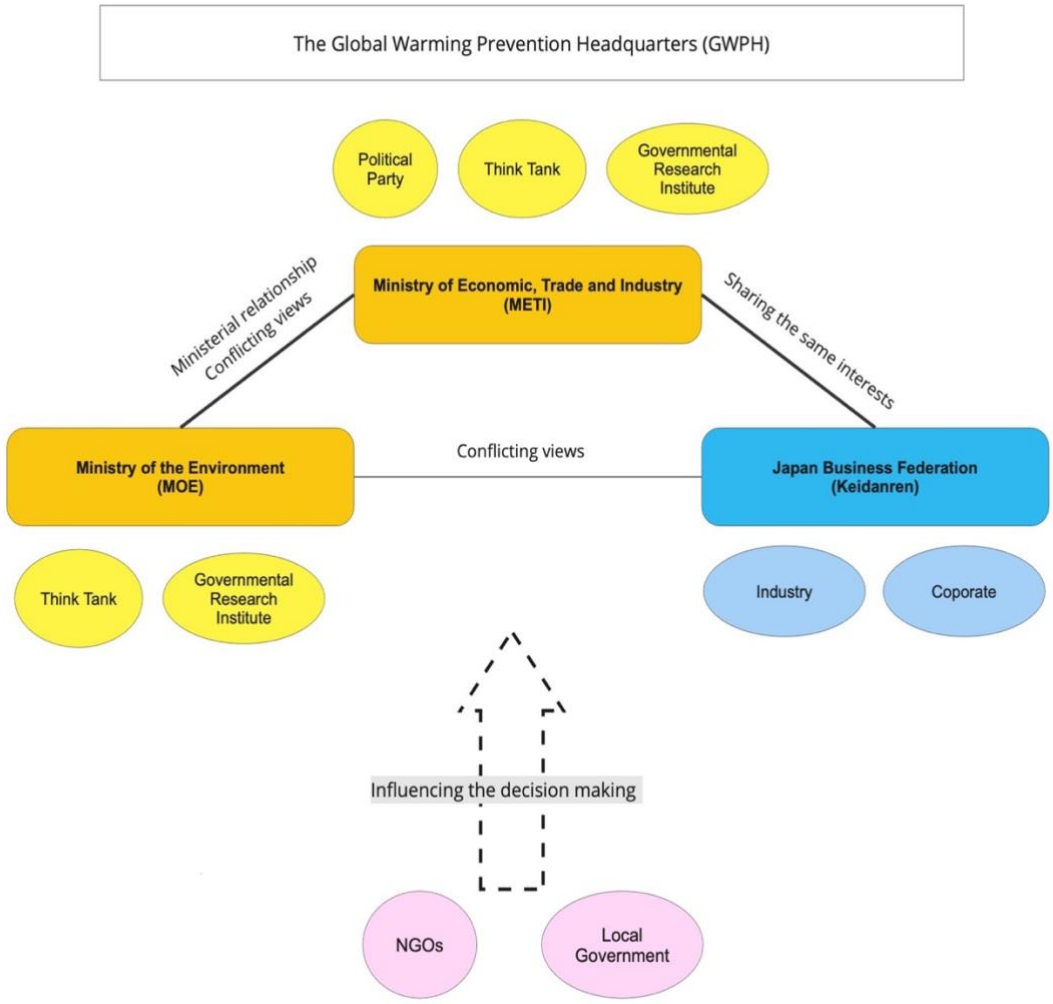

Figure 7: The political influence and structure of Japanese Climate policy (based on Satoh, 2014; Gilson, 2021; Kameyama, 2021; Koppenborg & Hanssen, 2021)

Furthermore, non-state actors also represent the innovation process for climate change mitigation alongside the government, industry, and academia. For instance, local governments initiated climate change mitigation projects through networking (MOFA, 2021). Additionally, NGOs contribute to knowledge production and climate mitigation projects through collaboration with other helices (MOE, 2018).

NGOs are also key actors in innovation development in Japan. The Integrated Innovation Strategy 2023 indicates that the government will strengthen the Quadruple Helix to advance the innovation process (Cabinet Office, 2023). In the strategy, the involvement of non-state actors such as local governments, citizens and NGOs in the policy and innovation process promotes knowledge production that leads to social change. In short, the interaction of actors from the Quadruple Helix in the network promotes innovation and its adoption in Japan.

2.3 Conceptual Framework

The MSF focuses primarily on agenda-setting in the political context while the Quadruple Helix theory focuses on collaborative innovation involving government, industry, academia, and civil society. These theories provided the conceptual framework for this research (Figure 8). As suggested by the theory and its application to the Japanese context, this research focuses on four main groups as relevant actors in the geoengineering discourse in Japan: Government, Industry, Academia and NGOs. When innovations (i.e. geoengineering) are adopted in society, it is assumed that actors from these four groups will shape the Japanese discourse and be involved in the debates on geoengineering. The emergence of the geoengineering discourse is thus constructed through the Quadruple Helix. Thereafter, the developed discourse flows into problem, policy, and politics streams in order to shape the agenda-setting in Japan.

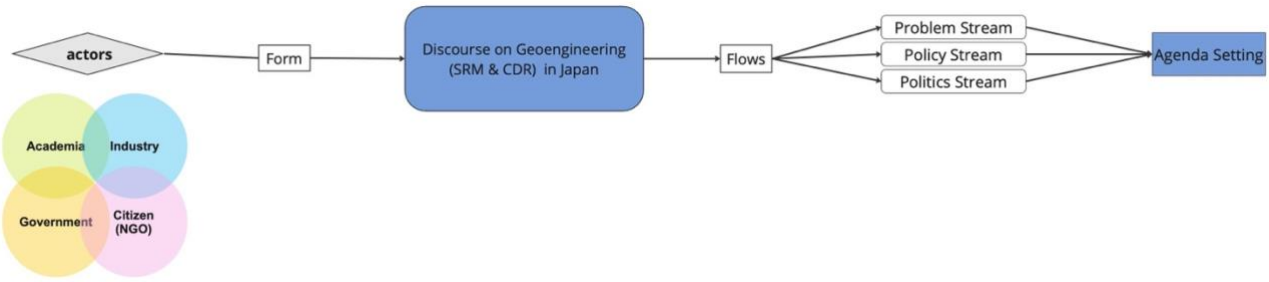

Figure 8: Conceptual framework

3. Technical Research Design

3.1 Methodology

This research adopted an inductive approach based on qualitative analysis consisting of desk research and interviews. The analysis employed two main research strategies: discourse analysis and network analysis. *1.3 research framework* provides a detailed description of the research steps. The analyses examined CDR and SRM separately.

3.1.1 Discourse Analysis

Hajer (1997) defines discourse analysis in environmental politics as an approach that helps to analyse "the ways in which certain problems are represented, differences are played out, and social coalitions on specific meanings somehow emerge" (p. 44). Discourse analysis proceeds by starting with open coding, which later leads to axial coding for comparison (Cho & Lee, 2014). This step facilitates the development of storylines, which are generations of collected statements (Hajer, 1997). The construction of storylines helps to identify the relevant actors and their positions in the relevant discourses (Hajer, 1997).

Many scholars have also conducted discourse analysis on geoengineering from diverse perspectives. For example, Anshelm and Hansson (2014) conducted a discourse analysis on geoengineering by processing news articles to identify the storylines. Jaschke and Biermann (2022) analysed the land-based CDR and its political debate on a global scale. Similarly, Burnard and Colvin (2022) studied the storyline of SRM in the Australian media by following the approach of Anshelm and Hansson (2014). Therefore, discourse analysis was desirable in this research to reveal the statements and storylines on geoengineering in Japanese society.

In this research, discourse analysis aimed to develop the storylines and understand the overview of the current Japanese debate on SRM and CDR. As there had been no previous study on the Japanese debate on geoengineering, the inductive approach was used to identify the statements and relevant actors. The statements identified formed the storylines of the debate in Japan.

The storylines were developed by classifying the statements into themes through inductive coding. This process enabled an understanding of the statements and their intentions constituting the current SRM and CDR debate in Japan. In addition, the interests in the collected statements were also identified through coding. An overview of the Japanese debate on SRM and CDR was developed with the statements and interests.

3.1.2 Network Analysis

Network analysis allows researchers to gain an overview of the relationships between the actors involved in an issue. Aurenhammer (2016) defines a network as "a construct of actors and their interactions within a field/arena of political interest/dispute (or 'problem field'/'issue related network')" (p. 34). Borgatti et al. (2009) explain that there are three focuses of network analysis: network structures; network positions; and dyadic properties. Network structure focuses on cohesion and shapes that are represented as ties between actors (nodes). Position, on the other hand, explores the location of the actors in the network, such as centrality. Dyadic properties analyse the closeness of the actors by measuring the distance and overlap of the relationships.

Gupta et al. (2020) suggest network analysis in the study of geoengineering governance to identify the different views and rationales. They argue that network analysis can help reveal the relationships between actors and identify their visions. However, to my knowledge, network analysis has not been adopted in many geoengineering studies.

Here, this research focused on the network structure and position. Exploring the network structure identified the overall cohesion of the network while the network position explained the centrality, which reveals the balance of power. Network analysis is generally conducted with quantitative and qualitative approaches (Aurenhammer, 2016); however, this research only sought the qualitative result of this analysis, as the degree of connectedness within the networks was beyond the scope of the research.

In this research, the network analysis mapped the relationships between the actors and the transnational influences on the CDR and SRM networks. Mapping the relationships between the actors provided an overview of the interactions between the actors and their involvement in the current debate on SRM and CDR in Japan. This was essential for understanding how the actors in the Quadruple Helix accept geoengineering and for identifying the power balance in the networks. Furthermore, it also illustrated the relationships with international actors, such as countries and organisations that could influence the Japanese debate on geoengineering.

3.2 Data Collection

3.2.1 Desk Research

This step aimed to identify actors and their statements through the synthetic literature review. Table 2 shows the data source and the types of documents collected for each group. Different types of documents were collected for the data collection: newspaper articles, journal articles, policy documents, reports, website blogs and minutes. These documents helped to identify statements and actors from government, industry, academia, and NGOs. Various search engines and websites were used to collect documents. For

example, the MOE, METI and Cabinet Office of Japan websites were used to collect government documents, and the Keidanren website was used for industry documents.

Additional documents were also collected through the interviews. For example, if the relevant actors for geoengineering were mentioned during the interviews, further document searches were conducted to collect statements from these actors (e.g. national research institutes).

	Source	Types of documents collected
General Idea	Nikkei/Asahi/Yomiuri/Mainichi /The Japan Times	Newspaper Articles
Government	MOE/METI/Cabinet Office of Japan	Policy documents, Minutes, Reports
Industry	Keidanren	Policy Recommendations, Reports
Academia	Web of Science/CiNii	Journal Articles
	Google search	Research/ Project Reports
NGOs	Google search	Policy Recommendations, Blogs

Table 2: The source of documents and their types

The first screening collected 310 documents from the term search (*see*: Table 3 for the term used for the search). As the amount of data on Japan and its geoengineering was unpredictable, the period was not fixed at this stage. Appendix A provides a detailed list of the collected data.

The number of documents collected was then screened again to select the most relevant documents for the research. The selection of documents was based on two criteria: the time period (2015-2022) and the content. Documents were selected if they were published between 2015-2022 and if their content included some statements about geoengineering, rather than an explanation of the technologies. After this screening process, 61 documents were selected as suitable documents and proceeded to coding in NVivo.

Term	in Japanese
(Climate) Geoengineering	気候工学、ジオ・エンジニアリング
CDR or CCS or CCUS : climate change	CDR : CCS: CCUS : 気候変動
Carbon Removal : Climate Change	炭素除去 : 気候変動
Carbon neutral : Negative Emission	カーボンニュートラル：ネガティブエミッション
SRM : Sunlight : Climate Change	SRM : 太陽: 気候変動

Table 3: Search terms for the web search and data in Japanese

3.2.2 Interviews

Semi-structured interviews were conducted to identify the statements of relevant actors (Appendix B). As the desk research was not able to collect enough statements, the interviews helped to provide detailed information. At least two actors from each of the four actor groups (government, industry, academia and NGOs) were interviewed. Interviewees were identified through a synthetic literature review (Appendix C). In addition, a 'snowballing approach' was used to ask interviewees to suggest other relevant actors (Cairns & Stirling, 2014).

11 interviews were conducted in Japanese and took place online or in person in Japan. Participants were asked questions about themselves, their knowledge and their opinions. They were first asked to introduce themselves, followed by several knowledge questions about SRM and CDR. These questions were mainly about their knowledge of geoengineering and related technologies and actors. The main part of the interview was the discussion questions, which were designed to ask how they felt about the debate on SRM and CDR both in Japan and internationally, and what their personal opinions were towards such climate technologies. At the end of the interview, the interviewees were asked about their idea of climate change mitigation and its solution independent of geoengineering.

The interviews were carried out in accordance with the provisions of the GDPR and respondents were given a consent form prior to the interviews. The consent form stated that participants would provide honest information and opinions. Anonymity was also guaranteed.

3.3 Data Analysis

3.3.1 Coding

NVivo coding was used for discourse analysis. Based on the findings, the data was organised into four main codes: statements, actors, interests and influencing factors (*see*: Table 4 for SRM & 5 for CDR).

The following codes were adopted in an inductive approach. First, the collected statements were classified into four codes: statements, actors, interests and influencing factors. In each group, a key term was extracted from the statements, which allowed them to be categorised into similar statements in each category.

Statements were defined as opinions on CDR and/or SRM. Governance, concerns, implementations, research and development, and business (for CDR only) were the keywords in the collected statements that were included in the codes. Each statement was further organised by topic. For example, the statement codes for SRM were divided into risk, CO2 reduction and ethics.

The actors were the speakers of the respective statements of CDR and/or SRM. They were coded as government, industry, academia and NGOs. The actors were also grouped according to their affiliations: a researcher from the university or national research institute, a government official from the ministries, people from the industries, and Japanese or international NGOs.

The interests were the actor's intentions defined as the actor's rationale behind their statements. Codes such as governance, research and development, opposition, and business were applied by analysing the whole statements.

Finally, international influence was defined as the actors' international networks in which they were involved. It was assumed that if actors were involved in international communities such as research groups and NGOs, they would receive some degree of ideological influence on their statements on CDR and/or SRM. Codes such as North America, Europe, International, Asia and the Middle East were used.

In short, the coding was performed in an inductive approach and the collected data was categorised into statements, actors, interests and influencing factors. In this way, storylines were developed to analyse the discourse of the geoengineering debate in Japan.

Codes		
Statements	Governance	International
		Japan
	Concerns	CO2 emission reduction
		Risks
		Ethics
	Implementations	Unrealistic
		Positive
		Against
	Research & Development	
Actors	Government	Ministry
	Industry	Keidanren
	Academia	National research institute
		University
	NGOs	International
		Japanese
	Media	Newspaper
Interests	Governance	
	Opposition	
	Research and Development	
International Influence	North America	
	International	

Table 4: list of codes for SRM

Codes		
Statements	Governance	International
		Japan
	Concerns	CO2 emission reduction
		Rulemaking
	Implementations	Unrealistic
		Positive
		Against
	Research & Development	
	Business	
Actors	Government	The government of Japan
		Ministry
	Industry	Keidanren
		Business Company
		Research Company
	Academia	National research institute
		University
	NGOs	International
		Japanese
Interests	Governance	
	Business	
	Opposition	
International Influence	Europe	
	International	
	Asia	
	Middle East	

Table 5: List of codes for CDR

3.3.2 Visualising Networks

As the number of related actors for SRM and CDR was around 20, the visualisation of the actor network was drawn by hand in a diagram. It was originally planned to use the UCINet software. An actor's interaction was counted if they mentioned other actors during the interviews or in the documents. As for the researchers, the network connection was counted if the actors wrote academic articles together.

Furthermore, centrality and power balance were measured by the number of connections with actors. If the actors had the most connections with several actors, they were considered to be central, representing the power balance.

The actors were grouped into four groups (government, industry, academia, NGOs, and media) using the results of the coding. They were visualised on the map illustrating the interaction between the actors. The network map provided insights into the relationships between actors and the existence of the Quadruple Helix model in the debate on SRM and CDR.

3.4 Validity and Reliability

The validity and reliability of the qualitative research were ensured through the 'triangulation' of the data source, logical proposition and methodology (Verschuren et al., 2010). In this regard, this research achieved validity and reliability by carefully designing the research process. Firstly, data collection was carried out by carefully selecting the data without bias based on the criteria. In addition, different types of data such as documents and interviews were included to enhance external validity.

Secondly, the research questions, i.e. the Japanese discourse on geoengineering, were developed based on the theoretical debate in the growing research fields. The literature review identified the knowledge gap that regional perspectives are lacking in geoengineering research. Therefore, internal validity was ensured by defining the research objective and question by providing adequate knowledge to identify the research findings.

Thirdly, the research strategy was carefully developed and implemented to ensure reliability. The methodology was built upon numerous previous studies that used similar methods to study discourse analysis on geoengineering. In addition, the inclusion of steps such as coding and visualisation ensured the exclusion of errors and accurate interpretation in data collection and analysis and provided consistent results.

4. Results

4.1 SRM

The analysis identified the numerous statements and actors for SRM. The data collection revealed that out of 72 documents including the 11 interview transcripts, 25 documents referred to SRM. SRM was a relatively new climate issue and not well known in Japan.

The analysis identified 12 statements on SRM. The statements on SRM were at an early stage of development and were made by a handful of actors. Most of the statements related to the governance of SRM and concerns, but there was no mention of the technological development of SRM.

15 actors with knowledge and a position on SRM were mainly researchers and NGOs, while industry and government did not have an opinion on SRM. Although NGOs expressed a position of SRM, their knowledge of the technology was limited compared to that of researchers. The actors' network on SRM was very fragmented and only shared within academia. The balance of power and international influence was concentrated in academia.

In summary, the debate on SRM in Japan was still developing and the current opinions and actors towards SRM in Japan were limited. Moreover, SRM was not recognised by different actors, although some actors mentioned 'Typhoon Shot' as a similar geoengineering technology taking place in Japan.

4.1.1 Discourse Analysis

Table 6 summarises 12 statements extracted from the SRM data analysis. Table 7 shows the list of speakers for each statement. These statements were categorised into four codes: governance, concerns, implementations, and research and development. The statements for SRM mainly included concerns such as uncertainties and risks of SRM. On the other hand, there were a few statements supporting the establishment of SRM research governance at both international and national levels for knowledge production and transparency. Overall, most statements referred to SRM as 'uncharted territory'.

The statements on governance indicated further involvement of the Japanese government in the SRM debate, both internationally and domestically, to establish the norm and rules. The statements also argued for the delay of the political debate on SRM in Japan and encouraged further discussion within the government. Such statements attributed to researchers showed a high level of interest in the governance of SRM.

Statements of concern were the most prominent issue in Japan. Actors such as researchers and NGOs perceived SRM as a threat to society. Considering that SRM still has uncertainties, the findings are similar to other SRM discourse analysis studies in different regions (e.g. Burnard & Colvin, 2022). NGOs were concerned about the problem-shifting and risks of SRM, while only one newspaper article (Media) argued the ethics of SRM to the socio-ecological system.

Several statements referred to the implementation of SRM, but most were sceptical or strongly opposed to their use. Only one statement, from researchers, mentioned the possibility of implementing SRM and their effectiveness.

Finally, research and development were not a focus of the statements, with the

exception of one statement supporting further research and development of SRM. This statement suggested the research and development to uncover the uncertainties of SRM and study the governance possibilities.

In short, the SRM statements showed that most of them indicated how to manage, prevent and research a highly uncertain technology. Moreover, the results showed that the actors were relatively accepting SRM as itself, as only one statement questioned the technology and its intervention in the ecosystem. This indicated the silence of ethics in the SRM discourse.

Based on the analysis of the statements, three discourse interests were identified: governance, opposition, and research and development. First, actors were interested in the establishment of institutions to govern SRM globally and in Japan in the future. This could be influenced by the political currents of research and development competitions in the Global North. Given the climate crisis and the development and research of SRM in other developed countries, actors indicated that the Japanese government should prepare for future international dialogue on SRM by initiating discussions within the government. In addition, governance at the international level was also of interest to actors, who suggested the establishment of an international body to discuss the rules and ethical issues.

Second, opposition was another interest of the actors. Most of the actors were opposed to SRM. The statements indicated opposition to both research and development as well as deployment. Although SRM is still at the research stage, opposition was of great interest to some researchers and NGOs in Japan.

Third, the Japanese discourse on SRM was interested in research and development. Although only one statement referred to research and development of SRM, it was considered the main interest because a leading researcher of SRM expressed interest in research and development. Further specifications of the actors are explained in the next section.

Topic	Speakers
Governance	
<u>International</u>	
"There should be more discussion on the governance of SRM at the international level" This narrative argues that given the impacts of the use of SRM, social science researchers (A, B & C) and industrial researchers (A) believe that global governance, including rules, controls and projects, is necessary. In addition, they believe that the democratic and international governance of SRM is essential as it could threaten conflicts between countries under national interests and superpowers.	Researcher A, Researcher B, Researcher C, and Industry A
"In the coming future, the International Ethics Panel should be established under the UN to discuss SRM" Researcher D (expert in ecological design) argues that the current institutions are not sufficient to discuss SRM because SRM is a sensitive and ethical issue that should be discussed at the Round Table.	Researcher D
<u>Japan</u>	
"Considering international trends, the Japanese government should start the discussion on SRM in terms of governance and international relations" Social science researchers (A, D & E) and industry (A) discuss that it is of utmost importance to start the discussion on SRM in Japan at a time of climate crisis, as there are opportunities for global deployment and experimentation. They argue that transparent decision-making is required for SRM and should begin at an early stage with relevant stakeholders.	Researcher A, Researcher D, Researcher E, and Industry A

Concerns	
<u>CO2 emission reduction (problem shifting)</u>	
"Government should focus on reducing CO2 emissions and not rely on or invest in SRM alone" Researchers from a national research institute (B&F) and both international and Japanese NGOs are concerned that SRM is an uncertain technology and gives the wrong impression to global society about climate change mitigation. They predict that SRM could cause problem-shifting that the Japanese government will continue relying on coal-based energy production. They believe that the Japanese government should invest in and pursue current CO2 emission reduction projects, rather than focusing on SRM as a panacea.	Researcher B, Researcher F, NGOs (J) A, NGO (I) B, NGO (I) C, and NGO (I) D
<u>Ethical</u>	
"It is not ethical to intervene in the Earth system by humankind and its technologies" A media reporter from a Japanese newspaper raises ethical concerns about the idea of SRMs controlling the climate and believes that such human interventions in the Earth system should not be accepted.	Media A
"The emergence of SRMs shows the struggles of humanity" Researcher H, who specialises in economic and environmental ideology, discusses how the ongoing climate crisis is the result of economic development, which humanity is no longer able to control. H believes that the development of SRMs represents humanity's struggles to control the Earth system.	Researcher H
<u>Risk</u>	
"There are still risks involved in SRM and the effects and side effects are uncertain" Researchers A and E, who have expertise in SRM and data technology respectively, and NGOs are concerned that controlling solar radiation with the discussed technologies is dangerous and the risks are uncertain. They believe that the risks and side-effects and impact of SRM have not yet been fully clarified, which poses a great threat to the Earth	Researcher A, Researcher E, NGOs (J) A and NGO (I) B

and humankind.	
Implementations	
<u>Unrealistic</u>	
"The implementation of SRM is not realistic at this stage" Researchers A (SRM), F and G (climate modelling) state that given the uncertainties of SRM and its research stage, the implementation of SRM is not realistic. They are concerned that although the effect of SRM on climate change mitigation is theoretically possible, there are many difficulties to overcome for its deployment.	Researcher A, Researcher F, and Researcher G
<u>Positive</u>	
"SRM could be a possible option to mitigate climate change in the future" This narrative by researchers A (SRM) and E (data science) suggests that the international community may require SRM as a complementary tool to mitigate climate change in the future. They suggest that SRM could buy some time to avoid the climate crisis, rather than relying solely on emissions reductions.	Researcher A and Researcher E
<u>Against</u>	
"Such technologies should not be used" Researchers B (CDR) and D (Ecological Design) argue that SRM should not be deployed on Earth because the risk is greater than the effects as discussed in the research.	Researcher B and Researcher D
Research & development	
"Governance and technological research should be continued"	Researcher A

Researcher A from a university (SRM) believes that research on SRM, such as technological development and governance, should be carried out at this stage.	
"The more the scientific debate continues, the more the possibilities for the development of SRM will increase, and this would lead to an international research and development race" Researcher B (CDR) from a national research institute considers that allowing the research and development of SRMs could lead to a technological development race between China and the US, which would have a negative impact on global governance.	Researcher B

Table 6: The results of the statements of SRM identified through the analysis

4.1.2 Network Analysis

The actors involved in the SRM debate were not diverse (Table 7). The analysis identified 15 actors: government (1); industry (1); academia (8); NGOs (4); and media (1). In addition to the original four groups (government, industry, academia, NGOs), one actor from the media was found with a statement.

As the number of actors indicates, academia was one of the groups of actors with the most SRM statements. Researchers A and E, who had positive opinions about the effects of SRM, worked in a Japanese university, and Researcher A led the SRM research in Japan and also worked closely with the American research group on SRM. Researchers A and E have expertise in climate science and data science respectively. On the other hand, Researchers B and D, who shared concerns and opposition to SRM, both specialise in social science, specifically governance and ecological design respectively. Researcher B worked for the national research institute and D was an honorary professor at a Japanese university.

Government actors were silent on SRM. No statements were found in interviews or policy documents. The MOE was the only government institution indirectly involved in the SRM discussion. They have been organising committee meetings with academics since the 2010s. The committee meetings were held under the Central Environment Council and mainly discussed environmental issues. SRM was mentioned as a topic by actors during the meeting. However, the MOE had not taken a position on SRM in its policy documents or public statements. The interview with a bureaucrat from the Global Environment Bureau at the MOE indicated that the ministry had not yet established a department for SRM. However, A bureaucrat from MOE was once assigned to SRM tasks and contacted a researcher in the late 2010s (Researcher A). Yet, no such person in charge of SRM was found during this research.

Similarly, industry did not comment on SRM. However, the interview with one industry actor (B) indicated that the company's board of directors have acknowledged the emergence of SRM, but did not specify the future direction of technological development or interest.

NGOs were another important actor leading the SRM discourse in Japan. They perceived SRM as a threat to society and the environment, and their views were in line with those of their international partners. However, interviews with NGOs revealed that they did not have specific campaigns or research departments within the organisations. Furthermore, one youth NGO (NGO E) did not state its position or have any knowledge of SRM.

In summary, academia and NGOs were the main actors in the SRM discourse in Japan. The government was silent and industry had almost no interest in SRM. There was no central actor in the debate on SRM in Japan and the balance of power was almost non-existent. However, Researcher A could position himself as a central actor in the future SRM debate. In light of the limited knowledge diffusion about SRM in Japan, SRM expert A can influence knowledge production and shape the debate.

Figure 9 shows the actors and their relationships in the SRM discourse. Actor interaction was limited; no interaction was observed with each group (i.e. government, industry, academia, and NGOs) and only researchers were linked to each other. Instead, a few links indicated the indirect networks of actors. For example, the links between

industry and government, and academia and government were included because the relevant actors attended the committee meeting organised by the MOE. Subsequently, the link between researcher A and MOE showed past interactions.

Some transnational influence was identified in the discussion of SRM in Japan. One of the links identified was between Researcher A and North America. Researcher A is a leading scholar in Japan on geoengineering, particularly SRM. Researcher A was involved in the North American SRM research project that initiated the SRM experiments. The analysis showed that A's statements were relatively similar to the aim and ideology of the research projects.

Researcher A has also published journal articles on SRM and geoengineering in English and Japanese. Most of the newspaper articles on SRM included Researcher A's commentary, which could give an idea of A's potential influence on the Japanese SRM debate. As the international debate on SRM continues, Researcher A could lead the debate on SRM in Japan by communicating the idea to Japanese society through the media in the coming future. In this respect, the future Japanese debate on SRM could be influenced by North America, which favours research and development of SRM.

Another international interaction was observed within NGOs. International NGOs in Japan had the same attitude towards SRM as their partner organisations. Although the Japanese international NGOs did not specifically work on SRM or prioritise the issue in their organisations, they mentioned that they would work on advocacy, if necessary, in the future. In addition, the Japanese NGO (NGO (J) A) mentioned that they would contact researchers outside Japan to gather knowledge, as they believed that no such research had been conducted in Japan. This statement suggested that there was no interaction between NGOs and Japanese researchers such as Researcher A who has expertise in SRM.

Government		
	Name	**Interview?**
Ministry	MOE	Yes
Industry		
Keidanren (Japan Business Federation)	Industry A	No
Academia		
University	Researcher A	Yes
	Researcher C	No
	Researcher D	Yes
	Researcher E	No
	Researcher H	No

National Research Institute	Researcher B	Yes
	Researcher F	No
	Researcher G	No
NGOs		
Japanese	NGOs (J) A	Yes
International	NGO (I) B	Yes/No (answered by email)
	NGO (I) C	Yes/No (answered by email)
	NGO (I) D	No
Media		
Newspaper Article	Media A	No

Table 7: Actors in the SRM statements

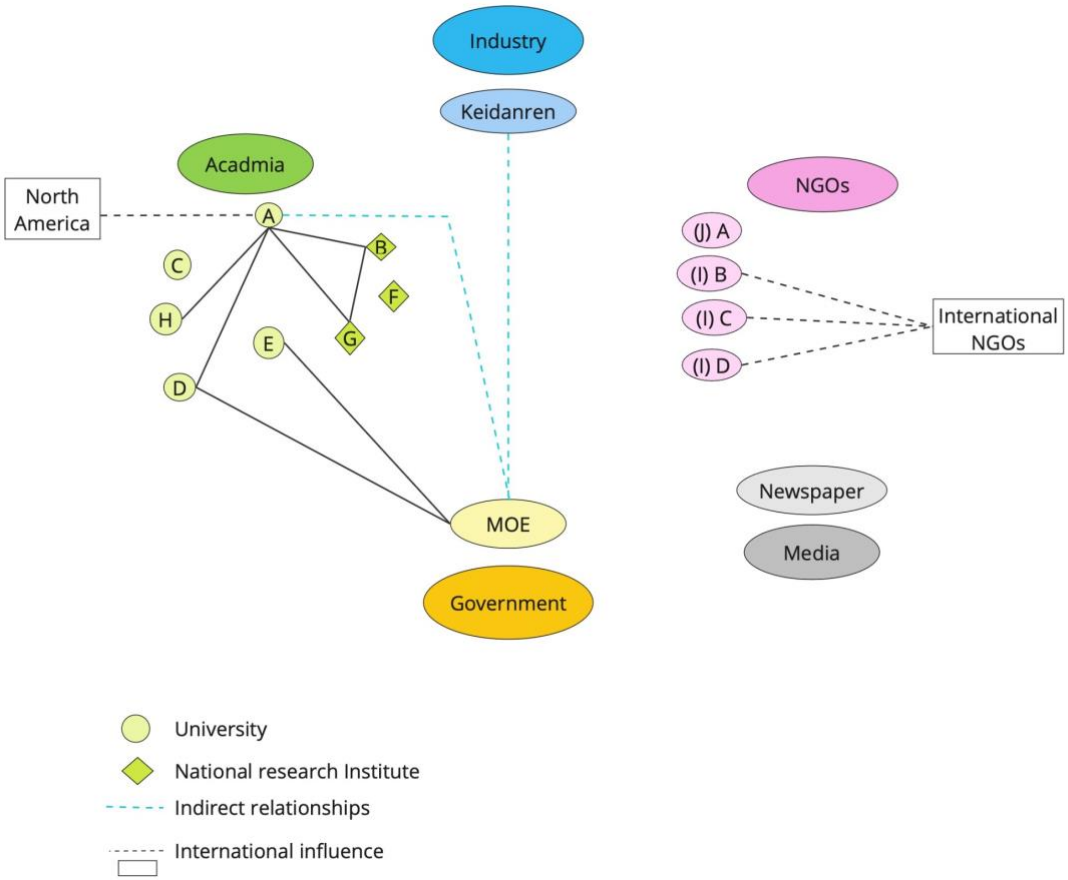

Figure 9: The SRM network in Japan

4.2 CDR

In contrast to SRM, the discussion of CDR was active. Almost 70% of the coded documents were related to CDR, indicating a greater interest in CDR in the Japanese geoengineering debate. In particular, CCS and CCUS were the main technologies of the CDR discussion in Japan and were widely acknowledged by relevant actors: government, industry, academia, and NGOs.

11 statements were extracted from the data. The CDR debate focused on CCS and its implementations, indicating that CCS was more familiar to Japanese society than SRM. The statements included topics such as governance and implementation, indicating that CCS was already in the implementation phase.

The study identified 24 actors. Although only 15 actors were found to have statements on CCS, the remaining actors were also involved in the debate as they were mentioned in the collected documents and interviews. The main debate on CCS was between government and industry, and they worked closely together in networks. Government, industry and academia were influential in the debate as they were the main actors. International influence, both internal and external, was observed in the discourse.

In short, the CCS debate was more established than the SRM debate. The technology of carbon removal and its storage and use was positively accepted by the actors involved as they believed that CCS was a necessary option to achieve Japan's NDC under the Paris Agreement.

4.2.1 Discourse Analysis

The analysis revealed the CDR discourse. 11 statements were categorised into governance, concerns, implementation, research and development and business (Table 8). Table 9 shows the list of the contributors to the statements. The discussion on CDR consisted of the development of CCS technology and business market opportunities. This indicates that the discussion on CDR, and CCS in particular, is already well advanced compared to SRM. The statements included relatively positive opinions and actors such as government, industry and academia supported CCS as a necessary technology to achieve Japan's NDC under the Paris Agreement and decarbonisation.

However, there were also some negative statements about CCS. For example, NGOs and some researchers were sceptical about the development of CCS. They were concerned about the effectiveness of CCS and storage issues in Japan due to the earthquake and limited availability. A number of actors also opposed the implementation of CCS on the grounds that it would give the Japanese government time to phase out fossil fuels.

Governance-related statements included support for the development of CCS and the establishment of the institutional framework in Japan. In addition, actors, particularly government and industry associations, expressed a strong desire to be involved in global CCS governance. The Japanese government and industry were interested in the Middle East and South East Asia for the technological co-development and transfer of CCS.

The expressions of concern were slightly different from the SRM findings. Similar to SRM, NGOs and a researcher expressed concern that CCS could increase Japan's dependence on coal (i.e. problem shifting). The risks and social and environmental impacts of CCS were not mentioned. One researcher questioned the lack of transparency in the decision-making process on CCS in Japan, while the government focused on technical issues such as developing frameworks and regulations for CCS.

In terms of implementation, the government, industry and one researcher insisted on the implementation of CCS as a necessary technology to mitigate climate change. They recognised CCS as a necessary technology to mitigate climate change and contribute to the Paris Goal. However, some actors, including researchers and NGOs, questioned the effectiveness and feasibility of implementation.

The statements on research and development included views on the further development of the technology from actors who also supported the implementation of CCS.

Last but not least, statements on CCS included some business-related views. The government and industry saw CCS as an important emission reduction technology and a new business product. They believed that maintaining competitive industrial performance while pursuing decarbonisation was of paramount importance. Therefore, the statement noted that the development of CCS technology could stimulate business opportunities in the global market.

In summary, the CDR statements focused on CCS that could be applied to industrial processes to remove CO2. Actors from the government, industry, and a part of academia supported CCS and its implementation, while NGOs and some researchers were concerned about delaying the transition to renewable energy from fossil fuels in Japan.

The analysis identified three areas of interest in the CCS statements: governance, business and opposition. First, actors were highly interested in formulating the framework for CCS implementation and initiating the governance system in Japan and internationally. Significantly, the government had the ambition to lead Southeast Asia in CCS research and development by providing technical and financial support. This intention was linked to the Joint Crediting Mechanism (JCM), which was mentioned in the interview with a bureaucrat from the Industrial Science and Technology Policy and Environment Bureau at METI. The JCM is a carbon quota mechanism developed by Japan. Under the scheme, the Japanese government contributes to reducing CO2 emissions in developing countries by providing technical assistance and implementing countermeasures, in exchange for offsetting Japan's carbon emissions (METI, 2020). In addition, it could be assumed that since most countries in the Global North had initiated the development of CCS, the Japanese government would seek out the region where CCS was not yet mature so that it could lead regional research and development while securing the potential business market.

Second, business was also an important interest of the statements. The government and industry were interested in developing CCS because it could provide a new business opportunity to maintain industrial competitiveness during the transition to net zero. Under the Carbon Neutral 2050 policy, the Japanese government aims to share 30% of the global CCS and CCS-related business, which is expected to grow to 10 trillion yen annually by 2050 (Cabinet Office, 2021).

Lastly, opposition was the main component of the statements from NGOs and some researchers concerned about shifting the problem and delaying emission reductions.

CCS can be applied to the industrial process and capture carbon, which benefits the industry and the government to continue with the business-as-usual industrial structure for the time being. The Japanese government intended to apply CCS, particularly to the energy sector, which accounts for 80% of Japan's total carbon emissions (Cabinet Office, 2021). In contrast, some researchers and NGOs opposed problem-shifting and continued reliance on coal, arguing that the most important solution to mitigating climate change is an energy transition from fossil fuels to renewables.

Topic	Speakers
Governance	
<u>International</u>	
"The Government of Japan will promote international standardisation and regulation of CCS with relevant countries" The Japanese government and its ministries (METI & MOE) state that they would work closely with international communities (the US, Canada, Russia, Indonesia, Singapore, Thailand and the UAE) to pursue further innovation for climate change mitigation through policy communication and research and development. Significantly, the Japanese government would coordinate with the Middle East on resource diplomacy and decarbonisation. In addition, Japan advocates a regional knowledge-sharing platform with ASEAN countries.	GOV, METI and MOE
<u>Japan</u>	
"CCS is a key mitigation technology for achieving the Paris Agreement and the Japanese NDCs, which will result in a carbon-neutral society and climate mitigation" The Japanese government (GOV, METI & MOE) and the Japan Business Federation (Industry A) envisage achieving the Paris goals and their pledges through the implementation of CCS. They believe that CCS will support the decarbonisation policy and gradually phase out thermal power generation in Japan in the future.	GOV, METI, MOE, and Industry A
"In order to proceed with the implementation of CCS, the development of institutions and the legal system as well as social acceptance are urgently needed" This narrative from the government (GOV, METI & MOE), Japan Business Federation (Industry A) and a trading company (Industry B) argues that the government should establish the institutional system to implement CCS and gain a public understanding of the technologies and the storage of sequestered carbon in the soil.	GOV, METI, MOE, Industry A, and Industry B

Concerns	
CO2 Emission Reduction (problem shifting)	
"CCS is a tool to avoid the social transition from the fossil fuel economy and to continue burning coal". Researcher B (CDR) and international and Japanese NGOs (A, B, C&D) are concerned that the implementation of CCS will lead to a problem-shifting of reliance on coal burning, which could delay CO2 reductions. Instead, they argue that the Japanese government should invest in more renewable energy and phase out coal as an immediate priority.	Researcher B, NGOs A, B, C, and D
Rulemaking	
"In order to pursue the implementation of CCS, the institutional framework such as public acceptance, environmental protection and carbon leakage from storage should be established" RITE (national research institute), the MOE and METI argue that CCS is crucial to pursuing decarbonisation in Japan, so a well-established framework should be developed to strive for its implementation. Therefore, they expect the government to discuss the consensus-building process, carbon leakage issues and the environmental impact of CCS in a timely manner.	RITE, MOE and METI
"The current debate on CCS has only taken place within the government and there are fewer voices criticising the technology and the government's policy" Researcher B (CDR) is concerned that the current political debate on CCS is not open to the public. Moreover, B notes that researchers in Japan have not yet raised their voices against CCS.	Researcher B
Implementations	
Unrealistic	

"CCS is still an uncertain technology in terms of its effectiveness, and there is a carbon storage problem in Japan. Therefore, CCS should be the very last resort" Researchers B (CDR) and D (ecological design and sustainable business expert) discuss that the development of CCS and its implementation is not realistic and the impact of CCS on the environment and climate mitigation is still uncertain. Therefore, they believe that the Japanese government should prioritise the reduction of CO2 emissions and use CCS for the remaining carbon as a last resort.	Researcher B, Researcher D
<u>Positive</u>	
"CCS is a supplement tool to CO2 emission reduction technology and is necessary to achieve a carbon-neutral society" Researcher A (SRM), NEDO (national research institute), government (GOV, METI&MOE) and industry (A&B) and C (research and development company) support CCS as an innovative solution to achieve carbon neutrality in Japan. They expect further technological innovation and development related to CCS in the coming years.	Researcher A, NEDO, GOV, MOE, METI, Industry A, Industry B, and Industry C
<u>Against</u>	
"CCS should not be implemented as it would not contribute to emission reduction and would delay the coal phase-out" Researcher B (CDR) and the international and Japanese NGOs oppose the implementation of CCS because they believe that CCS cannot be the solution to climate change mitigation and will buy the government some time to delay the withdrawal from the coal-based industrial society.	Researcher B, NGOs A, B, C, and D
Research & development	
"Research and development of CCS should be continued" Researcher A (SRM) and the government (METI&MOE) and industry (A, B&C) support the research and development of CCS because CCS is a necessary solution to mitigate climate change while securing industrial activities.	Researcher A, METI, MOE, Industry A, Industry B, and Industry C
Business	

"CCS will be implemented for carbon removal and commercial purpose" The executive government (MOE&METI) and Industry A (business federation) encourage the implementation of CCS because the introduction of CCS could open up a new business opportunity in Japan and sell the technology to the global market. They also believe that the development of CCS could maintain industrial competitiveness while pursuing carbon emission reduction.	MOE, METI, and Industry A

Table 8: The results of the statements of CDR identified through the analysis

4.2.2 Network Analysis

In contrast to the SRM results, the CDR, i.e. CCS, more diverse actors were found (Table 9). A total of 24 actors were found in the data: government (7); industry (4); academia (9); NGOs (4). The analysis identified 13 actors with statements on CCS: government (3); industry (3); academia (5); NGOs (4).

Notably, most of the actors were linked to the government. The academic actors were mostly national research institutes affiliated with the government. The national research institutes worked closely with the ministries and functioned as knowledge producers. For instance, the Research Institute of Innovative Technology for the Earth (RITE) focuses on the research and development of CCS technologies. RITE has organised workshops for the industry in collaboration with METI (Picture 1).

Picture 1: The innovative CO2 capture, storage and sequestration symposium organised in February 2023 in Tokyo, Japan. The purpose of this event was to provide networking for the industries and updates about the current research and development to promote the technology and future implementation.

Subsequently, the government actors were more diverse and presented compared to SRM. Significantly, METI was the central actor among government agencies, initiating CCS policy and development. For example, METI led the first CCS demonstration project in Tomakomai, Hokkaido, in collaboration with industry and national research institutes (METI, 2023). METI worked closely with other ministries, including MOE, national research institutions, and industry to promote and develop CCS policies. METI supported the implementation of CCS because it believed that CCS was critical to achieving Japan's NDC.

Industry was another group with a variety of actors representing in the CCS debate. Keidanren (Industry A) is a business organisation of over 1,500 representative companies,

about 100 industrial associations and regional economic organisations (Keidanren, n.d.). They support the economic activities of Japanese companies and advocate economic and policy issues to government agencies, particularly METI.

Keidanren initiated the development and implementation of CCS. For example, its annual report 'Carbon Neutrality Action Plan' stated that member companies in four industrial sectors, namely commerce, heavy industry, energy and transportation, strive to introduce and develop CCS in their industrial processes or services (Keidanren, 2022). A research and development company specialising in CCS was also involved in the CCS debate.

NGOs from the SRM debate also expressed their views on CCS, with the exception of one youth NGO (NGO E). They were all against the implementation of CCS and had a negative impression of the technology and its impact on delaying the phase-out of coal. They regularly publish blogs and reports to educate the public and the government on the issue of CCS. The role of NGOs was important because most of the actors in the Japanese debate on CCS support its implementation.

In short, almost all actors from government, industry, and academia supported the implementation of CCS, while NGOs and some researchers were opposed and expressed concerns about climate technologies. The balance of power was skewed towards METI, as it was closely linked to industry and academia, such as national research institutes.

A denser interaction of actors was observed in the CDR network map (Figure 10). METI, Keidanren (Industry A) and national research institutes were linked in terms of policy and research and development. On the other hand, there was limited interaction between NGOs and other groups, except for the exchange of policy recommendation papers with the government. In Japan, both international and Japanese NGOs worked together to publish position papers and lobby against CCS policy. The environmental NGOs in Japan have jointly developed a campaign called 'Japan Beyond Coal' to advocate the end of coal use in Japan by 2030 (Japan Beyond Coal, 2020). Here, NGO interaction on CCS has been actively observed.

The network of CCS debate in Japan exerted and received transnational influence from Asia, Europe and global NGO networks. Compared to SRM, actors in Japan, especially government and industry, had a strong focus on Asia to influence surrounding countries. The Japanese government sought leadership in ASEAN to improve the carbon offset mechanism. The Japanese government also prioritised relations with countries in the Middle East to promote CCS development, given Japan's heavy reliance on oil in the region.

Similar to the debate on SRM, NGOs shared the same position as their international organisations on CCS and its implementation, criticising the government for shifting the problem.

One researcher had a link to the European CCS research group. Researcher B was a member of the CCS research group and an expert on CCS governance. In terms of knowledge production, researchers (A&B) were involved in the international research communities in North America and Europe respectively. Researcher B is a member of the European research group on carbon removal and studies with a critical approach. In addition, the national research institutes also collaborated with the international research institutes.

Government		
	Name	**Interview?**
Government	GOV	No
Ministry	MOE	Yes
	METI	Yes
	MAFF (Ministry of Agriculture, Forestry, and Fisheries)	No
	MLIT (Ministry of Land, Infrastructure, Transport, and Tourism)	No
Agency	FSA (Financial Service Agency)	No
Independent Administrative Institution	JOGMEC (Japan Organization for Metals and Energy Security)	No
Industry		
Keidanren (Japan Business Federation)	Industry A	No
	Including commercial, heavy industry, energy, and transportation sectors.	
Trading Company	Industry B	Yes
Research and Development Company	Industry C	Yes
Financial Exchange	Industry D	No
Academia		
University	Researcher A	Yes
	Researcher D	Yes
National Research Institute	Researcher B	Yes
	NEDO (New Energy and Industrial Technology Development Organization)	No

	RITE (Research Institute of Innovative Technology for the Earth)	No
	AIST (Advanced Industrial Science and Technology)	No
	IGES (The Institute for Global Environmental Strategies)	No
	IEEJ (The Institute of Energy, Economics, Japan)	No
International Think Tank	ERIA (The Economic Research Institute for ASEAN and East Asia)	No
NGOs		
Japanese	NGOs (J) A	Yes
International	NGO (I) B	Yes/No (answered by email)
	NGO (I) C	Yes/No (answered by email)
	NGO (I) D	No

Table 9: Actors in the CDR statements and debate. The grey column indicates the actors whose statements were not identified in the analysis but were involved in the CCS debate in Japan.

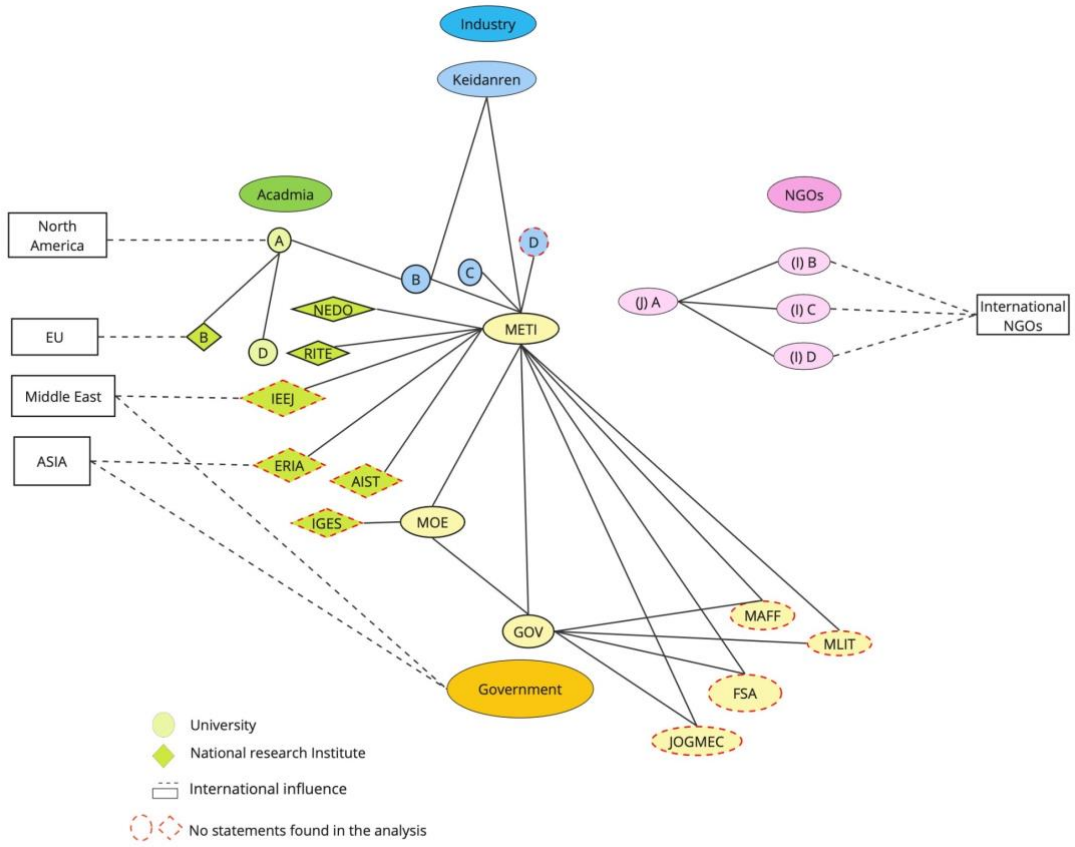

Figure 10: The CCS network in Japan

4.3 Typhoon Shot

In addition to the discussion of CDR (CCS) and SRM, other types of climate technologies were mentioned in the documents collected and by the interviewees: typhoon shot. Typhoon shot or modification (typhoon-kaihen) and power generation (typhoon-hatsuden) are the climate technologies that aim to modify the course of typhoons or destroy storms (Fudeyasu, 2021). Typhoon shot is climate geoengineering for climate change adaptation, while CDR and SRM aim to mitigate climate change.

The Japanese government proposed the Moonshot Research and Development Programme in 2021 to address multifaceted societal issues (Cabinet Office, 2020). The Moonshot Programme has nine goals, and the 'Typhoon Control Research Aiming for a Safe and Prosperous Society', known as the Typhoon Shot Project, has been progressing under Goal 8 'Controlling and Modifying the Weather': Realisation of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050' (The Department of Moonshot R&D Programme, 2023). Typhoons are one of the climate threats in Japan, causing severe social and economic damage (Nayak & Takemi, 2020). In this context, this research and development is an interdisciplinary project that aims to intervene in typhoon forces and harness the energy generated by typhoons. The energy extracted from typhoons is a massive natural energy that can contribute to decarbonisation (Fudeyasu, 2022).

Although Typhoon Shot is not a geoengineering technology, it is a climate technology that could influence the research and development of SRM. Both Typhoon Shot and SRM aim to intervene in the climate system with uncertain technologies that could have significant socio-environmental impacts. Researcher B was concerned about the possible military use of Typhoon Shot due to its destructive power. In addition, no NGOs or actors have so far opposed the Typhoon Shot project or raised ethical concerns in public.

5. Discussion and Recommendations

5.1 Discussion

The analyses identified the statements and actors for SRM and CDR(CCS) respectively. However, 'debate' did not appear to be taking place in Japanese society. Debate, defined as "(a) serious discussion of a subject in which many people take part" (Cambridge Dictionary, n.d.), should be a form of discussion that people interact with, which was not identified by the network analysis, especially for SRM. This finding is in line with previous research that the discussion of SRM only takes place in developed and English-speaking countries, namely the UK and the US (Raimi, 2021).

This section employs the MSF and the Quadruple Helix Theory to discuss how SRM and CCS are politically framed and adopted as agendas and innovations. It also argues why and how novel technologies are adopted as agenda-setting in the identified discourses.

5.1.1 SRM

Problem Stream

Most Japanese actors were not fully aware of 'geoengineering' and only associated it with SRM or referred to Typhoon Shots. Knowledge of SRM was concentrated among researchers, especially Researcher A, who had some influence on the discourse on SRM.

This unfamiliarity and lack of knowledge about SRM in Japan could be highlighted by the inactive debate on the climate crisis in Japanese society. During the interviews, several participants (Researchers A and D) mentioned the reluctant attitude of Japanese citizens towards the climate crisis and its politics in Japan as a possible reason for the limited debate on SRM in Japan. A small number of collected newspaper articles also showed the inattention of climate change in Japan. Only 22 Japanese news articles on SRM were found between 2000 and 2022, while over 100 news articles were published in Australia between 2006 and 2018 (Barnard & Colvin, 2022). These findings are consistent with data on Japanese perceptions of the climate crisis and urgency (*see*: 2.1.1).

Most of the newspaper articles on the SRM cited Researcher A, who also publishes most of the academic articles on the SRM in Japan. The concentration of geoengineering knowledge among experts is understood as a 'monopolisation of social power' (Sikka, 2012). Sikka (2012) argues that because geoengineering is a specialised field that requires scientific and technical knowledge, only the experts have the influence and power over the public debate on geoengineering. However, SRM has not yet reached the governmental level where climate issues and policies are discussed.

In short, the lack of interest in the climate crisis could shape the way SRM is accepted and framed in Japan. In addition, the lack of a 'problem entrepreneur' in SRM blocks the attention of policymakers. This hinders the establishment of a problem stream in Japanese climate change policy in which SRM cannot reach the agenda-setting level. As a result, the priority and urgency of SRM issues are perceived as low, and governments and NGOs do not recognise SRM as an urgent issue to be discussed in the organisation. This was also mentioned by some interviewees (NGOs, government officials and researchers). Therefore, the Japanese government has not defined its position on SRMs.

Policy Stream

Given the limited presence of SRM in Japanese politics, the policy idea of SRM could not be collected in the 'policy primeval soup'. In addition, one of the possible reasons for the underdevelopment of policy discussion on SRM could be related to the bureaucratic structure in Japan. For example, interviewees mentioned the top-down system of government bureaucracy. The Japanese ministry uses the job rotation system, which requires government officials to change departments every two to three years. "A few years ago, there was a bureaucrat from MOE who was in charge of SRM, but that person was transferred to another department. I do not know anyone in the government who is currently working on SRM. (Researcher A)".

In addition, the isolation of the academic community from Japanese society and international academic groups was identified as a problem for the limited discussion of SRM in Japan. Researcher D mentioned the isolation of the Japanese research community (including national research institutes) from society and international society, as Japanese researchers tend to isolate themselves from public opinion. Additionally, researcher A mentioned language difficulties (i.e. English proficiency) for Japanese researchers, which could prevent them from interacting with international academic communities.

Therefore, the limited knowledge production and sharing of SRM in Japan and the few interactions with the international community hinder the accumulation of the SRM idea in Japan. In addition, the bureaucratic structure restricts the policy stream by preventing bureaucrats from promoting the policy idea of SRM. However, the policy stream could be influenced by the transnational effect of researcher A, who is involved in the North American SRM projects, which favours SRM in the future.

Politics Stream

The number of actors from each group varied, showing the power imbalance in the SRM debate. In other words, an interactive Quadruple Helix network was not identified in the Japanese debate on SRM. In particular, the researchers who initiated knowledge production (Researcher A) had limited contact with actors from other groups. In addition to the limited visibility of SRM within the government, one of the causes could be the knowledge production system. As discussed in *2.2.1*, the government works closely with national research institutes and seeks scientific advice. Given that SRM is not yet a priority and the urgency of the issue is not clear to the Japanese government, SRM may not be on the research agenda within the think tank. SRM could reach the government if actors from academia were involved in the knowledge production and dissemination process.

In addition, the limited budget and human resources within the government and NGOs could also limit their involvement in the SRM debate. Several actors, including researchers and NGOs, mentioned resource capacity within organisations as a constraint that prevents government and NGOs from expanding their departments to deal with a wide range of climate issues.

Furthermore, young and female actors are not involved and most actors are male. Researcher B also noted during the interview that the participants of the SRM workshop organised with colleagues a few years ago were also mostly men.

Thus, the limited representation of actors and the weak interactions between them in the SRM discourse limit the policy flow to promote their interests. This suggests that

the Quadruple Helix is almost not established which results in no actors' interactions. In addition, the management of human and financial resources and diversity to address climate issues should be improved.

In summary, the insufficient streams hinder SRM agenda-setting in Japan. There is also a high degree of ambiguity in policy-making, specifically the 'fluid participation' of stakeholders in the decision-making process and 'unclear technology' in the bureaucratic system. However, in this context, if Typhoon Shot is relatively well accepted by the public, there is a possibility that the debate on SRM in Japan could be advanced. Similarly, the debate on CCS and Typhoon Shot could in the future stimulate research and development and the Japanese debate on SRM in Japan as a basis for the Japanese debate on climate change mitigation through technology.

5.1.2 CDR

Problem Stream

CDR technologies, and CCS, in particular, were widely recognised by actors and mentioned extensively in policy documents. While CCS was recognised in Japan, CDR, the group of technologies to which CCS belongs, was unfamiliar to actors. Most actors were also unaware that geoengineering was a generic term for CCS or that they were linked.

Pressure from the NDC and the international community may explain the visibility of CCS in Japan. CCS was a necessary solution to decarbonise and move away from coal-based power generation. The government encouraged industry to develop and implement CCS and to invest in research and development. For example, the Japanese government established a dedicated CCS research and development company to pursue the implementation of the technology.

In short, financial and international climate policies motivate the adoption of CCS in Japan. The government frames CCS as an innovative and necessary solution to the climate crisis. Therefore, the problem stream of CCS is well established by the government, part of industry and academia, which made it easier for CCS to reach the agenda-setting.

Policy stream

CCS gained popularity after the Japanese government adopted the 2050 Carbon Neutral Policy in 2020. The policy idea comes from the think tank, and the government always contacts the same scientists and invites them to committee meetings (MOE government officials A) or seeks advice from researchers at national research institutes. Again, the government and national research institutes are interlinked in the CCS discourse and policy idea.

In addition, the involvement of industry strongly influences the policy flow. One of the reasons for this could be the benefits of CCS, which opens up business opportunities in the context of climate policy. This creates a win-win situation for both government and industry to pursue economic growth while developing new business products that could also be applied to existing industrial processes, including coal fuels.

Another impact on the policy stream could be related to transnational influence. The Japanese government is keen to develop relations with Southeast Asia for the JCM.

However, the Global North's competitive technology development and market could also explain the Japanese government's intention. CCS has attracted global policymakers and industries in developed countries that are already investing in technology development and market expansion. Thus, the Japanese government has shifted its focus to Southeast Asia, working with industry to accelerate technology development and implementation in the region to secure economic opportunities.

Thus, similar to the problem stream, the policy idea is determined by the government, think tanks and industry, creating the 'policy primeval soup' that constitutes the policy stream. In addition, transnational factors also influence the policy stream, driving CCS further up the agenda.

Politics stream

Although most actors had a position on CDR, this had not reached the level of a full debate among all actors. Researchers who were heavily involved in the CCS study were not invited to the meetings organised by the individual ministries (Researcher B). Again, the Quadruple Helix is not fully engaged in Japanese policy, but is dominated by government, think tanks and industry. For example, the government and national research institutes often organise workshops for industry. However, this indicates the well establishment of the Triple Helix as represented by the 'triangle structure' (*see*: 2.1.1)

Although there is no direct interaction between NGOs and government, METI, MOE and industry have recognised the voice of NGOs in society (METI government official A, MOE government official A and industry B). However, the current 'closed debate' between government and industry may lead to a lack of transparency and collective decision-making. More importantly, none of the interviewees acknowledged the situation or mentioned the closed debate on CCS.

Furthermore, the actors represented in the interviews and in the documents on CCS were mostly men. A youth climate NGO (NGO E) was also not included in the policy stream. This suggests that young people's voice is under-represented in Japan's geoengineering policy, as in other countries (Dunlop et al., 2022). Again, diversity in the CCS stakeholder network is not guaranteed.

Thus, although actors share positions and interests on CCS, the politics stream is driven by a limited number of actors led by government and industry. The balance of power in the CCS policy stream is heavily skewed towards traditional male-dominated politics, which easily drives the politics stream.

Overall, three streams are interlinked in CCS policy-making that has enabled the agenda-setting of CCS. The way CCS is framed in Japan is similar to general climate change policy-making (*see*: 2.1.1), which removes the ambiguity in CCS agenda-setting. Moreover, the active Triple Helix is represented in the CCS debate that enhances the adaptation of innovation and knowledge production.

5.2 Policy Recommendations

This research suggests four policy recommendations for the future geoengineering debate in Japan. First, stimulating the Quadruple Helix is essential to develop and foster the geoengineering debate in Japan. The involvement of more diverse actors and their debate on SRM and CDR (CCS) is ideal for collective decision-making. With regard to SRM,

the first challenge is to disseminate knowledge in society in order to involve different actors and raise awareness of the technology. Researchers and NGOs could use their scientific knowledge and provide an overview from a neutral perspective.

On the other hand, as for CDR (CCS), the communication channel could be developed within the existing groups and actors that promote an inclusive debate. For example, the interactive debate in society would be enhanced by organising a workshop for the networking of relevant actors. Furthermore, a balance of gender and age is vital for a constructive debate on both technologies. To overcome such challenges, neutral actors are needed who can connect existing stakeholders.

Second, participation in international networks, such as research and civil society, is required for actors to stimulate the debate on geoengineering. This study found that the Japanese debate on geoengineering still lags far behind the existing discussions in English-speaking countries, which could exclude Japan, one of the G7 countries, from the international debate in the future. In particular, SRM is still unknown in Japan, and knowledge and opinions are highly concentrated within the research community. Given the increasing possibility of international debate or governance in the future, the Japanese government needs to prepare communication channels for stakeholders and knowledge accumulation.

Third, additional human and financial resources could be improved in climate change mitigation sectors, including the bureaucracy and civil society organisations. Current Japanese climate change projects are limited to a few issues due to resource constraints within organisations. This could prevent actors from participating in the international debate on new climate technologies. In this regard, the government can provide subsidies to strengthen climate change departments in both government and civil society organisations.

Fourth, knowledge sharing from academia is essential to promote awareness of the climate change crisis and the ongoing climate intervention technologies. This 'science communication' has a powerful influence in shaping public discourse and leading to policy development (Blanton & Ikizer, 2019). Scientists could provide scientific evidence as a basis for the debate on geoengineering and climate change, which generates and transfers innovation and policy development.

5.3 Limitations and Future Research Directions

Five limitations of this study should be noted, which will further strengthen future research on the study of Japanese or regional discourse on geoengineering. Firstly, the limited number of interviews limits the representation of the diversity of statements and actors that may exist in the geoengineering debate in Japan. This study is the first to analyse the geoengineering debate in Japan, focusing on both SRM and CDR. As a result, it was possible to identify the ideas and actors surrounding both technologies, but the detailed overview was limited due to time constraints. In addition, the network of actors and their interactions could be expanded if more interviews were conducted. For example, the group of four actors could be expanded to include media, youth and international organisations. Gender balance is also important to improve the reliability of the research, as the interviewees were predominantly male. Based on the findings of this research, future research can look for more actors and remaining statements around SRM and CDR by focusing on each technology.

Secondly, this research is built on the cultural context, therefore the degree of reliability is limited. In addition, one's perspectives change over time and external effects could reduce the replicability (Baum et al., 2022). Nevertheless, it is important to consider the idea of cultural and linguistic context. In particular, studying non-English speaking countries with indirect expressions or different language use could lead to different understandings. For example, in Japanese culture, 'one's public stance and real opinion (Honne and Tatemae)' is common business behaviour, especially when discussing sensitive issues. In addition, it is important to read the lines when discussing with Japanese people in order to understand the whole picture. Therefore, researchers studying the regional discourses should carefully build trust and relationships with respondents and examine the data with a cultural understanding. In addition to the cultural context, understanding the local political and social system is essential to understand the debate and the networks of actors.

Thirdly, the external validity of this research is limited. In addition to the high cultural context and the paucity of discourse analysis research on geoengineering in other Asian countries, the external validity may not be applicable to different contexts. In other words, the application of the research methods can be extended to different regions. For example, South Korea and Taiwan have a similar political and social structure to Japan, so the research could be applied to explore public discourse. In this regard, future research could be developed to focus on other Asian countries where geoengineering, especially SRM, could be applied in the future. This will also ensure validity while adding new theoretical knowledge to the growing research on geoengineering.

Fourth, the inductive coding scheme was too simplified to understand the detailed debate. However, the codes were able to extract the main idea of each technology and group the actors, resulting in an unbiased overview of the Japanese geoengineering debate. The coding could be further improved by maximising the data from more interviewees and documents.

Finally, the research results could be shared with the identified stakeholders, which could provide an opportunity for stakeholders to network and learn about the existing ideas of SRM and CDR. Scientific knowledge should not end in the academic field but should reach out to society and support social change. However, the workshop was not held due to time constraints.

6. Conclusion

The aim of this research was to explore the current debate on geoengineering (CDR and SRM) for global climate change mitigation in Japan and how the narratives are shaped. Through discourse and network analysis of documents and interviews, the study identified the debate on geoengineering technologies, namely SRM and CDR, and their relevant actors.

First, SRM was still an unfamiliar climate-related issue for actors in Japan and had not reached the governmental level. The storylines of SRM were about emerging governance in Japan and the Global North, concerns about highly uncertain technology, and research and development. These storylines were mainly constructed by actors from academia.

Second, CCS, one of the CDR technologies, was supported by the government, industry and several researchers. Climate policy and finance were the key themes of the CCS storylines, and actors were interested in the institutional development of CCS in Japan and in research and development promoting business opportunities. However, the interactive discussion among actors did not take place, which limited the inclusive debate on CCS. Although the civil voice was present in the CCS discourses, NGOs were not involved in the interactive debate with government, industry and academia.

The transnational influence on the debate on SRM and CDR was also observed to some extent. For example, actors from academia belonged to North American and European research groups on SRM and CCS, respectively, which could influence the future discourse in Japan as the debate matures. In addition, the CCS debate focused on international influence on other countries, as the Japanese government was keen to lead the development of CCS in Southeast Asia.

Overall, in the emerging geoengineering debate in other Global North countries, Japan lagged behind in terms of public debate on geoengineering and dynamic interactions among actors. Inadequate and unbalanced power in the political currents may hinder the appropriate agenda-setting process and limit the Japanese government's participation in the global debate on geoengineering in the future. More importantly, the inadequate Quadruple Helix hinders collective decision-making on the uncertain new technologies of the future. In this respect, science can play a crucial role in the public discourse by providing scientific insights and bridging actors throughout the knowledge production process.

This research identified the issues and improvements that contribute to the fostering of innovative societal practices. In addition, this study provided new insights into the growing literature on geoengineering discourse, which is currently dominated by English-speaking countries in the Global North. In conclusion, the academic community is challenged to explore the regional discourse of geoengineering and how the novel technology of geoengineering is adopted and framed in each country.

7. Acknowledgement

First of all, I would like to thank Prof. Frank Biermann for supervising the 31.5-week research process. His encouragement and constructive feedback motivated and supported me to complete this research. I would also like to thank Dr Rakhyun Kim for the advice he gave me on my research proposal. The encouragement and insight on my proposal helped me to improve my research.

Secondly, I would like to express my appreciation to all the interviewees for taking the time to participate in this study. Their insights are valuable to this research and I also learned a great deal from talking to them.

Finally, I am grateful to the Rotary Global Grants Scholarship and the Iizuka Takeshi Scholarship Foundation for giving me an opportunity to pursue my master's degree in Europe. Enrolling in and completing this two-year programme would not have been possible without the support of the scholarships. Although my academic journey would come to a pause here, I will continue to learn and contribute to society throughout my life, using what I have learnt during this MSc Programme and experiences.

8. References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 1-21. https://doi.org/10.1007/s11356-022-19718-6

Anshelm, J., & Hansson, A. (2014). Battling Promethean dreams and Trojan horses: Revealing the critical discourses of geoengineering. *Energy Research & Social Science*, *2*, 135–144. https://doi.org/10.1016/j.erss.2014.04.001

Asayama, S., Sugiyama, M., & Ishii, A. (2017). Ambivalent climate of opinions: Tensions and dilemmas in understanding geoengineering experimentation. *Geoforum*, *80*, 82–92. https://doi.org/10.1016/j.geoforum.2017.01.012

Asayama, S., Sugiyama, M., Ishii, A., & Kosugi, T. (2019). Beyond solutionist science for the Anthropocene: To navigate the contentious atmosphere of solar geoengineering. *The Anthropocene Review, 6(1-2),* 19-37. https://doi.org/10.1177/2053019619843678

Aurenhammer, P. K. (2016). Network analysis and actor-centred approach — A critical review. *Forest Policy and Economics*, *68*, 30–38. https://doi.org/10.1016/j.forpol.2014.12.010

Baba, K., Doi, M., & Tanaka, M. (2021). Developing Future Scenarios for Climate Change Adaptation Policy: Case Study of Farming Community in Japan. In *Handbook of Climate Change Management* (pp. 1–30). Springer International Publishing. https://doi.org/10.1007/978-3-030-22759-3_280-1

Babiker, M., G. Berndes, K. Blok, B. Cohen, A. Cowie, O. Geden, V. Ginzburg, A. Leip, P. Smith, M. Sugiyama, F. Yamba. (2022). Cross-sectoral perspectives. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).* Cambridge University Press. doi: 10.1017/9781009157926.005

Blanton, H., & Ikizer, E. G. (2019). Elegant Science Narratives and Unintended Influences: An Agenda for the Science of Science Communication. *Social Issues and Policy Review*, *13*(1), 154–181. https://doi.org/10.1111/sipr.12055

Batres, M., Wang, F. M., Buck, H., Kapila, R., Kosar, U., Licker, R., Nagabhushan, D., Rekhelman, E., & Suarez, V. (2021). Environmental and climate justice and technological

carbon removal. *The Electricity Journal*, *34*(7), 107002. https://doi.org/10.1016/j.tej.2021.107002

Baum, C. M., Low, S., & Sovacool, B. K. (2022). Between the sun and us: Expert perceptions on the innovation, policy, and deep uncertainties of space-based solar geoengineering. *Renewable and Sustainable Energy Reviews*, *158*, 112179. https://doi.org/10.1016/j.rser.2022.112179

Bednarz, E. M., Visioni, D., Richter, J. H., Butler, A. H., & MacMartin, D. G. (2022). Impact of the Latitude of Stratospheric Aerosol Injection on the Southern Annular Mode. *Geophysical Research Letters*, *49*(19). https://doi.org/10.1029/2022GL100353

Biermann, F., Oomen, J., Gupta, A., Ali, S. H., Conca, K., Hajer, M. A., ... & VanDeveer, S. D. (2022). Solar geoengineering: The case for an international non-use agreement. *Wiley Interdisciplinary Reviews: Climate Change*, *13(3)*, e754. https://doi.org/10.1002/wcc.754

Blanton, H., & Ikizer, E. G. (2019). Elegant Science Narratives and Unintended Influences: An Agenda for the Science of Science Communication. *Social Issues and Policy Review*, *13*(1), 154–181. https://doi.org/10.1111/sipr.12055

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network Analysis in the Social Sciences. *Science*, *323*(5916), 892–895. https://doi.org/10.1126/science.1165821

Brack, D., & King, R. (2021). Managing Land-based CDR: BECCS, Forests and Carbon Sequestration. *Global Policy*, *12*, 45-56. https://doi.org/10.1111/1758-5899.12827

Brent, K., McDonald, J., McGee, J., & Gogarty, B. (2018). Carbon dioxide removal geoengineering. *Australian Law Journal*, *92*(10), 830-838.

Burnard, A., & Colvin, R. M. (2022). Storylines of Geoengineering in the Australian Media: An Analysis of Online Coverage 2006–2018. *Environmental Communication*, 1–16. https://doi.org/10.1080/17524032.2022.2141290

Buylova, A., Fridahl, M., Nasiritousi, N., & Reischl, G. (2021). Cancel (out) emissions? The envisaged role of carbon dioxide removal technologies in long-term national climate strategies. *Frontiers in Climate*, *3*, 675499. https://doi.org/10.3389/fclim.2021.675499

Cabinet Office. (n.d.). *Carbon Neutrality*. The Government of Japan. Retrieved December 10th, 2022 from https://www.japan.go.jp/global_issues/carbon_neutrality/index.html

Cabinet Office. (1997). *地球温暖化対策の推進に関する法律 [The Act on Promotion of Global Warming Countermeasures]*. https://www.kantei.go.jp/jp/singi/ondanka/siryou1.pdf

Cabinet Office. (2020). *The basic approach for the Moonshot Research and Development Program*. https://www8.cao.go.jp/cstp/english/moonshot/basicapproach_en.pdf

Cabinet Office. (2021). *Green Growth Strategy Through Achieving Carbon Neutrality in 2050*. https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/ggs_full_en1013.pdf

Cabinet Office. (2023). *Integrated Innovation Strategy 2023*. https://www8.cao.go.jp/cstp/tougosenryaku/togo2023_honbun.pdf (in Japanese)

Cai, Y., & Etzkowitz, H. (2020). Theorizing the Triple Helix model: Past, present, and future. *Triple Helix Journal*, 1–38. https://doi.org/10.1163/21971927-bja10003

Cairns, R., & Stirling, A. (2014). 'Maintaining planetary systems' or 'concentrating global power?' High stakes in contending framings of climate geoengineering. *Global Environmental Change*, *28*, 25–38. https://doi.org/10.1016/j.gloenvcha.2014.04.005

Caldeira, K., Bala, G., & Cao, L. (2013). The Science of Geoengineering. *Annual Review of Earth and Planetary Sciences*, *41*(1), 231–256. https://doi.org/10.1146/annurev-earth-042711-105548

Cambridge Dictionary. (n.d.). Debate. In *Cambridge Dictionary*. Retrieved May 12, 2023, from https://dictionary.cambridge.org/dictionary/english/debate

Carayannis, E. G., & Campbell, D. F. J. (2021). Democracy of Climate and Climate for Democracy: the Evolution of Quadruple and Quintuple Helix Innovation Systems. *Journal of the Knowledge Economy*, *12*(4), 2050–2082. https://doi.org/10.1007/s13132-021-00778-x

Center for Research and Development Strategy, Japan Science and Technology Agency (CRDS). (2021). PANORAMIC VIEW REPORT Japanese Policies for Science, Technology and Innovation. https://www.jst.go.jp/crds/pdf/2020/FR/CRDS-FY2020-FR-06.pdf

Centre for Research on the Epidemiology of Disasters (CRED). (2022). *Disasters in*

numbers 2021. Brussels. https://cred.be/sites/default/files/2021_EMDAT_report.pdf

Cho, J. Y., & Lee, E-H. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *The Qualitative Report, 19*(64), 1-20. Retrieved from https://doi.org/10.46743/2160-3715/2014.1028

Cox, E., Spence, E., & Pidgeon, N. (2020). Public perceptions of carbon dioxide removal in the United States and the United Kingdom. *Nature Climate Change*, *10*(8), 744-749. https://doi.org/10.1038/s41558-020-0823-z

Delina, L. L. (2020). Potentials and critiques of building a Southeast Asian interdisciplinary knowledge community on critical geoengineering studies. *Climatic Change*, *163*(2), 973-987. https://doi.org/10.1007/s10584-020-02921-0

Delina, L. L. (2021). Southeast Asian expert perceptions of solar radiation management techniques and carbon dioxide removal approaches: caution, ambivalence, risk precaution, and research directions. *Environmental Research Communications*, *3*(12), 125005. https://doi.org/10.1088/2515-7620/ac3dc1

Department for Business, Energy & Industrial Strategy. (2020). *The UK Government's View on Greenhouse Gas Removal Technologies and Solar Radiation Management*. https://www.gov.uk/government/publications/geo-engineering-research-the-government-s-view

Dunlop, L., Rushton, E., Atkinson, L., Cornelissen, E., de Schrijver, J., Stadnyk, T., Stubbs, J., Su, C., Turkenburg-van Diepen, M., Veneu, F., Blake, C., Calvert, S., Dècle, C., Dhassi, K., Edwards, R., Malaj, G., Mirjanić, J., Saunders, W., Sinkovec, Y., … Yuan, X. (2022). Youth co-authorship as public engagement with geoengineering. *International Journal of Science Education, Part B*, *12*(1), 60–74. https://doi.org/10.1080/21548455.2022.2027043

Etzkowitz, H., & Leydesdorff, L. (1995). The Triple Helix--University-industry-government relations: A laboratory for knowledge based economic development. *EASST review*, *14*(1), 14-19.

Fagiewicz, K., Churski, P., Herodowicz, T., Kaczmarek, P., Lupa, P., Morawska-Jancelewicz, J., & Mizgajski, A. (2021). Cocreation for Climate Change—Needs for Actions to Vitalize Drivers and Diminish Barriers. *Weather, Climate, and Society*, *13*(3), 555–570. https://doi.org/10.1175/WCAS-D-20-0114.1

Fawzy, S., Osman, A. I., Doran, J., & Rooney, D. W. (2020). Strategies for mitigation of climate change: a review. *Environmental Chemistry Letters*, *18*(6), 2069-2094.

https://doi.org/10.1007/s10311-020-01059-w

Financial Service Agency (FSA). (2022). *金融機関における気候変動への対応についての基本的な考え方 [The fundamental idea for the climate change by the financial agency]*. https://www.fsa.go.jp/common/law/kikouhendou_dp_final.pdf (in Japanese)

Fitch-Roy, O., & Fairbrass, J. (2018). The Problem Stream. In O. Fitch-Roy & J. Fairbrass (Eds.), *Negotiating the EU's 2030 Climate and Energy Framework* (pp. 33–55). Springer International Publishing. https://doi.org/10.1007/978-3-319-90948-6_3

Fudeyasu, H. (2021). Research and development on typhoon control and typhoon power generation, and initiative research on practical implementation with the aim of achieving the Moonshot Goal: Initiative Report. *Moonshot R&D MILLENNIA Program*. https://www.jst.go.jp/moonshot/en/program/millennia/pdf/report_en_19_fudeyasu.pdf

Fudeyasu, H. (2022). 台風科学技術研究センターとタイフーンショット計画 [Tyhoon Science and Technology Research Center and Tyhpoon Shot Project]. *Journal of Industry-Academia-Government Collaboration*, 18(8), 4-7. https://www.jst.go.jp/tt/journal/journal_contents/2022/08/2208-02_article.html (in Japanese)

Gardiner, S., & McKinnon, C. (2020). The Justice and Legitimacy of Geoengineering. *Critical Review of International Social and Political Philosophy*, *23*(5), 557–563. https://doi.org/10.1080/13698230.2019.1693157

Gilson, J. (2023). From Kyoto to Glasgow: is Japan a climate leader?. *The Pacific Review*, 36(4), 723–754. https://doi.org/10.1080/09512748.2021.2008475

Global CCS Institute. (2022). *GLOBAL STATUS OF CCS 2022*. https://status22.globalccsinstitute.com/

Gough, C., & Mander, S. (2019). Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS. *Current Sustainable/Renewable Energy Reports*, *6*(4), 116–123. https://doi.org/10.1007/s40518-019-00137-0

Grubb, M., C. Okereke, J. Arima, V. Bosetti, Y. Chen, J. Edmonds, S. Gupta, A. Köberle, S. Kverndokk, A. Malik, L. Sulistiawati. (2022). Introduction and Framing. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working*

Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. doi: 10.1017/9781009157926.003

Gunderson, R., Stuart, D., & Petersen, B. (2019). The political economy of geoengineering as plan B: Technological rationality, moral hazard, and new technology. *New Political Economy*, *24*(5), 696-715. https://doi.org/10.1080/13563467.2018.1501356

Gupta, A., Möller, I., Biermann, F., Jinnah, S., Kashwan, P., Mathur, V., Morrow, D. R., & Nicholson, S. (2020). Anticipatory governance of solar geoengineering: conflicting visions of the future and their links to governance proposals. *Current Opinion in Environmental Sustainability*, *45*, 10–19. https://doi.org/10.1016/j.cosust.2020.06.004

Hajer, M. A. (1997). 2 Discourse Analysis. In M. A. Hajer (Eds.), *The Politics of Environmental Discourse* (pp. 42–72). Oxford University PressOxford. https://doi.org/10.1093/019829333X.003.0003

Hakeem, M. M., Goi, H. C., Frendy, & Ito, H. (2023). Regional sustainable development using a Quadruple Helix approach in Japan. *Regional Studies, Regional Science*, *10*(1), 119–138. https://doi.org/10.1080/21681376.2023.2171313

Hasui, S., & Komatsu, H. (2021). Climate Security and Policy Options in Japan. *Politics and Governance*, *9*(4), 79–90. https://doi.org/10.17645/pag.v9i4.4414

Herweg, N., Zahariadis, N., & Zohlnhöfer, R. (2022). Travelling Far and Wide? Applying the Multiple Streams Framework to Policy-Making in Autocracies. *Politische Vierteljahresschrift*, *63*(2), 203–223. https://doi.org/10.1007/s11615-022-00393-8

Hoefer, R. (2022). The Multiple Streams Framework: Understanding and Applying the Problems, Policies, and Politics Approach. *Journal of Policy Practice and Research*, *3*(1), 1–5. https://doi.org/10.1007/s42972-022-00049-2

Horton, J. B., Brent, K., Dai, Z., Felgenhauer, T., Geden, O., McDonald, J., McGee, J., Schenuit, F., & Xu, J. (2023). Solar geoengineering research programs on national agendas: a comparative analysis of Germany, China, Australia, and the United States. *Climatic Change*, *176*(4), 37. https://doi.org/10.1007/s10584-023-03516-1

Hueholt, D. M., Barnes, E. A., Hurrell, J. W., Richter, J. H., & Sun, L. (2023). Assessing Outcomes in Stratospheric Aerosol Injection Scenarios Shortly After Deployment. *Earth's Future, 11*(5). https://doi.org/10.1029/2023EF003488

IEA. (2022). *Achieving Net Zero Heavy Industry Sectors in G7 Members*. IEA. https://www.iea.org/reports/achieving-net-zero-heavy-industry-sectors-in-g7-members

IMF. (2023). *Public Perceptions of Climate Mitigation Policies: Evidence from Cross-Country Surveys.* IMF. https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2023/02/07/Public-Perceptions-of-Climate-Mitigation-Policies-Evidence-from-Cross-Country-Surveys-528057

Jacobson, B. (2018). Constructing legitimacy in geoengineering discourse: The politics of representation in science policy literature. *Science as Culture*, *27*(3), 322-348. https://doi.org/10.1080/09505431.2018.1465910

Japan Beyond Coal. (2020). *Launch of Japan Beyond Coal: Campaign to Phase Out Coal Power.* https://beyond-coal.jp/en/news/pr_jbc-launch_20200929/

Jaschke, G., & Biermann, F. (2022). The policy discourse on negative emissions, land-based technologies, and the Global South. *Global Environmental Change*, *75*, 102550. https://doi.org/10.1016/j.gloenvcha.2022.102550

Ju, Y., Sugiyama, M., Kato, E., Matsuo, Y., Oshiro, K., & Silva Herran, D. (2021). Industrial decarbonization under Japan's national mitigation scenarios: a multi-model analysis. *Sustainability Science*, *16*(2), 411–427. https://doi.org/10.1007/s11625-021-00905-2

Kameyama, Y. (2021). Climate Change Policy: Can New Actors Affect Japan's Policy-Making in the Paris Agreement Era? *Social Science Japan Journal*, *24*(1), 67–84. https://doi.org/10.1093/ssjj/jyaa051

Keidanren. (n.d.). *About Keidanren*. Retrieved June 4, 2023 from https://www.keidanren.or.jp/en/profile/pro001.html

Keidanren. (2022). *Keidanren Carbon Neutrality Action Plan.* https://www.keidanren.or.jp/en/policy/2021/102.html

Kingdon J. W. (1995). *Agendas alternatives and public policies* (2nd ed.). Longman.

Knaggård, Å. (2015). The Multiple Streams Framework and the problem broker. *European Journal of Political Research*, *54*(3), 450–465. https://doi.org/10.1111/1475-6765.12097

Koppenborg, F., & Hanssen, U. (2021). Japan's Climate Change Discourse: Toward Climate Securitisation? *Politics and Governance*, *9*(4), 53–64. https://doi.org/10.17645/pag.v9i4.4419

Kythreotis, A. P., Mantyka-Pringle, C., Mercer, T. G., Whitmarsh, L. E., Corner, A., Paavola, J., Chambers, C., Miller, B. A., & Castree, N. (2019). Citizen Social Science for More Integrative and Effective Climate Action: A Science-Policy Perspective. *Frontiers in Environmental Science, 7*. https://doi.org/10.3389/fenvs.2019.00010

Lawrence, M. G., Schäfer, S., Muri, H., Scott, V., Oschlies, A., Vaughan, N. E., ... & Scheffran, J. (2018). Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals. *Nature communications*, *9(1)*, 1-19. https://doi.org/10.1038/s41467-018-05938-3

McLaren, D., & Corry, O. (2021). The politics and governance of research into solar geoengineering. *WIREs Climate Change*, *12*(3). https://doi.org/10.1002/wcc.707

Ministry of Agriculture, Forestry and Fisheries (MAFF). (2022). *Field for Knowledge Integration and Innovation Introductory Pamphlet*. Available: https://www.knowledge.maff.go.jp/en/Pamphlet_Field_for_Knowledge_Integration_and_Innovation.pdf

Ministry of Economy, Trade and Industry (METI). (n.d.). *Industry-Academia-Government Collaboration*. Retrieved December 10th, 2022, from https://www.meti.go.jp/english/policy/economy/industry_academia/index.html

Ministry of Economy, Trade and Industry (METI). (2020). *Carbon Credits Issued for Three Projects under Joint Crediting Mechanism (JCM) with Indonesia*. https://www.meti.go.jp/english/press/2020/0120_003.html

Ministry of Economy, Trade and Industry (METI). (2021). *Basic Policies for Green Innovation Fund*. https://www.meti.go.jp/english/press/2021/pdf/0312_002a.pdf

Ministry of Economy, Trade and Industry (METI). (2023). *Press Conference by Minister Nishimura (Excerpt)*. https://www.meti.go.jp/english/speeches/press_conferences/2023/0613001.html

Ministry of Foreign Affairs (MOFA). (2021). *Initiatives by stakeholders in various fields to implement the Paris Agreement: Leading Municipalities*. https://www.mofa.go.jp/ic/ch/page23e_000509.html

Ministry of the Environment (MOE). (2018). *Japan's Assistance Initiatives to Address Climate Change 2018*. https://www.env.go.jp/press/106168/%E6%97%A5%E6%9C%AC%E3%81%AE%E6%B0%97%E5%80%99%E5%A4%89%E5%8B%95%E5%AF%BE%E7%AD%96%E6%94%AF%E6%8F%B4%E3%82%A4%E3%83%8B%E3%82%B7%E3%82%A2%E3%83%86%E3%82%A3%E3%83%962018%28%E8%8B%B1%E8%AA%9E%29.pdf

Ministry of the Environment (MOE). (2021a). 改正地球温暖化対策推進法　成立 [The establishement of revised the Act on Promotion of Global Warming Countermeasures]. *脱炭素ポータル [Decarbonisation Portal]*. https://ondankataisaku.env.go.jp/carbon_neutral/topics/20210604-topic-03.html

Ministry of the Environment (MOE). (2021b). *Japan's Nationally Determined Contribution (NDC).* https://www.env.go.jp/content/900442543.pdf

Nayak, S., & Takemi, T. (2020). Robust responses of typhoon hazards in northern Japan to global warming climate: cases of landfalling typhoons in 2016. *Meteorological Applications*, *27*(5). https://doi.org/10.1002/met.1954

Oshiba, R. (2021). Multilateralism and global governance: Japan in the World Bank, the G7 and G20 summits. In *Japan, the European Union and Global Governance*. Edward Elgar Publishing. https://doi.org/10.4337/9781788114462.00009

Parson, E. A., & Reynolds, J. L. (2021). Solar geoengineering: Scenarios of future governance challenges. *Futures*, 133, 102806. https://doi.org/10.1016/j.futures.2021.102806

Patt, A., L. Rajamani, P. Bhandari, A. Ivanova Boncheva, A. Caparrós, K. Djemouai, I. Kubota, J. Peel, A.P. Sari, D.F. Sprinz, J. Wettestad. (2022). International cooperation. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).* doi: 10.1017/9781009157926.016

Raimi, K. T. (2021). Public perceptions of geoengineering. *Current Opinion in Psychology*, *42*, 66-70. https://doi.org/10.1016/j.copsyc.2021.03.012

Reynolds, J. L. (2019). Solar geoengineering to reduce climate change: a review of governance proposals. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *475*(2229), 20190255. https://doi.org/10.1098/rspa.2019.0255

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

Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren. (2022). Mitigation pathways compatible with long-term goals. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).* Cambridge University Press. doi: 10.1017/9781009157926.005

Satoh, K. (2014). The Japanese Climate Change Policy Network : The Relationship between a Triple-Pole Structured Organizational Support Network and Policy Output. *Journal of Environmental Sociology*, 20, 100–116. https://doi.org/10.24779/jpkankyo.20.0_100 (in Japanese)

Saviano, M., Barile, S., Farioli, F., & Orecchini, F. (2019). Strengthening the science–policy–industry interface for progressing toward sustainability: a systems thinking view. *Sustainability Science*, *14*(6), 1549–1564. https://doi.org/10.1007/s11625-019-00668-x

Scalia, M., Barile, S., Saviano, M., & Farioli, F. (2018). Governance for sustainability: a triple-helix model. *Sustainability Science*, *13*(5), 1235–1244. https://doi.org/10.1007/s11625-018-0567-0

Sikka, T. (2012). A critical discourse analysis of geoengineering advocacy. *Critical Discourse Studies*, *9*(2), 163–175. https://doi.org/10.1080/17405904.2012.656377

Sovacool, B. K. (2021). Reckless or righteous? Reviewing the sociotechnical benefits and risks of climate change geoengineering. *Energy Strategy Reviews*, *35*, 100656. https://doi.org/10.1016/j.esr.2021.100656

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

Sugiyama, M., Asayama, S., Ishii, A., Kosugi, T., Moore, J. C., Lin, J., ... & Xia, L. (2017a). The Asia-Pacific's role in the emerging solar geoengineering debate. *Climatic Change*, *143*(1), 1-12. DOI: 10.1007/s10584-017-1994-0

Sugiyama, M., Asayama, S., Kosugi, T., Ishii, A., Emori, S., Adachi, J., Akimoto, K.,

Fujiwara, M., Hasegawa, T., Hibi, Y., Hirata, K., Ishii, T., Kaburagi, T., Kita, Y., Kobayashi, S., Kurosawa, A., Kuwata, M., Masuda, K., Mitsui, M., … Yoshizawa, G. (2017b). Transdisciplinary co-design of scientific research agendas: 40 research questions for socially relevant climate engineering research. *Sustainability Science*, *12*(1), 31–44. https://doi.org/10.1007/s11625-016-0376-2

Sugiyama, M., Asayama, S., & Kosugi, T. (2020). The north–south divide on public perceptions of stratospheric aerosol geoengineering?: a survey in six Asia-Pacific countries. *Environmental Communication*, *14*(5), 641-656. https://doi.org/10.1080/17524032.2019.1699137

Sugiyama, M., Fujimori, S., Wada, K., Endo, S., Fujii, Y., Komiyama, R., Kato, E., Kurosawa, A., Matsuo, Y., Oshiro, K., Sano, F., & Shiraki, H. (2019). Japan's long-term climate mitigation policy: Multi-model assessment and sectoral challenges. *Energy*, *167*, 1120–1131. https://doi.org/10.1016/j.energy.2018.10.091

Sugiyama, M., & Fujiwara, M. (2016). Public perception of climate engineering in Japan: Results from online and classroom surveys. *The University of Tokyo PARI Working Paper No. 23*. Retrieved from https://pari.ifi.u-tokyo.ac.jp/publications/WP16_23.pdf.

The Department of Moonshot R&D Programme. (2023). *Moonshot R&D Program Overview*. The Japan Science and Technology Agency (JST). https://www.jst.go.jp/moonshot/en/pr/index.html

United Nation (UN). (1992). *REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT*. Available: https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf

United Nations Environment Programme (UNEP). (2022). *Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies*. Nairobi. https://www.unep.org/emissions-gap-report-2022

Verschuren, P., Doorewaard, H., & Mellion, M. J. (2010). *Designing a research project* (Vol. 2). Eleven International Publishing.

Warren, B. (2022). *NATURE-BASED SOLUTIONS FOR CLIMATE CHANGE*. Think 7. https://www.think7.org/wp-content/uploads/2022/03/Climate-Environment_Nature-based-Solutions-for-Climate-ChangeBrittaney-Warren_Draft.pdf

Yoda, N., & Kuwashima, K. (2020). Triple Helix of University–Industry–Government Relations in Japan: Transitions of Collaborations and Interactions. *Journal of the*

Knowledge Economy, *11*(3), 1120–1144. https://doi.org/10.1007/s13132-019-00595-3

Zahariadis, N. (2014). Ambiguity and multiple streams. In Sabatier, P. A., & Weible, C. M. (Eds.). *Theories of the policy process*. Westview Press.*Theories of the policy process*, *3*(1), 25-59.

Zahariadis, N. (2019). The Multiple Streams Framework. In P. A. Sabatier (Eds.), *Theories of the Policy Process* (pp. 65–92). Routledge. https://doi.org/10.4324/9780367274689-3

Zohlnhöfer, R., Herweg, N., & Rüb, F. (2015). Theoretically refining the multiple streams framework: An introduction. *European Journal of Political Research*, *54*(3), 412–418. https://doi.org/10.1111/1475-6765.12102

9. Appendix

Appendix A

Following tables show the number of documents collected through the data collection.

News Articles					
	NIKKEI	**YOMIURI**	**MAINICHI**	**ASAHI**	**JAPAN TIMES**
Articles (found)	11	2	3	11	60
Total (found)					87
Articles (coded)	4	1	2	7	0
TOTAL (coded)					**14**

Government			
	MOE	**METI**	**Cabinet Office**
Documents (found)	35	35	3
Total (found)			73
Annual REPORT (2018-2022) (coded)	5	5	1
Minutes (2015-2022) (coded)	10	2	0
Policy papers (coded)	0	1	1
Total (coded)	15	8	2
TOTAL (coded)			**25**

Industry		
	Keidanren	
Documents (found)	33	
Report (coded)	5	
Policy Recommendations (coded)	3	
TOTAL (coded)	**8**	

Journal Articles		
	ENG (WOS)	JPN (CiNii)
Total (found in search results)	99	13
No access	0	3
Related to the research topic	24	12
Articles with the statement/opinion of Japan and geoengineering	0	0
TOTAL (coded)		**0**

Academia (national research institutes)		
	NEDO	RITE
Project Reports	2	2
TOTAL (coded)		

NGO				
	A	**B**	**C**	**D**
Blog/Report/ Position Papers	3	3	3	2
Total (coded)	3	3	3	2
TOTAL (coded)				**11**

Appendix B

The following list shows the interview questions. The interview was semi-structured and the questions changed depending on the answers.

- Language: Japanese
- Duration: 40 minutes to 1-hour
- Venue: online or in-person

1. About the interviewees

- Your name
- Your job and title (position)
- What is your role in corporate/NGO/ministry?
- How does your job or organisation relate to climate change mitigation?

2. Knowledge questions

- Are you familiar with geoengineering? (Assuming the answer is YES)
- → If yes, what types of geoengineering are you familiar with?
- → If no (or even yes), are you familiar with CDR or SRM?
- How did you find out about geoengineering? (Research? Government reports/meetings? IPCC report? etc.) (Intend to identify national or international influence)
- Do you know how geoengineering works? (Intend to understand to what extent interviewees are familiar)
- Do you know of any actors involved in or familiar with geoengineering in Japan?
- Do you know of any networks or communities working on CDR or SRM in Japan?
- Do you know of any leading actors on CDR or SRM in Japan?

3. Answer questions

- In the current global discussion on geoengineering (both CDR and SRM), some have a positive impression that it will be the key solution to climate change, while others have more doubts and warnings. What do you think about the current debate?
- How do you perceive the current debate on CDR or SRM in Japan?
- How do you compare the current debate on CDR or SRM in Japan with the international debate?
- What is your personal opinion on CDR and/or SRM?
- What is the solution to climate change mitigation?

Appendix C

The list of interviewees. The grey colour column indicates the interview was declined but received an email answer to the questions.

NO.	Name	Affiliation	Position
Government			
1	MOE	Global Environmental Bureau	Chief
2	METI	Industrial Science and Technology Policy and Environment Bureau	Chief
Industry			
3	Industry B	Trading Company	Manager (Department of Natural Gas)
4	Industry C	Research and Development	Manager (Department of International Affairs)
Academia			
5	Researcher A	University (pubic)	Associate Professor
6	Researcher B	National research institute	Senior Researcher
7	Researcher D	University (public)	Honorary Professor
NGOs			
8	NGO A	Japanese NGOs	Executive Director/Board Member
9	NGO B	International NGOs	Climate Change Office
10	NGO C	International NGOs	Climate Change Office
11	NGO E	Japanese Youth NGOs	Members