Using Marketing Concepts to Facilitate Upstream Public Engagement with Science

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy in Marketing

At Massey University, Palmerston North, New Zealand

Pamela May Feetham

2016

Abstract

This thesis investigates whether marketing theories and methodologies can be used to facilitate upstream public engagement with contentious scientific issues. Upstream engagement requires the early involvement of citizens in decisions about new science or technology from the conceptualisation stage onwards; before ingrained attitudes, social representations or frames in the media bias responses. Contemporary approaches to science communication lack consensus on the most appropriate approach to engage the public with new science and technology.

The research addresses upstream communication in the context of climate engineering. Scientists and the International Panel for Climate Change are considering climate engineering as a potential solution to global warming, given that the present methods of mitigation and adaptation have so far failed to sufficiently reduce global temperatures to a level of 1.5 degrees above pre-industrial levels. The communication of potential solutions to global warming is a vital part of a critical global issue that will impact the planet's eco-systems, biodiversity and future generations. Marketing may be able to provide methodologies and techniques for evaluating and measuring public perceptions of climate engineering.

As well as contributing to upstream science communication and public engagement, the research contributes to marketing theory in two ways. First, it extends the application of brand image research founded on the Associative Network Theory of Memory (ANTM) to science concepts, demonstrating the robustness of the theory. Second, it extends the information dual-processing theory to investigate the effects of intuitive and deliberative thinking on concept evaluations, and whether these views change with greater deliberation.

In the qualitative phase, thirty exploratory semi-structured depth interviews, using two methods of attribute elicitation, provided 12 common attributes associated with climate engineering. The findings identified an overall negative public reaction to the four climate engineering technologies tested. The independent qualitative findings also revealed a strikingly clear result – Carbon Dioxide Removal technologies are perceived more positively than Solar Radiation Management technologies.

The subsequent quantitative on-line surveys tested public perceptions of six climate engineering techniques in Australia (*n* =1,006) and New Zealand (*n* =1,022). The results of the on-line surveys supported the qualitative findings that associations with climate

engineering techniques are predominately negative, and allowed further diagnostic insights into the sources of these evaluations for each of the individual techniques tested. The analysis established the data are robust and stable across the two countries and the methodologies are validated by the strikingly similar aggregate findings across the qualitative and quantitative stages.

For the comparison of intuitive and deliberative thinking on memory associations with climate engineering the effects are measured by comparing within sample groups split by the length of time taken to complete the online survey. In Australia, the findings show that greater deliberative thinking is associated with more negative evaluations, indicating that intuitive and deliberative thinking do give different results in *magnitude,* if not in *direction* for these data. In New Zealand, greater deliberative thinking is not associated with more negative evaluations suggesting that the effect of deliberative thinking on the evaluation of climate engineering concepts is moderated by the country of study, or by the prior beliefs of the country's population.

A final stage of research used five focus groups in New Zealand to investigate whether deliberative arguments and interactions help participants make sense of unfamiliar, multi-faceted or contentious issues, and whether different perspectives are influenced by age, gender or the ethnicity of participants. Overall, most participants were sceptical of climate engineering, although some between-group differences were apparent. Knowledge of climate engineering varied between groups, with younger participants unaware of climate engineering, and reluctant to consider research on the technologies. Conversely, in the retiree group all but one participant had heard of climate engineering and the most of the participants were receptive to the idea of proceeding with research on climate engineering technologies. This further demonstrates that the effects of deliberation may be context specific.

The results confirm the practicality of extending concept testing and measurement of memory associations to upstream engagement for controversial scientific methods, showing convergent validity across countries and methods. The results demonstrate that mixed mode research using marketing techniques yields a range of insights that are not otherwise available in upstream public engagement. Finally, the research finds that more deliberative responses may affect the magnitude of concept evaluations, but the effect is contextual. This highlights the need for further research to provide better understanding of the effect of deliberation on evaluations.

Acknowledgements

I have three reasons for undertaking this thesis journey:

My primary supervisor, Professor Malcolm Wright, offered me an enlightening topic and created the opportunity for me to work and complete this thesis. His unwavering support and enthusiasm are priceless.

It took me some time in life to realise that to keep sane I needed intellectual as well as physical challenges. The Ph.D has allowed me an intellectual challenge and kept me motivated to continue my learning journey.

I wanted to lead the way for all the women in my family and show the wonderful women I have encountered along life's road that it's never too late to make changes and fulfil your dreams. If you believe in yourself nothing is impossible.

I have not taken this journey alone, daughters, family, friends, second supervisor, A. Prof. Margie Comrie, other colleagues, and my students have motivated, nurtured and believed in me too.

Thank you all, most humbly, Pam.

I pass on to you an Irish blessing from my cultural heritage.

May love and laughter light your days,
And warm your heart and home,
May good and faithful friends be yours,
Wherever you may roam,
May peace and plenty bless your world,
With joy that long endures,
May all of life's passing seasons,
Bring the best to you and yours.

Table of Contents

List of Figures ix
List of Tables xi
List of Publications xii
Chapter One: Introduction 1
1.1 Research Aims 1
1.2 Background to the Problem 2
1.3 Research Approach 6
1.4 Structure of the Thesis 8
Chapter Two: Climate Engineering Research 13
2.1 Introduction 13
2.2 Climate Engineering in the Public Domain 13
2.3 Public Perceptions of Climate Engineering Research before January 2013 15
2.4 Public Perceptions of Climate Engineering Research after December 2012 18
2.5 Framing Effects in Climate Engineering Discourses 27
2.6 Chapter Conclusion 30
Chapter Three: Associative Networks of Human Memory 33
3.1 Introduction 33
3.2 Consumer Choices and Judgements in Decision Making 34
3.3 Associative Network Theory of Memory in Marketing 38
3.4 The Role of Brand Attributes in Brand Evaluations 40
3.5 Using Brand Attributes to Quantify Brand Evaluations 41
3.6 Limitations of Brand Association Measures 42
3.7 A Second Model of Associative Memory Theory 43
3.8 Brand Attribute Elicitation Methodologies 44
3.9 The Effects of Salience on Brand Choice 50
3.10 Chapter Conclusion 50
Chapter Four: Science Communication, Public Engagement and Deliberation 53
4.1 Introduction 53
4.2 Science Communication Models 54
4.3 Upstream Public Engagement 59
4.4 Chapter Conclusion 61
Chapter Five: Intuitive and Deliberative Thinking in Decision Making 63

5.1 Introduction 63
5.2 The Development of Dual-processing Models and Theories 64
5.3 Distinguishing Characteristics of Dual-processing Models 65
5.4 Capabilities and Interactions of Type 1 and Type 2 Processes 70
5.5 The Accuracy of Type 1 and Type 2 Outcomes 71
5.6 Motivating Drivers for Type 1 and Type 2 Thinking 73
5.7 The Effects of Meta-cognition on Reasoning Outcomes 74
5.8 Arguments Against Dual-theories of Information Processing 77
5.9 Three Stages of Dual-processing 79
5.10 Chapter Conclusion 80
5.11 Relevance of the Literature Findings to the Research Questions and Approaches ..82
Chapter Six: Stage One – Qualitative Attribute Elicitation 85
6.1 Stage 1 – Research Question 85
6.2 Justification for Stage One Methodology 85
6.3 Stage 1 Method 87
6.4 Stage One Results 90
6.5 Stage One Discussion 93
6.6 Stage One Limitations and Future Research 93
Chapter Seven: Stage Two – Quantitative On-line Surveys 95
7.1 Stage Two – Research Questions 95
7.2 Justification for Stage Two Methodologies 95
7.3 Stage Two Method 96
7.4. Stage Two Results 100
7.5 Stage Two – Discussion 115
7.6 Stage Two Limitations and Future Research 116
Chapter Eight: Stage Three – Intuitive and Deliberative Analysis 118
8.1 Stage Three – Research Question 118
8.2 Stage Three – Justification for Methodology 118
8.3 Stage Three – Method 119
8.4 Stage Three – Results 119
8.5 Stage Three – Discussion 124
8.6 Limitations and Future Research 126
Chapter Nine: Stage Four – Qualitative Focus Groups 128

9.1 Stage Four – Research Question..128
9.2 Stage Four – Justification for the Methodology..128
9.3 Stage Four – Method 129
9.4 Stage Four – Results..130
9.5 Stage Four – Discussion 134
9.6 Limitations and Future Research..135
Chapter Ten: Conclusions...136
References..141
Appendices..156
Appendix A: Stage 1 – Concept Boards...157
Appendix B: Stage 1 – List of 30 Pre-determined Attributes Biochar Concept.............160
Appendix C: Qualitative Interviews Sample Demographics..161
Appendix D: On-line Survey Sample Demographics & Census Comparison 162
Appendix E: Stage Two – Copy of the Quantitative Survey Questionnaire 163
Appendix F: Matrix of Average Kendall Tau-b Nonparametric Correlation (Australia) 165
Appendix G: Histograms and Q-Q plots 170
Appendix H: Focus Group Demographics 173
Appendix I: Focus Group Topic Guide...174
Appendix J: *Nature Climate Change* Publication 175
Appendix K: Supplementary Material *Nature Climate Change* Publication 176

List of Figures

Figure 1: Climate engineering publications by domain…………………………………… 14
Figure 2: Climate engineering publications in WoS………………………………………. 15
Figure 3: On-line survey concept block – Enhanced weathering………………………. 99
Figure 4: Changes in net positive associations by quartiles…………………………… 125

List of Charts

Chart 1: Biochar Concept Image – New Zealand………………………………………. 106

Chart 2: Air Capture Concept Image – New Zealand…………………………………... 106

Chart 3: Enhanced Weathering Concept Image- New Zealand………………………… 107

Chart 4: Cloud Brightening Concept Image – New Zealand…………………………… 107

Chart 5: Stratospheric Aerosols Concept Image – New Zealand………………………. 108

Chart 6: Mirrors in Space – New Zealand……………………………………………… 108

Chart 7: Biochar – Mirrors in Space Concept Comparison New Zealand……………… 109

Chart 8: New Zealand and Australian Comparison – Biochar…………………………. 110

Chart 9: New Zealand and Australian Comparison – Air Capture…………………… 110

Chart 10: New Zealand and Australian Comparison – Enhanced Weathering…………. 111

Chart 11: New Zealand and Australian Comparison – Cloud Brightening……………... 111

Chart 12: New Zealand and Australian Comparison – Stratospheric Aerosols…………. 112

Chart 13: New Zealand and Australian Comparison – Mirrors in Space……………….. 112

Chart 14: Australian commenters in time quartiles …………………………………….. 125

Chart 15: New Zealand commenters in time quartiles………………………………….. 125

List of Tables

Table 1: Frequency of context frames in geoengineering appraisals…………………… 228
Table 2: Type 1 and Type 2 processing characteristics……………………………… 79
Table 3: Pre-determined list attribute associations………………………………….. 90
Table 4: Comparison of associations across climate engineering techniques………….. 91
Table 5: Kelly's repertory grid attribute associations……………………………….. 92
Table 6: Common attribute associations across two elicitation methods………………. 93
Table 7: Climate engineering technique treatments……………………………………. 97
Table 8: Attribute association by percentage of all attribute mentions………………… 101
Table 9: Attribute association rankings reduced attributes…………………………… 102
Table 10: Attribute counts after elimination of overlapping attributes (New Zealand)… 103
Table 11: Attribute counts after elimination of overlapping attributes (Australia)…….. 103
Table 12: Percentage point deviations from expected attribute counts (New Zealand)… 104
Table 13: Percentage point deviations from expected attribute counts (Australia)……... 104
Table 14: Memory associations for climate engineering techniques……………………. 105
Table 15: Support for individual climate engineering techniques – Australia………… 112
Table 16: Support for individual climate engineering techniques – New Zealand……. 113
Table 17: Understanding of climate engineering techniques – Australia……………… 113
Table 18: Understanding of climate engineering techniques – New Zealand ………… 114
Table 19: Summary of sampling and common method bias controls………………… 115
Table 20: Australian time comparisons in quartiles………………………………….. 120
Table 21: Australian time comparisons in halves…………………………………….. 120
Table 22: New Zealand time comparisons in quartiles……………………………….. 121
Table 23: New Zealand time comparisons in halves………………………………….. 121

List of Publications

Journal Article

Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change, 4*(2), 106-110.

Conference Papers in Proceedings

Feetham, P., Wright, M., Comrie, M., Teagle, D. (2012, December 1). Public reaction to climate geoengineering: An exploratory study. In R. Lee (Ed.), 2012 *ANZMAC Annual Conference—sharing the cup of knowledge* Adelaide, South Australia.

Feetham, P., Wright, M., Teagle, D. Comrie M. (2015, November 30). Qualitative evaluations of new scientific concepts: Accurate, fast, easy and inexpensive. In A. Sinha., J. Cadeaux. J., T Bucic (Eds.), 2015 *ANZMAC Annual Conference-Innovation and growth strategies in marketing* Sydney, Australia.

Funded Panel Participant Climate Engineering Conference-Berlin 2014

Panel Presentation

Feetham, P., Wright, M.,Teagle, D. (2014, August 20). Qualitative in-depth interviews uncover public responses to climate engineering. *Climate Engineering Conference 2014: Critical Global Discussions.* Potsdam : Institute for Advanced Sustainability Studies (IASS) Berlin, Germany. DOI: http://doi.org/10.2312/iass.2015.008

Seminar Presentations

Invited speaker at the Biochar Workshop – The final answer 4 -5th July, 2013 at Massey University, Palmerston North.

Feetham, P., Wright, M.,Teagle, D. Comrie, M. (2013, July 5). Public perceptions of Biochar in a climate engineering context. *Biochar Workshop – The final answer*. Massey University: Palmerston North

Feetham, P. M. (2013, March 20). Public Reaction to Climate Engineering. *CJM Seminar Series.* Massey University, Palmerston North.

Feetham, P. M. (2015, March 18). Do Citizens' Evaluations of Climate Engineering vary with Deliberation? *CJM Seminar Series.* Retrieved from http://connect.massey.ac.nz/cjm-pn-seminar/

Chapter One: Introduction

1.1 Research Aims

The purpose of this thesis is to investigate whether marketing theories and methodologies can help facilitate upstream public engagement with contentious scientific issues. Upstream engagement is a relatively new term used to describe the inclusion of public in discussions and decisions about new science or technology from the conceptualisation stage onwards, before ingrained attitudes, social representations or frames in the media bias responses (Rodgers-Hayden & Pidgeon, 2007). Contemporary approaches to science communication lack consensus on the most appropriate approach to engage the public with new science and technology.

The research addresses upstream communication in the context of a relatively new science, climate engineering. Scientists and the International Panel for Climate Change are considering climate engineering as a potential solution to global warming, given that the current mitigation and adaptation methods have so far failed to sufficiently reduce global temperatures to a level of 1.5 degrees above pre-industrial levels. The communication of potential solutions to global warming is a vital part of a critical issue that will impact the planet and future generations. Marketing may be able to provide methodologies and techniques for evaluating and measuring public perceptions of climate engineering.

As well as contributing to upstream science communication and public engagement, the research contributes to marketing theory in two ways. It extends the application of brand image research founded on Associative Network Theory of Memory (ANTM) to science concepts, demonstrating the robustness of the theory. It extends information dual-processing, to investigate the effects of intuitive and deliberative thinking on concept evaluations, and whether these views change with greater deliberation.

The research applies two attribute elicitation methods in face-to-face depth interviews and establishes the criteria for further climate engineering evaluations in two large-scale surveys in Australia and New Zealand. The second stage quantifies how widely and strongly the associations in stage one are held, providing a systematic method for measuring public perceptions of climate engineering techniques and establishes a benchmark for measuring any future changes in public perceptions. The cross-country analysis establishes the robustness and stability of the data. Further analysis on the data considers whether intuitive or deliberative survey responses differ in substantive ways, and if so does intuitive thinking influence views that might be obtained from greater deliberation. A final stage investigates whether the ideas, arguments and interactions in five focus groups held in New Zealand help participants make sense of unfamiliar, multi-faceted or contentious issues and whether different perspectives are influenced by the age, gender or ethnicity of participants.

1.2 Background to the Problem

For over two decades The United Nations (UN) has recognized the severity of global warming and has tried to find a way to reduce atmospheric concentrations of carbon dioxide (CO_2) and other harmful gases. Protocols, Treaties and Carbon Emission Trading schemes were implemented (The Kyoto Protocol, 1997; The Copenhagen Diagnosis, 2009) in attempts to lessen the adverse effects of global warming. In December 2015, at the Paris Climate Change Conference (COP21/CMP11), 195 countries agreed to a long-term goal of keeping the increase in global average temperature to less than 1.5 degrees Celsius above pre-industrial levels (EU Climate Action, 2015). It is generally agreed that this temperature level "indicates the point at which the effects attributable to climatic changes become unacceptably negative for global society" (Corner, Parkhill & Pidgeon, 2011, p 4). The 1.5 degrees goal is due for enforcement in 2020. However following the Paris agreement, eleven of the world's top climate scientists signed a letter warning that a goal of 1.5 degrees is inadequate because it provides false hope that is counter-productive to reducing global warming. These scientists argued that the Paris agreement gives the impression that global warming is now addressed when in fact the present measures fall short of what is required to avoid runaway climate change (Bawden, 2016). The opposing views of governments and scientists to the agreement made at the Paris Climate Change Conference were reported in the global media, and are likely to polarise public opinions. The negative 'avoid runaway climate change' framing by scientists also has the potential to divide public opinion. These differing views highlight the need for informed deliberative discussions that open up debate rather than polarise or close it down.

Driven by the realisation that present mitigation and adaptation strategies have failed to reach global targets for reducing greenhouse gases, organisations such as the Intergovernmental Panel on Climate Change (IPCC), The United States Government Accountability Office (GAO), The Alisomar Scientific Organising Committee (ASOC), The Kiel Earth Institute, National Aeronautics and Space Administration (NASA) and The Royal Society have made investigations into the feasibility of climate engineering proposals. These organisations and scientists warn that if global temperatures rise more than 1.5 degrees Celsius above pre-industrial levels, the effects on the Earth's eco-systems and species will have severe consequences. Corner and Pidgeon (2010), report that global temperatures have risen around 0.74 degrees Celsius in the last 100 years and predict a further rise of 0.6 degrees Celsius is inevitable. The seriousness of the level of global warming was confirmed in May 2013. Concentrations of atmospheric CO_2 exceeded 400 ppm, the highest level recorded since 1958 when CO_2 levels were first measured (NASA, 2013). Should global warming continue occurring at this rate the consequences may be irreversible, and this increases the urgency for research into climate engineering.

Climate engineering technologies are large-scale and are designed to alter the Earth's climate systems intentionally by removing CO_2 and other gases from the air, or by increasing the Earth's albedo to reflect sunlight away from the surface of the Earth (Bellamy, Chilvers, Caldeira, Bala, & Gao, 2013; Keith, 2000; Linnér & Wibeck, 2015; National Aeronautics and Space Administration, 2013; Vaughan & Lenton, 2011; Wibeck et al., 2016). Other terms used for climate engineering are geoengineering, climate remediation, climate management, and climate interventions. Examples of potential carbon removal technologies (CDR) are: various forms of air capture, biochar, bioenergy with carbon capture storage (BECCS), ocean iron fertilisation and enhanced weathering. Examples of potential solar radiation management (SRM) technologies are: marine cloud brightening, injecting small reflective particles in the upper atmosphere (stratospheric aerosol injection), mirrors in space, and roof whitening (for more specific definitions of techniques see appendices A and E). These technologies vary by composition, temporal and spatial scales, and their potential to impact on human environments and nature's ecosystems (Linnér & Wibeck, 2015).

In 2012, when this research began the majority of the public in many countries were unaware of climate engineering and those who were aware of it had limited knowledge of the proposed technologies (Mercer, Keith & Sharp, 2011). Little public debate or policy discussions on climate engineering had taken place. Research on the science and the feasibility of potential climate engineering technologies was mostly restricted to laboratory experiments and computer modelling. Some carbon reducing technologies were already in the process of implementation. For example, Biochar processes, particularly those relative to soil enhancement are studied at Agricultural centres (eg. Massey University, New Zealand) and are utilised by several countries (Australia, Switzerland and China); however, without field testing the technical feasibility, risks and cost effectiveness of most climate engineering technologies remain unsubstantiated (Linnér & Wibeck, 2015).

Many climate engineering technologies are considered high risk due to the unpredictable global impacts on essential climate systems such as the West Antarctic ice sheet and West African monsoon and this raises ethical, political and regulatory concerns (Buck, 2012; Corner and Pidgeon, 2010; Dilling & Hauser, 2013; Mcnaghten & Szerszynski, 2013; Preston, 2013; Sillmann et. al., 2015; Wibeck, Hansson & Anshélm, 2015).

Researchers have pointed out several concerns about using climate engineering as a solution to mitigate global warming. One concern is the 'moral hazard'. Moral hazard refers to the idea that a 'technological fix' for climate change will create a situation where people lose the motivation to carry out mitigation methods such a reducing the use of fossil fuels and energy (Corner, Parkhill, Pidgeon, & Vaughan, 2013; Reynolds, 2014). Research by Corner and Pidgeon (2014) used a survey of 610 participants in the UK to investigate the effects of the moral hazard claim. They found people with more sceptical and self-enhancing views were more likely to agree that climate engineering would reduce their motivation to make the behavioural changes needed to counteract climate change. Overall, they believe the presence of climate engineering as a climate change solution will impact on existing levels of mitigation, and that this behaviour will be moderated by people's existing views on climate change. In contrast, a study in Germany used an online survey of 650 participants and found that knowledge of climate engineering does not reduce an individual's mitigation efforts (Merk, Pönitzsch & Rehdanz, 2015). To date support for the moral hazard argument is mixed at best.

Additionally, some members of the public remain sceptical as to whether global warming is the catalyst for the catastrophic climate changes parts of the world are experiencing (Neilsen, 2011; Mercer et al., 2011: Merk, Pönitzsch, Kniebes, Rehdannz & Schmidt, 2014). These sceptics are likely to dispute the need for any mitigation methods. Another concern is that the proposed technologies will take many more years to develop. Time is needed to develop more accurate assessments of the negative risks and impacts of the proposed technologies and provide this information to the public. Currently, any discussion of climate engineering requires the public to deal with uncertainty and therefore complex problem-solving (Amelung & Funke, 2013). Climate engineering research will also require international co-operation and governance. Currently, there are no laws to regulate the ethical issues that are likely to occur should climate engineering technologies be developed beyond laboratories.

Combined, these concerns are likely to create controversy and influence public reaction to climate engineering technologies. There is a danger that public debate will vacillate in a similar fashion to that experienced with human-induced global warming or genetic engineering. As global knowledge of climate engineering and media coverage is increasing, there is an urgency to inform and involve the public early in discussions (Carr et al., 2013; Corner & Pidgeon, 2010; Linnér & Wibeck, 2015; Rodgers-Hayden & Pidgeon, 2007: Scholte, Vasileiadou & Petersen, 2013). Climate experts, social scientists and policy makers need to work co-operatively to understand how to communicate new scientific findings effectively and gauge likely public reaction to climate engineering.

Adding to the likelihood that public debate will be controversial is the lag between formal and informal information sharing. Several social scientists recommend an upstream approach to engaging the public with new and controversial issues (Corner & Pidgeon, 2010; Linnér & Wibeck, 2015; Rodgers-Hayden & Pidgeon, 2007; Scholte et al., 2013). Upstream engagement advises that public input take place at the research and concept development stage. At present (2016), global knowledge of climate engineering and media coverage is increasing through a wide variety of sources such as books, academic journals, print media, websites (inclusive of videos), on-line news sites, and internet blog sites (see www.climate-engineering.eu). There is no guarantee that the information is from reliable or robust sources. It may be peer-reviewed or it may be from 'grey' literature (Amelung & Funke, 2013). Regardless, information about climate engineering has entered the public domain. While many of the climate engineering technologies lack research beyond the laboratory, discussion on science-based websites, social media and radio is robust. Formal public engagement is not keeping pace with this informal and often biased dissemination of information.

More recent research highlights the potential for adverse public health impacts if stratospheric aerosol technologies are deployed (Effiong & Neitzel, 2016). While only speculative, as exposure levels are unknown, Effiong and Neitzel's research explores the toxicity of aerosols likely to be used for solar radiation management. In particular, they have reservations about the health effects of barium titanate, a complex salt containing two metals, likening it to nanomaterials. Generally, barium titanate is known to have associations with respiratory, cardiovascular, gastrointestinal, musculoskeletal, metabolic, and neurologic effects; however, Effiong and Nietzel were unable to confirm whether these side effects would or would not occur after stratospheric aerosol deployment. Nonetheless, their research is likely to raise concerns among members of the public and policy makers, drawing attention to potential health issues relative to stratospheric aerosol and other climate engineering technologies.

Subsequently, for climate engineering technologies there is the potential for controversial and negative debate rather than constructive dialogue. The urgency for scientists and policymakers to provide appropriate information about climate engineering is becoming even greater. The public need access to information that will allow them to understand the proposed climate engineering techniques and make meaningful, rational judgements, or decisions, should the need for human intervention in climate systems become necessary. Importantly, the diverse peoples of the global world require methods of engagement with climate engineering that accommodate and treat vulnerable members of society equally and fairly (Payne, Schwom & Heaton, 2015). As well as satisfying public needs, scientists and policymakers require guidance on how to engage with public views on climate engineering techniques in a way that will not provoke controversy, and increases the urgency for research to provide diverse approaches to upstream public engagement with new science and technologies.

1.3 Research Approach

This research further develops existing marketing techniques by testing them across another discipline to provide new methods of upstream engagement with the public on issues of global concern. The methods currently used to engage the public with science and new technologies are widely criticised in the science and social science domains, lack empirical evidence that outcomes are seriously considered in policy decisions, and have no common consensus on an appropriate approach to provide deliberative responses. Specifically, this research contributes to an important gap in the climate engineering literature, as very few studies have investigated public perceptions of this relatively new and controversial science, or found appropriate approaches for engaging the public in upstream communication.

The research undertakes tests of robustness between countries and has convergent validity between methods. It also extends knowledge about how people's views evolve in response to deliberation rather than hasty intuitive reactions. The research proceeds through the four stages explained in the following sections.

1.3.1 Stage One

Stage one is exploratory and applies standard methods of brand elicitation, relying on the Associative Network Theory of memory, to gauge public reaction to climate engineering. The intention is to identify the associations (or memory structures) that are naturally evoked by climate engineering proposals, to understand how these vary both between the technical options, and between individuals or groups, and to lay the foundation for more detailed work with larger sample sizes. This first stage of the research uses two qualitative brand elicitation methods, Kelly's Repertory Grid and a Pre-determined attribute list (Breivik & Suphellen, 2003; Fransella, Bell & Bannister, 2004), by conducting 30 semi-structured depth interviews to identify the range of mental associations that people have with climate engineering solutions.

1.3.2 Stage Two

The second stage quantifies how widely and strongly the associations in stage one are held, and investigates the reasons for any differences in associations by implementing large scale on-line surveys in Australia (n = 1006) and New Zealand (n = 1022). It expands previous survey research that used memory associations to describe the cognitive structures that underlie subconscious reactions (Kahneman, 2011; Romaniuk, 2013). This stage of the research is designed to help policy-makers understand the concerns of the public and incorporate the public's viewpoints in decisions regarding new scientific concepts. Stages one and two, therefore, provide systematic methods for measuring public perceptions of climate engineering technologies and establish a benchmark for comparing any changes to these perceptions in the future.

Stage two of this research was supported by the Massey University Research Fund (M.J.Wright) and NERC Grant NE/1006311/1 (D.A.Teagle).

1.3.3 Stage Three

Stage three investigates whether public evaluations of climate engineering technologies change with more deliberation. Policy-makers rely on research outcomes that accurately reflect public views. Public reactions to new scientific ideas are likely to be dominated by fast intuitive thinking, yet scientists and policy-makers may prefer to evoke more considered deliberative responses during early public engagement with new scientific concepts. Before considering whether more deliberative responses can be encouraged, research is required to determine whether intuitive and deliberative responses do in fact differ in substantive ways. Do intuitive responses provide misleading indications of the views that would be held after greater deliberation? Conversely, do deliberative responses provide misleading indications of the hasty responses likely to be generated during a broader public debate on scientific issues? The exact point of time when deliberative thinking is occurring is unquantifiable; however, it is possible to observe when greater analytical processing takes place (De Neys 2006a; Evans and Curtis-Holmes 2005; Kahneman 2011; Thompson et al. 2011). Therefore, the time taken to complete the online surveys in Stage two and the provision of comments, are used as proxies for measuring deliberative thinking to explore whether deliberation has any effect on public evaluations of climate engineering.

1.3.4 Stage Four

Stage four investigates whether the public have any collective perceptions of climate engineering as one of three solutions to global warming. Five relatively homogenous focus groups of participants with various demographic characteristics are used to explore common themes and to understand how social representations of climate engineering are formed in New Zealand. Specifically, the focus groups examine how the ideas, arguments and interactions in the group conversations help participants make sense of unfamiliar, multi-faceted or contentious issues (Harré, & Moghadda, 2003; Marková, 1996). This second qualitative study also investigates whether different perspectives are influenced by the gender, age or ethnicity of participants.

1.4 Structure of the Thesis

This section of the introduction provides an overview of the whole thesis in a brief summary of each chapter. Chapter 1 provides an introduction to the research aims, presents the background to the research problem, explains the approach, and outlines the thesis structure. Chapters 2 – 5 of literature review develop the theoretical foundations for the methods applied in the four stages of research. Chapters 6 – 9 justify the methodologies, results, discussion of the findings, and the limitations and direction for further research for each of the four stages of research. Chapter 10 provides an overall discussion of the research findings and confirms the managerial and theoretical contributions of the thesis.

1.4.1 Chapter One

Section 1.1 sets out the overall purpose of the research; specific research questions are stated in sections 6.1, 7.1, 8.1, 9.1 of Chapters 6 – 9. One purpose is to establish whether marketing theories and methodologies can help facilitate upstream public engagement with critical scientific issues, specifically, whether marketing metrics can evaluate and quantify associations with a relatively new science, climate engineering. A second purpose is to explore whether intuitive or more deliberative thinking significantly alters public evaluations of the climate engineering technologies tested.

Section 1.2 identifies the problem the research is investigating and why it is a critical issue. Climate engineering technologies are proposed as potential solutions to climate change and since some members of the public are sceptical about the causes and existence of climate change, discussions about climate engineering are likely to evoke controversy and polarise views. This section also describes climate engineering, the categories, some of the technologies, and discusses some of the public's concerns about the use of the proposed climate engineering technologies.

Section 1.3 explains the research approach, the current problems with science communication and upstream public engagement, and describes the methodologies used in each of the four stages. The research stages proceed through qualitative depth interviews that elicit common climate engineering attributes, to large-scale quantitative surveys that quantify respondents' associations with the six climate engineering technologies tested, to a further round of analysis that uses time as a proxy for measuring deliberative thinking and its effects on respondents' evaluations of climate engineering. A fourth stage uses qualitative focus group discussions to examine how social representations are formed and whether any demographic segments influence participants' perspectives of climate engineering.

Section 1.4 explains how the thesis is structured.

1.4.2 Chapter Two

Chapter 2 reviews published climate engineering research. It identifies the increasing presence of climate engineering in academic research and mainstream media, although the number of papers published on public perceptions of climate engineering is relatively few. The academic climate engineering research is reviewed in two sub-sections: before and after the field-work for this research took place. The findings of three studies reported in the research before the field work commenced, helped guide the design of the materials used in stages one and two of this thesis. The research published after the fieldwork commenced, identified the lack of consideration of the cognitive processes underlying deliberative responses and decisions in current public engagement approaches. Subsequently, determining to what extent deliberative thinking has an effect on the evaluations of climate engineering is one of the main aims of this research. The few studies that investigated whether the way climate engineering is framed has an effect on public perceptions of climate engineering are also examined in chapter two.

1.4.3 Chapter Three

To provide an understanding of the processes used in consumer decision making chapter three examines the Associative Network Theory of Memory (ANTM). This chapter includes details on stimulus and memory based judgements, the importance of memory retrieval, the properties of short and long-term memory and how memory systems work. Memory activation effects and cognitive limitations are also discussed, leading to an explanation of how ANTM is widely applied in marketing as it conceptualises how brands are stored in memory and how brand information is processed. How this theory has been developed and extended in current marketing methodologies and practices justifies why these metrics will allow climate engineering concept evaluations. ANTM theory is the foundation for the metrics adopted in stages one and two of this thesis. This chapter also reviews the research on brand attribute elicitation techniques to identify which of the various elicitation techniques are the most suitable for obtaining common descriptors to test concept associations with climate engineering.

1.4.4 Chapter Four

Chapter four explores the approaches currently applied in science communication. In particular, upstream public engagement methods are examined to determine whether they are achieving the desired deliberative public engagement. There appears no consensus on which method of science communication will achieve deliberative public engagement and little evidence that the outcomes of public engagement with science and technology are translated into policy decisions. Identification of the gaps of knowledge in science communication will signal how relevant marketing theories and methodologies can help move public debate on new science and technologies upstream.

1.4.5 Chapter Five

Chapter five focusses on another theoretical approach that explains the cognitive systems humans use to process information in choices and decision making, the dual-system of information processing. This theory originated in psychology and proposes that humans' process information using two systems now termed Type1 and Type 2 thinking. Type 1thinking is characterised as intuitive, fast and automatic while Type 2 thinking is considered slower, more analytic and consciously enacted. However, the contribution of each type of thinking to decision making is not well evidenced. Likewise, little empirical evidence exists on whether intuitive or deliberative thinking takes place separately or along an interchanging continuum, although there is some suggestion that intuitive thinking can over-ride deliberative thinking, especially if the task is too difficult for the reasoner. There is also counter argument that information processing takes place in a single cognitive system rather than a dual-process (Reder, Park & Kieffaber, 2009). Knowing whether the information used to make decisions is processed intuitively or with deliberation is important if reported research on public opinion is to provide a perspective that represents a broad spectrum of public views. If either mode of thinking has an impact on respondents' evaluations of new science or technologies and this is not accounted for when reporting citizen's opinions, then there is a strong possibility of misreporting those opinions.

1.4.6 Chapter Six –Stage One

Chapter six explains and justifies the qualitative attribute elicitation methods, presents the results and discusses the outcomes of stage one. The key outcomes illustrated and discussed are:

- Frequency counts of attribute associations
- The Pre-determined list of attributes showed 24 popular associations with a mix of positive and negative attributes.
- The Kelly's Repertory Grid elicitation technique obtained 22 popular attributes.
- When both sets of attributes are merged, a ranked list of the 12 most common attributes is achieved for use in stage 2.

The limitations of this stage and future research is also discussed in Chapter six.

1.4.7 Chapter Seven – Stage Two

Chapter seven explains and justifies the marketing metrics used in Stage two, presents the results and discusses the stage two outcomes. The key outcomes illustrated and discussed are:

- Frequency counts of positive and negative attribute associations
- The Net positive variable, and deviations from the observed and expected frequencies that allow brand image charts

The limitations of this stage and future research is also discussed in Chapter seven.

1.4.8 Chapter Eight – Stage Three

Chapter eight justifies why dual-processing of information, that is Type 1 and Type 2 thinking allows a way to measure whether survey responses effect evaluations of climate engineering, presents the results and discusses stage three outcomes. The key outcomes illustrated and discussed are:

- The differences between the net positive evaluations when the sample is split into quartiles and halves on time taken to complete the on-line survey and the differences between the New Zealand and Australian samples on the same sample splits.

The limitations of this stage and future research is also discussed in Chapter eight.

1.4.9 Chapter Nine – Stage Four

Chapter nine describes the processes used in the focus groups, the type of analysis and the findings. The key outcomes illustrated and discussed are:

- Thematic content analysis
- Social representations of climate engineering

The limitations of this stage and future research is also discussed in Chapter eight.

1.4.10 Chapter Ten – Conclusion

Chapter ten provides a conclusion that answers the research questions and reiterates the key theoretical and methodological contributions of this research.

Chapter Two: Climate Engineering Research

The objectives of this chapter are to examine the research that explores public perceptions of climate engineering and to identify the current practices used to measure those perceptions. How framing affects perceptions of climate engineering is also examined.

2.1 Introduction

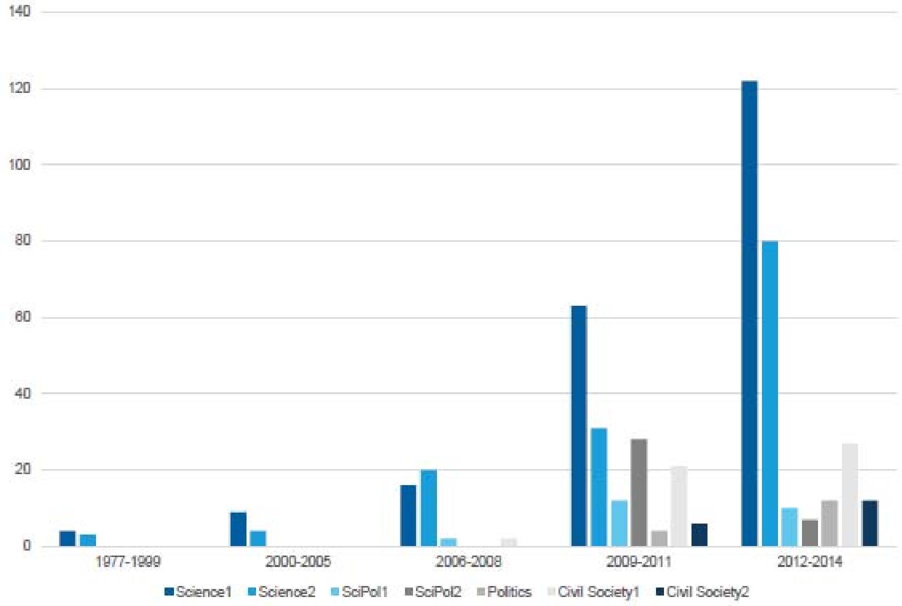
This chapter provides evidence of the increasing amount of climate engineering information appearing in the public domain, highlighting the need for more public involvement with early climate engineering concepts to ensure engagement is upstream. Upstream engagement involves more than informing the public early in the dialogue process. In practice it should take place prior to any research and development and continue through the decision phases. Involving the public at the early stages of new concept development helps ensure discussions are not biased by entrenched attitudes, social representations or frames in the media (Rodgers-Hayden & Pidgeon, 2007). Information about climate engineering is available from various sources: published academic research, scientific institutes, private and non-governmental organisations, government institutes, conferences and summits, civil society groups, think tanks, public forums in social media, science blogs, and broadcast mediums including radio talkback sessions. These numerous existing sources signal that bias from framing effects is likely already present in some climate engineering debates.

The few publications that investigate public perceptions of climate engineering are also examined in this chapter, along with recent studies that have considered how the framing of climate engineering influences public perspectives of the science.

2.2 Climate Engineering in the Public Domain

Published research on public perspectives of climate engineering technologies, including some that remain hypothetical, barely existed before 2005. Most climate engineering studies before this date used the term geoengineering and were science based or had science policy content. However, from 2005 onwards publications investigating public reaction to climate engineering, the risks, the ethics, and the need for international governance of climate engineering research have steadily increased. Barben and Matzner (2014) collected 501 documents from science, science policy, NGOs, civil society, and think tank records in the global north and categorized the content as shown in Figure 1.

Figure 1: Climate engineering publications by domain



Source: Nils Matzner, Conference Paper, December, 2015 (retrieved from http:www.researchgate.net/publication/281107281, 23 December, 2015)

The specific content of each category in Figure 1 is listed as follows:

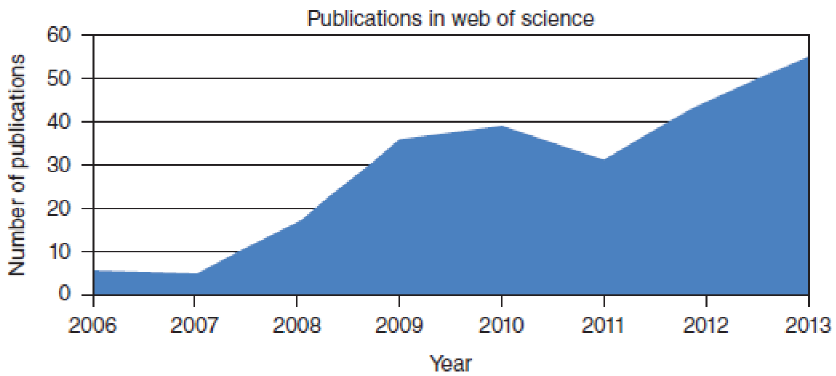
Science 1:	scientific research studies
Science 2:	non-research editorials, comments, review papers written by scientists
Science Policy 1:	science-policy papers
Science Policy 2:	science-policy reports
Politics:	policy papers from institutions and national parliaments
Civil Society 1:	NGOs
Civil Society 2:	think tanks

Barben and Matzner's (2014) analysis of climate engineering discourses reveals the vast majority of documents on climate engineering in the global north are scientific research studies. Although research in policy and from non-government organisations increased during 2008 – 2014, studies from civil society groups are minimal by comparison. To date, only one paper has reported public perspectives of climate engineering, in the global south. Stage two of this research quantified public perceptions of six climate engineering techniques in Australia and New Zealand and this work is published in *Nature Climate Change* (see Appendix J: Wright, Teagle & Feetham, 2014a).

Climate engineering discourses are also appearing more frequently in mainstream media. Between 2005 and 2013, Anshélm and Hansson (2014) collected 1500 newspaper articles in English, German, Swedish, Danish, and Norwegian to analyse climate engineering discourses, framings, and storylines in public debate or science communities. Over 75% of the articles used in their study were in English and published in either the USA or UK.

A study by Linnér and Wibeck, 2015 also demonstrated how publications on climate engineering have increased rapidly between 2006 and 2013. Their research retrieved 230 articles from the SCOPUS and Thomson Reuters Web of Science (WoS) databases using the key search words ‘climate engineering’ and ‘geoengineering’. They found the climate engineering literature in these two databases expanded from six publications in 2006 to 234 in 2013 as shown in Figure 2.

Figure 2: Climate engineering publications in WoS



Source: Linnér & Wibeck, 2015 p. 257.

These three studies evidence the increasing quantity and types of media offering information on climate engineering, signalling the urgent need to provide methods that will involve upstream and deliberative public engagement with the topic before attitudes are entrenched or social representations become established (Corner and Pidgeon, 2015).

The following sections (2.3 and 2.4) review the climate engineering publications that have included public perceptions of climate engineering split into time periods before and after data collection for this thesis.

2.3 Public Perceptions of Climate Engineering Research before January 2013

This section reviews the very few studies that investigated public perceptions of climate engineering published at the time of Stage two data collection (December, 2012).

Some preliminary work towards a public dialogue on climate engineering was undertaken by the Ipsos MORI project in the United Kingdom (UK), "Experiment Earth: Report on a Public Dialogue on Geoengineering" (2011). This work undertook several different stages of research: three sets of general public groups who met twice for discussions (total, $n = 90$); a sample of those sets who met for a third time with scientists ($n = 31$); two long discussion groups; a quantitative on-line survey of stakeholders in community groups ($n = 65$); and three open access events at science centres. The workshops and research processes were evaluated by independent researchers through surveys administered at the end of the public group meetings ($n = 80$).

Orr, Twigger-Ross, Kashefi, Rathouse and Haigh (2011) reported the findings of the Experiment Earth workshops. They found participants had low awareness of climate engineering before the deliberations. Overall, participants preferred carbon removal techniques and tended to reject solar radiation management techniques on the basis that they did not address the root causes of increasing atmospheric CO_2. When solar radiation management was discussed, the techniques of Cloud Brightening and Stratospheric Aerosols were more positively received than Mirrors in Space which was opposed by a majority of the participants.

After the Experiment Earth Report was published Corner et al. (2011) re-examined the findings and reflected on how the design and methodologies used in the Experiment Earth research may have impacted on the findings. Feedback from participants on the information they were presented in the workshops revealed that some people found the material 'science-heavy'. Corner et al. recommended that in future research a less technical approach is used, and that the participants should not be expected to become scientists, as this signals an expectation that they think like scientists rather than using their own social intelligence. Corner et al. also deem the focus on the physical risks and benefits is likely to have influenced discussions. Corner et al. support the use of artists' impressions of the various technologies as many of them did not exist yet. However, they caution that images should only contain information directly relative to the proposed technology. Additionally, Corner et al. voiced a concern that placing emphasis on the view that 'mitigation strategies are insufficient to deal with climate change' may have influenced the results of the deliberations. They also noted the effect of the naturalness framing. The original report highlighted that many participants had concerns about the perceived naturalness of the different climate engineering technologies and Corner et al. pointed out the effect this may have had on evaluations of the technology. Additionally Corner et al. felt the way participants questioned the naturalness of the technologies may reflect a deeper question about the sustainability of climate engineering. This reflective feedback on the original Experiment Report was useful information that was taken into consideration when designing the materials used in Stage one and two of this research.

However, quantitative research in this area remains at a very early stage. To date few studies have examined public perceptions of climate engineering. Mercer, Keith and Sharp (2011) surveyed the public of Canada, the UK and the United States of America (US) to assess knowledge of geoengineering and perceptions of SRM techniques. They found that only 8% of their sample (n = 3105) could correctly define the term geoengineering, while 45% were able to define climate engineering accurately. Subsequently, this research used the more understood term climate engineering.

Mercer et al. (2011) characterized supporters of SRM techniques as likely to believe in scientific research, to have an ability to prioritize the benefits of SRM, and to see it as natural. Detractors of SRM, on the other hand, were likely to hold the opinion that humans should not manipulate nature in this way. The same survey found that demographics and views on climate warming were not strong predictors of whether or not respondents held positive or negative opinions on climate engineering. Instead, they found the potential risks, particularly damage to the ozone layer and unknown risks, had the most influence on public perceptions of SRM. This research, however, only tested one SRM technique – spreading sulphate particles in the atmosphere – in isolation from other SRM methods or CDR, and primed questions in the survey are likely to have caused bias in participants' responses.

The United States Government Accountability Office (2011) also surveyed public opinion on climate engineering in the US and found that the majority of the population was not familiar with climate engineering. In a split-ballot survey (n = 506, n = 500) they tested the effects of climate engineering information, by selecting techniques with low and high levels of effectiveness and safety. The information they used conveyed reflective methods such as roof whitening and air capture as relatively safe technologies, while the information on stratospheric aerosols and ocean fertilisation techniques was conveyed as less safe. The results indicated that participants' degree of concern about harm from climate engineering differed, "depending on whether they received information about more or less safe technologies" (p. 87). More than 50% of both survey ballot groups were somewhat concerned to extremely concerned that climate engineering could be harmful. They also found that half the respondents would support government funded research on CDR technologies, but less than half the respondents would support government-funded research on SRM technologies. The findings of this research are challenged because inadequately controlled concept presentations contributed to the bias noted between the subsamples (Wright, Teagle & Feetham, 2014).

2.4 Public Perceptions of Climate Engineering Research after December 2012

The three studies on public perceptions of climate engineering reported before 2013 mostly took place in the UK, US and Canada. Since then some qualitative and quantitative research has spread to other parts of the globe and this research is discussed in this much larger section reflecting the increased number of studies undertaken since 2013. However, despite the increased number of studies, given the global scope of the issue they are still relatively few. Two studies report on workshops in the African continent and Pacific Islands close to New Zealand and Australia. Two studies have used focus groups in the UK and Sweden to demonstrate lay-people's perspectives of climate engineering. Other studies reported in section 2.4.4 have used large-scale surveys. One study uses the opinions of a group of experts to evaluate climate engineering's potential to cause controversial debate and another study merges the views of experts, stakeholders, and lay citizens to appraise several options for addressing climate change, including three geoengineering technologies. The methodologies used in these studies and their findings are critiqued in sections 2.4.1-2.4.7.

2.4.1 Global Workshops

In 2013, The African Academy of Sciences reported African perspectives of solar geoengineering (SRM). This report summarised three workshops held in Senegal, South Africa and Ethiopia, with 100 participants from 21 African countries. Workshop participants consisted of scientists, policy-makers, non-government organisations, media and, as the result of newspaper advertisements, some members of the public. The debate in the workshops was unstructured as its purpose was not to seek consensus or conclusions; rather, the purpose was to introduce African stakeholders to the concept of SRM, and to seek ideas on governance and what conditions would be needed to encourage public engagement in Africa. Suggestions for future engagement with SRM were a pan-African expert group, and increased research and teaching in schools and universities. The proportion of members of the public involved in these workshops was minute and the sample was very small; these suggestions are therefore heavily biased towards the ideas of the invited attendees.

Opinions on climate engineering were also sought from representatives of twelve Pacific Island nations in a workshop of 30 participants, in Fiji, in August 2013. Invited participants were students from the Pacific Centre for Environment and Sustainable Development and representatives of regional, international, and local non-governmental Pacific Island organisations, making the workshop's participants, and consequently the findings, unrepresentative of Pacific Island lay citizens. The main outcome of the workshops was that the invited participants agreed more research, awareness, and debate about climate engineering are needed (Beyerl & Maas, 2014).

2.4.2 Focus Groups-UK

Macnaghten and Szerszynski (2013) analysed public discourse on solar radiation management in the UK and built on the existing research to develop a deliberative focus group methodology. Their main concern was that past research on SRM did not account for the assumptions the public have to make about the world if SRM is deployed. Macnaghten and Szerszynski believe the 'intended' effects of SRM are probabilistic and that 'SRM has a distinctive and constitutive relationship with uncertainty" (p. 466). To combat the 'intended' effects Macnaghten and Szerszynski suggest using techniques that allow focus group participants to imagine the kind of world SRM might create.

Macnaghten and Szerszynski maintain that other challenges for improving engagement with the public include the need to use a method that does not simply repeat dominant framings, to understand the factors that shape public responses, and to interpret correctly public responses and their implications for SRM governance. To overcome these challenges, in their focus groups, Macnaghten and Szerszynski did not use an expert to explain the technology (thereby avoiding the potential for participants to mimic expert framings), ensured their participants had diverse backgrounds, and did not require participants to reach a common consensus. Instead, participants were encouraged to articulate shared definitions of issues.

Macnaghten and Szerszynski recruited seven focus groups in the UK. Each group consisted of 6 – 8 people with shared lifeworld experiences (e.g. mothers of young children, keen gardeners or manual workers), although overall the groups reflected diverse backgrounds and demographics. Participants were shown concept boards with both pictures and text.

Discussion began with weather and climate and progressed to climate change, policy responses, topics of current debates on these issues, and then to SRM and CDR methods, framed as a response to anthropogenic climate change that would buy more time for greenhouse gas mitigation projects to become effective. Macnaghten and Szerszynski found their focus group participants had general concerns about the uncertainties of the techniques, unintended effects, and 'unnaturalness' of SRM techniques, and also perceived climate engineering as a quick-fix to climate change.

Macnaghten and Szerszynski also found that as groups took more time to deliberate collectively about what conditions they would find acceptable for the adoption of SRM, the respondents became more wary and sceptical of SRM. However, unlike Mercer et al. (2011), they did not find clear or opposing divisions of supporters and detractors of climate engineering. Macnaghten and Szerszynski believe the opportunity to explore issues and the time taken to think through the implications more fully in their focus groups achieved a more deliberative method of engagement than previous research on climate engineering. However, there is no guarantee the responses given by participants in this research were deliberative, rather than being overridden by intuitive, or emotive thinking.

2.4.3 Focus Groups – Sweden

Wibeck, Hansson and Anshelm (2015) also used focus groups to determine how lay-people in Sweden make sense of climate engineering. The underlying theory of Wibeck et al.'s approach is the idea that people have systems of common social values and ideas that help them make sense of unfamiliar information. Further, when people try to make sense of unfamiliar information the two communication processes of 'anchoring' and 'objectification' are keys to forming social representations. Wibeck et al. explain when objectifying, people use metaphors or prototypical examples to make abstract concepts more tangible. Anchoring takes place when people categorise new phenomena. Wibeck et al. believe social representation theory is helpful for analysing how abstract, science-based knowledge becomes common knowledge over time.

Wibeck et al. (2015) conducted eight internally homogenous focus groups with 45 lay-people in Sweden in 2013. Similar to Macnaghten and Szerszynski (2013) Wibeck et al. also led their focus group discussions through the topics of environmental issues and climate change before introducing the idea of climate engineering. The participants in the Swedish focus groups perceived climate change as a serious threat to people. They emphasised the need for individuals to change their lifestyles and use low-carbon technologies but had little trust that politicians would address the challenges of climate change. The groups' understanding of climate engineering was low; even though 13% said they had heard about climate engineering, none of these participants could describe the technologies.

Wibeck et al. (2015) found recurring themes: deploying climate engineering technologies would result in unpredictable negative side-effects; climate engineering would not be sustainable in the long-term, it is a short-term fix; and that climate engineering is 'unnatural' or 'artificial'. When examining the group's social representations Wibeck et al.'s analysis showed that if arguments in support of geoengineering research were raised, they were explored and then discarded due to the risk of unknown side effects and the inability to predict impacts. When the moral hazard argument was raised participants thought 'other' people more likely to reduce their mitigation efforts, rather than themselves. Repeatedly, participants asserted individual and collective mitigation methods, particularly renewable energy technologies, should be given preference over adaptation or climate engineering as a solution for climate change. Quantitative research by Corner and Pidgeon (2014), however, linked responses to the moral hazard argument to particular beliefs or behaviours, such as climate change sceptics and self-orientated people.

2.4.4 Quantitative Large-scale Surveys

Corner and Pidgeon (2014) examined public perceptions of the 'moral hazard' argument in the UK to see whether knowledge of climate engineering would impact on people's mitigation behaviours. They believe that rather than an economic risk, the moral problem in the context of climate engineering is centred on social, ethical and political concerns. The moral hazard argument speculates that individuals who believe climate engineering will 'fix' the carbon emissions problem will curb their voluntary efforts to reduce carbon emissions. Some people may perceive that there is a risk other members of society will reduce their mitigation efforts and this has potential to alter social thinking on the urgency of climate policies. At a political level, the belief that climate engineering can fix the impacts of climate change may result in resources being diverted from mitigation and adaption (Corner & Pidgeon, 2014).

Corner and Pidgeon (2014) surveyed 610 people online in the UK. They found 28% of the participants had heard about the term 'geoengineering'. However, only 2% reported they knew a fair amount or great deal about geoengineering. The overall findings from this study suggested members of the public agree that introducing geoengineering into policy would have an adverse impact on existing mitigation efforts. However, the people most likely to agree with the moral hazard argument are sceptics of climate change and people who were more self-orientated. This suggests the moral hazard argument may have a differential impact on different types of people (Corner & Pidgeon, 2014).

A study in Germany explored public perceptions of a single climate engineering technique, stratospheric aerosols. Merk, Pönitzsch and Rehdanz (2015) conducted an on-line survey in 2012 to investigate whether the German public would be likely to accept stratospheric aerosol research in either the laboratory or the field, and their overall attitudes towards the technique. Their sample (n = 1,040) broadly represented the demographics of the German population with a slight over-representation on the high-level of education demographic. In their survey, respondents were shown a video containing information on climate change. Mitigation, adaptation, and sulphate aerosols were presented as three options to address climate change. Questions using a Likert scale asked respondents whether they would accept laboratory research, field testing, or deployment of sulphate aerosols in various circumstances, and their attitudes to the sulphate aerosols technique.

Merk et al. (2015) found overall that German respondents were highly sceptical of the use of sulphate aerosols. Respondents had higher acceptance of laboratory testing over field research. Just over half the sample agreed on deployment of sulphate aerosols in an emergency situation, but 35% of the sample believed sulphate aerosols should never be used in any circumstances. Eighty-one percent of respondents perceived the overall risk of sulphate aerosols as very large, or somewhat large. Regression showed most of the explanatory variables had a significant effect on acceptance. Risk aversion negatively affected acceptance of field research and deployment as did the perceived seriousness of climate change. While trust in government was a predictor of acceptance, it was not as strong a predictor as trust in scientists or firms. The socio-demographics of education and age exhibited explanatory power, with higher education strongly affecting acceptance of immediate deployment of sulphate aerosols. Age was positively related to the acceptance of immediate deployment but negatively related to the acceptance of emergency deployment and pointed to intergenerational differences in perceptions of sulphate aerosols (Merk et al., 2015).

Research by Kahan, Jenkins-Smith, Tarantola, Silva and Braman (2015) used large online surveys in the US (n = 1,500) and the UK (n = 1,500) to investigate the extent to which the scientific exploration of geoengineering as a policy response might impact on public debate on climate change. Kahan et al. supported the theory that cultural meanings influence public perceptions of risk and pointed out how important it is to consider cultural effects in science communication. They explained that conflict in debate arises from differing cultural values. They noted scientific debates are often polarised, with people of individualistic or hierarchical values dismissive of environmental and technological risks. These values are in opposition to the values of egalitarian and communitarian people, who perceive commerce and industry as sources of inequality and who support regulatory action against commerce. These contrasting views are thought to be the cause of the polarisation in science communication, rather than the scientific issue per se being the source of conflict. Kahan et al. asserted that these cultural differences and others have evoked risk controversies in many global issues, including climate change.

Kahan et al.'s (2015) experiments manipulated two channels of communication and included a control group. One channel focused on presenting information based on empirical evidence; the second focused on presenting information with cultural meanings. Their results supported the concept that cultural values affect people's perceptions of risk and they concluded that many of the people who dismiss the seriousness of climate change do so because the information presented to them threatens their cultural outlooks. This has implications for science communication and engagement with the public. Kahan et al. believe open-minded public engagement with geoengineering and other scientific information requires an environment where no group of citizens is forced to accept information that is adverse to their cultural beliefs (Kahan et al.).

2.4.5 Expert Opinion Groups

After reviewing published literature on public perceptions of climate engineering, including stage one and two of this research, Scheer and Renn (2014) concluded it was too difficult to present a clear picture of how public opinion will develop over time. Instead, Scheer and Renn believe various discipline experts engaged in the field of climate engineering and climate change, inclusive of social sciences, philosophy, communication studies, and natural sciences, would provide consistent judgements on the likelihood of social and cultural conflicts associated with climate engineering. In Germany, they recruited 12 experts and used a Group Delphi technique to assess and calibrate the experts' judgements on climate engineering. Scheer and Renn explained most variants of the Delphi technique use numerical results of the experts' discussion rounds which are communicated before each new round, ensuring the feedback and views of other experts are considered in the next round. The rounds continue until the experts stop changing their views when challenged by the opinions of the other experts. The Group Delphi technique varies a little in that it randomly assigns participants to small groups who are asked to vote by agreeing or disagreeing with statements that are identical across groups. A plenary session consisting of representatives of the extremes of both ends of the agreement scales defends their position publically and reconsiders their positions until a new assessment is reached.

Scheer and Renn (2015) report their expert participants were united in their opinion that research on climate engineering has the potential to cause conflict, particularly if it involves stratospheric aerosols. Also likely to cause conflict, but to lesser degrees, are ocean fertilisation and cloud brightening. The experts in this research thought the likelihood of afforestation causing conflict was quite low. They also thought spatial proximity likely to affect conflict with all the technologies: the closer to the climate engineering deployment site the more likelihood of conflict. However, the greatest area for conflict, in the experts' view, would originate with environmental non-government organisations, particularly if any of the climate engineering technologies involved converting land in food production to energy production. This group of experts concluded the public should be more informed about climate engineering sooner, rather than later, and the composition of information should be split so that 30% of the information explains the processes and technologies and 70% discusses the potential benefits and risks of climate engineering in different public participant forums. A final conclusion of Scheer and Renn was that, due to the scarcity of data on climate engineering, the future of public debate on climate engineering and public responses cannot be predicted – even by experts.

2.4.6 Structured Interviews

Amelung and Funke (2015) used a qualitative think-aloud interview technique on 91 participants in their study in Germany to assess under what circumstances laypeople might embrace the idea that climate engineering technologies could represent a back-up plan if mitigation efforts fail to lower CO_2 levels. The majority of the participants for the face-to-face interviews were recruited from a university environment, although 20 of the 91 university participants were also active members of environmental groups or organisations. Over-representation in demographic groups caused a large bias in the sample composition: 93% were under 35 years of age; over 75% were female; and 98% were studying towards or had already completed a university degree. Amelung and Funke used a scenario that asked participants whether a federal climate change budget should be allocated to mitigation, stratospheric aerosols, cloud whitening, or ocean fertilisation techniques. Their findings suggested people are likely to accept a specific climate engineering technique only in circumstances where the perceived risk of the technique does not exceed the risks of mitigation. However, the large sample bias and the forced decision scenario are likely to have confounded these results.

2.4.7 Deliberative Workshops

Corner, Parkhill, Pidgeon and Vaughan (2013) explored public perceptions of geoengineering, particularly how humans relate to it in the context of 'nature'. They carried out four one-day deliberative workshops in the UK early in 2012. Discussions in the workshops considered geoengineering, mitigation and adaptation as three possible responses to climate change. Each workshop had 11 participants of varied demographic characteristics recruited through a professional agency. Questions generated from small group discussions were placed on post-it notes on a 'question wall' and later reflected on by all participants. Audio transcripts were analysed to identify common and important issues. One of the main themes emerging from this study was the moral consequences of using the frame 'messing with nature'. Overall, there was agreement that implemented geoengineering would interfere with the Earth's natural systems but there was no consensus on whether this was a negative or positive issue. Corner et al. concluded the framing of geoengineering will play a critical role in how the public perceive it.

2.4.8 Deliberative Mapping – Experts, Stakeholders and Citizens

Another methodological approach for investigating public perspectives of climate engineering was proposed by Bellamy, Chilvers & Vaughan (2016). In the UK, in 2012, they implemented an analytic-deliberative participatory appraisal process (deliberative mapping technique) to open up the climate engineering debate and provide upstream engagement. This technique merges the analysis of discussions by experts, citizens, and stakeholders who come together in a workshop during the process. Bellamy et al. believe the inclusion of other options for responding to climate change as well as CDR and SRM proposals opens up the climate engineering debate. The advantages of this method are that citizens frame the problem themselves and that directly comparable differences and similarities in responses are visually mapped out rather than aggregated. Contrary to previous studies that used mixed gender groups, Bellamy et al. split their citizen panels by gender due to observed differences in how males and females perceive risk. The discussions took place in a full-day workshop followed by a half-day workshop several weeks later with a purpose-built website and printed booklets provided for information revision in between workshops.

Bellamy et al. (2016) concluded the citizen groups were capable of making considered judgements comparable to those made by the experts in the workshops. Participants in the workshops formed seven core options for appraisal: voluntary low carbon living; offshore wind energy; new market mechanism (carbon trading); biochar, air capture and storage; stratospheric aerosols; and business as usual. Bellamy et al. found men discussed global environmental issues in the context of over-population, while women discussed environmental issues in the context of human resilience to change. Both genders were in agreement that renewable energy and individual actions are possible solutions for dealing with climate change. In the early part of discussions, geoengineering was mentioned implicitly through afforestation and natural processes for sinking carbon dioxide. Common themes regarding the geoengineering techniques were levels of naturalness, scale (biochar was considered too small and air capture storage too large), conflicts on land use, impacts on the environment, reversibility, and the moral hazard argument.

From the workshop discussions Bellamy et al. (2016) also developed criteria for appraising the seven core options. Each of the seven core options was evaluated on various criteria pre-determined by the citizens and specialists attending the workshops. Ranking of the options had various levels of support, or opposition, under different perspectives and criteria, although voluntary low carbon living and offshore wind energy performed better than the other options. With the geoengineering techniques, air capture and storage and stratospheric aerosols performed markedly worse than biochar. A final conclusion of Bellamy et al.'s research is after gaining more knowledge about climate engineering some citizens became more cautiously supportive and less sceptical.

The research discussed in sections 2.3 and 2.4 highlights the scarcity of research on public perceptions of climate engineering, the lack of methodological replications or validations, and the lack of longitudinal research. The various methodologies reported in the research consist of workshops of approximately 30 participants, focus groups, expert opinion groups, structured citizen interviews, one combined expert, stakeholder, citizen workshop and some large-scale surveys. The reported research is not widely global and excludes several major countries or continents (e.g. Russia, South America and South-East Asia).

While some authors of the research reviewed claim their methodologies are deliberative processes, the extent of deliberation is not measured; rather it is assumed that public participation in climate engineering discussions is deliberation. However, regardless of the methodology used, the research has some common findings about current public perceptions of climate engineering: low levels of awareness of climate engineering, concerns about the risks associated with the technologies, and overall negativity towards climate engineering, in particular to SRM technologies.

The chapter continues with an examination of the research on framing effects in climate engineering due to the potential for certain frames to close down rather than open up debate.

2.5 Framing Effects in Climate Engineering Discourses

This section investigates one of the main concerns about public engagement approaches in science communication, the effects of framing. Framing is the process people use to conceptualize an issue (Chong & Druckman, 2007). Reese (2007) believes people use frames to structure their social world by connecting the issue of interest to previously known information. A framing effect takes place "when (often small) changes in the presentation of an issue or an event produce (sometimes large) changes of opinion" (p. 104). If framing effects occur during public engagement the legitimacy of public opinions of climate engineering is questionable.

The effects of framing in science communication are widely researched, particularly in the context of climate change, global warming and, more recently, in climate engineering (Bellamy, Chilvers & Vaughan & Lenton, 2012; Bellamy, Chilvers & Vaughan, 2014; Bellamy & Lezaun, 2015; Huttenen & Hildén, 2014; Kreuter, 2015; Macnaghten & Szerszynski 2013). Bellamy et al. (2012) believe framing climate engineering in contextual isolation from other options to address climate change narrows and restricts climate engineering discussions to a set of technologies, rather than allowing deliberation about technical advantages and disadvantages, and social and ethical concerns. In a review of 25 published articles from the Web of Knowledge database and Google's search engine, Bellamy, Chilvers, Vaughan and Lenton (2012) selected articles that formally appraised geoengineering proposals and found the most mentioned frames were ‘climate emergency’ and ‘insufficient mitigation’ (see Table 1).

Table 1: Frequency of context frames in geoengineering appraisals

Context Frame	**Frequency of Frames**
Climate emergency	15
Insufficient mitigation	15
Climate change impacts	13
Climate policy	3
Societal responses to climate change	2
Alternative to mitigation	1

Source: Bellamy et al., 2012, p. 605

Bellamy et al. consider the ‘climate emergency’ and the ‘insufficient mitigation’ frame implies climate engineering is a necessity (to pre-empt the future) and is likely to influence the perceived acceptability of the proposals. They also believe these two frames marginalise alternative solutions. Corner, Parkhill, and Pidgeon (2011) agree that these two frames infer climate engineering is a necessity and likely to lead to inflated levels of the acceptability of conducting research on the technologies. Markusson, Ginn, Ghaleigh and Scott (2014) challenged the use of the ‘climate emergency’ frame on the grounds that it would not meet the legal justification of a ‘necessity’. However, they caution against ignoring the emergency frame, rather they believe greater deliberation and more justification for research from scientists is needed to help defuse the rhetoric of emergency framing.

Using Bellamy et al.’s (2012) research findings that climate emergency and insufficient mitigation were prevalent framings in climate engineering publications, Amelung and Funke (2015) tested the implication that climate engineering was a ‘Plan B’ or back-up should mitigation and adaption strategies fail to meet the set emissions reductions. In their interviews with 91 lay-citizens in Germany they determined that lay-citizens who perceive climate engineering as a back-up strategy for mitigation have a more favourable attitude, or at least a conditional tolerance, to the concept of climate engineering, leading Amelung and Funke to conclude ‘Plan B’ framing has the potential to “significantly influence opinion forming processes in scientific, public and political debate” (Amelung & Funke, 2015, p. 556).

Buck’s (2013) work used radio broadcast and print media to investigate the frames and voices around geoengineering. Buck analysed 93 articles from major world newspapers between 1990 and 2010 and found five key frames: *catastrophic*, often linked to save the planet;

cautionary, doubt of geoengineering; *spatiotemporal struggle*, the amount of land use and time needed to have sufficient effect; *managerial*, geoengineering as a solution; and *bildungsroman*, metaphorically the planet is a patient that needs a cure.

Scholte, Vasileiadou and Petersen (2013) examined how newspaper frames of climate engineering are changing. They searched the newspaper data-base LexisNexis, and found 181 articles on climate engineering between the years 2002 and 2011. However, all but three of the articles were written between 2006 and 2011, demonstrating the recent focus on climate engineering in the media. Scholte et al. used principal components analysis and reduced the initial 21 coded frames to the following nine frames in order of the most to least reported: *ambivalence,* weighing risks and benefits; *avoiding catastrophe,* the planet needs saving; *pragmatism,* failure of current approaches to address climate change; *norms and values,* should not interfere with nature; *benefits for society,* solve the climate change problem; *controversy,* conflict and debate; *techno-fix; governance*, question of how; and *out of proportion,* exaggerated reaction. By comparing the climate engineering frames reported by Buck (2013) to their frames, Scholte et al. concluded that the later media coverage was more negative than the frames Buck reported, and the increased diversity of frames suggests the climate engineering debate is opening up. They also noted the predominance of the *ambivalence* frame (71% of the articles) might provide reflexive debate, as both positive (benefits) and negative (risks) are presented simultaneously.

Research by Corner and Pidgeon (2015) tested the framing of geoengineering by analogy to natural processes in an online experiment with public in the UK. Previous research highlighted two predominant frames that made comparisons to natural processes during climate engineering discussions: capturing CO_2 from the air was described as 'artificial trees' and the release of sulphur particles into the stratosphere was reported to participants as being 'no different to a volcano' (Corner et al., 2013). Corner and Pidgeon's experiment used a commercial on-line panel to recruit 412 survey participants. The information presented to participants referred to climate engineering as one of three options for responding to climate change. The sample was split into two groups: one group was presented with material on climate engineering that referred to 'artificial trees' to capture CO_2 and that spreading sulphur particles in the stratosphere would be 'imitating the effect of a volcano', while the control group was given standard information using the language of scientists with no referral to 'natural' analogies.

Corner and Pidgeon's central finding was that "support for geoengineering was slightly – but significantly – higher when a natural analogy was included in a description of geoengineering technologies" (p. 434). Further, "the extent to which participants perceived geoengineering as natural was the strongest positive predictor of support for geoengineering" (p. 434). The strongest negative predictors of support for geoengineering were the variables , 'the Earth's climate is too complex to fix' and 'it is wrong to manipulate nature'. Corner and Pidgeon found no relationship between support for geoengineering and the demographics of gender, socio-economic status or self-reported knowledge of geoengineering. However, a negative relationship with age and support for geoengineering was present. These findings led Corner and Pidgeon to conclude "that framing geoengineering by analogy to natural processes is likely to produce more positive attitudes among the general public" (p. 434). However, to avoid undue positivity in research results and public communications, Corner and Pidgeon advocate caution if a naturalness framing is used.

Huttunen and Hildén (2014) also investigated the policy implications of geoengineering using three frames common to academic literature: 'risk-benefit', 'governance' and 'natural balance'. They used the search terms climate engineering, geoengineering, aerosol cooling and solar radiation management and extracted 473 peer reviewed articles from the Web of Science database to analyse differences on views about the nature of these technologies. They found different framings were associated with different recommendations about the future of geoengineering.

2.6 Chapter Conclusion

The research reviewed in this chapter provides evidence that the number of climate engineering research publications is increasing along with increasing mainstream media coverage. Despite climate engineering being an issue of global concern, the number of publications on public perceptions of climate engineering remains relatively few, and research has only taken place in a small number of countries. The limited number of replications, and limited number of countries that have carried out any research on public perceptions of climate engineering, signifies knowledge of public reactions to climate engineering is at a very early stage of discovery: research is exploratory rather than confirmative. However, across these qualitative and quantitative methodologies there are some common findings. Low levels of public awareness of climate engineering, concerns about the risks associated with the technologies, and overall negativity towards climate engineering, in particular towards SRM technologies, are reported.

The various approaches used to measure public perceptions of the proposed climate engineering technologies have ranged from workshops, inclusive of lay-citizens and experts, to focus groups, large-scale surveys, structured interviews, and deliberative mapping. Each of these approaches has strengths and weaknesses. Qualitative research usually has small numbers of participants rendering it unlikely to represent whole populations. Unless quantitative surveys are carefully designed and controlled for sampling error and common method bias they are also unlikely to obtain representative results. However, the greatest concern with the methodological approaches in science communication is that some forms of engagement are considered deliberative yet there is no reported evidence that the outcomes of the discussions are the result of deliberative thinking.

Especially important in the reported studies on public perceptions of climate engineering are the unanswered questions regarding the extent of deliberation and the quality of public engagement. The reviewed studies lack methodologies that measure the key attributes associated with the concept of climate engineering and the attributes associated with individual climate engineering techniques. None of the reported studies have attempted to investigate the cognitive processes that underlie deliberation. The research methodologies used in this thesis fill this gap of knowledge by using marketing methodologies to systematically quantify public perceptions of climate engineering, and comparing the evaluations of six climate engineering techniques. The research is also the first work to examine whether deliberation has any effect on the evaluations of climate engineering, an important area of research that can help science communicators better understand likely public reactions and the cognitive processes used in deliberative engagement.

The three studies that attempted to measure public perceptions of climate engineering before the fieldwork and data collection for this thesis took place provided results that helped develop some of the stimuli materials used in stage one and two of this research. One of these studies, the Experiment Earth deliberative workshops (Corner et al., 2011), was used for content analysis and development of the descriptors used in the stage one face-to-face, semi-structured interviews. Also, Corner et al.'s work found climate engineering processes were perceived more positively when they were thought to be natural. As a result, natural analogies were avoided in the materials presented in stage one and two of this research.

The few studies that investigated whether the way climate engineering is framed has an effect on the public's perceptions of climate engineering highlighted not only the need to avoid 'natural' framing analogies, but also the framings of 'climate emergency', 'insufficient mitigation', and 'Plan B' frames. These three frames infer climate engineering is a necessity that may lead to magnified levels of acceptability in any findings. However, most of these framing studies were published after the field work of this thesis was completed; therefore, the findings were unavailable for consideration in the design phase of Stages 1, 2, and 3 of this research. These studies show that distinct faming leads to distinct and differential results; the neutral framing adopted in this thesis is therefore a fortuitous choice. Another limitation of framing studies is that they do not include mitigation and adaptation as alternative solutions to climate change. Instead, a majority of studies have considered CDR and SRM, or just SRM technologies. To help meet this gap, the fourth stage of this research encouraged focus group participants to discuss climate engineering alongside mitigation and adaptation as solutions for climate change.

Chapter three proceeds to review the literature that explains the theoretical link between people's associations with a concept's attributes and how this theory is applied in marketing research to measure consumers' evaluations of concepts. These theoretical applications in marketing provide a way to identify the memory structures that are intrinsically evoked by climate engineering proposals and to do so on a large-scale as well as in smaller qualitative studies.

Chapter Three: Associative Networks of Human Memory

The main objectives of this chapter are to provide an understanding of the human memory processes used in decision making, and to demonstrate how the Associative Network Theory of Memory (ANTM) provides a way to identify memory structures that are naturally evoked by climate engineering proposals. Another objective is to establish an appropriate attribute elicitation method to identify a salient attribute set for use in concept evaluations and concept imaging.

3.1 Introduction

Since the context of this research is climate engineering, a relatively new science, there could be an expectation that the theoretical foundations of decision making used in this research would be based on science communication theories and models. However, as further discussed in the following Chapter (4), the field of science communication lacks a consensus on the best approach to use when engaging the public in issues and policy decisions regarding new science and technologies. Social scientists warn that "existing participatory models have not sufficiently considered constructivist perspectives on knowledge, analysis and deliberation" (Chilvers, 2008, p. 155). Other research on public engagement calls for more inter-disciplinary, mixed-method approaches that combine surveys and participatory methods (Corner, Pidgeon & Parkhill, 2012).

This chapter, therefore, reviews the literature that examines how consumers evaluate new concepts or products as part of an interdisciplinary approach to informing science communication. In purchase situations consumers are commonly faced with choice decisions. Over many years, marketing practitioners and academics have studied how these choices and decisions are made; as a result they are highly experienced in methodologies for measuring consumer behaviour (reactions) and cognitive reasoning used in the decision-making process.

A large body of research in marketing has established that the Associative Network Theory of Memory (ANTM) plays a crucial role in understanding consumer behaviour as it explains how human memory works and the cognitive processes such as encoding, storage, and information retrieval, undertaken in choices and decisions (Keller, 1993; Krishnan, 1996; Meyers-Levy, 1989; Romanuik & Sharp, 2004; Romaniuk, 2013; Stocchi, Wright & Driesener, 2016; Wright, Teagle & Feetham, 2014). The properties of memory structures and how memory systems are used, along with the cognitive limitations of memory systems, are also investigated in this chapter as they impact on an individual's ability to process information. Academic marketing research that has applied and developed ANTM is reviewed, together with brand attribute elicitation and brand imaging methodologies as they are the basis of the methodologies used in Stages one and two of this thesis.

3.2 Consumer Choices and Judgements in Decision Making

As early as the 1960s and '70s marketing academics were investigating consumers' decision making processes in order to describe actual choice behaviour (Lynch & Srull, 1982). However, research from this period focused on the economic theory of rational choice, which assumes each option in a choice set has a utility, and that people make choices based on maximising utility (Bettman, Luce & Payne, 1998). This approach did not account for a consumer's mental representation of the information used in decisions and the fact that the human memory has a limited ability (bounded rationality) to process more than a few pieces of information simultaneously. Another criticism of the research in this era is that it was focused on the conscious features of information processing rather than on the more dominant unconscious processes; although, some researchers of the time were beginning to point out that conscious thinking is more of an exception than a rule (Lachman, Lachman & Butterfield, 1979; Mandler, 1975). The awareness that unconscious cognitive activity influences information processing and subsequent decisions led to work on human memory systems that continues to develop.

3.2.1 Stimulus and memory-based judgements

Lynch and Srull (1982), discussing the importance of memory-based judgements compared with stimulus-based judgements, maintain that when all the relevant information is present a stimulus-based judgement may take place. The external stimulus has activated the cognitive process. Yet often not all relevant information is present; rather judgements might take place utilising earlier experience with a product or service, or by remembering similar choices made by family and friends. In this scenario, information is reclaimed from memory – hence the process is internal and memory-based. Judgement processes are complex as they may be purely memory-based, purely stimulus-based, or may be mixed judgements formed by considering information stored in memory and information that is physically present (Lynch & Srull, 1982). The reliance on memory highlights the need to understand memory retrieval processes, long- and short-term memory capacity, and the cognitive limitations of human memory, given these functions vary among individuals.

3.2.2 Information retrieval from memory

Lynch and Srull (1982) make a distinction between two kinds of information retrieval processes. Information is either ‘available’ or ‘accessible’. Once information is comprehended and encoded it is stored in long-term memory and always available; however, humans are “only capable of retrieving a fraction of the total information available” (p. 20) at any given time. While information in long-term memory is always available, the amount that is accessible at a particular point in time is limited. A further limitation is that the accessibility of information varies according to contextual situations. Whether information is accessible depends both on the amount of competing information and on what external and self-generated cues are present (Romaniuk & Gaillard, 2007). These limitations were considered when designing the stimuli in stages one and two of this research and in the number of concepts participants evaluated.

Lynch and Srull (1982) point out that information retrieval is also inhibited by retroactive interference. Retroactive interference theorises that material that is learned later can interfere with previously learned information in two ways. earning interference happens when stored information deteriorates or the access mechanism fails (Tulving & Psotka, 1971) Lynch and Srull note replications of Tulving and Psotka’s work allowed the generalisation that most occasions of forgetting information are due to retrieval failure. “Information continues to be available but becomes less accessible without the aid of relevant retrieval cues” (Lynch and Srull, p. 20).This has implications for experimental and survey research by highlighting the importance of cues and the limitations of human memory systems during information retrieval.

3.2.3 How memory systems are used

Related to the ability to retrieve and link information are the properties of the types of systems that store memory. Bettman (1979) suggests there are different types of memory storage systems, typically a sensory store, a short-term memory store, and a long term-memory store. Each system has different functions and properties that affect the ability to process information. Bettman outlines the sequence for processing and storing information as very short lived: received information is lost in a fraction of a second unless attention is allocated to the stimulus. If the information is given attention it is transferred to short-term memory, although unless it is kept active it is of limited use. Active information, on the other hand, is easily and almost automatically retrieved. If information is processed further it is transferred to long-term memory where capacity is unlimited and permanent (Bettman, 1979).

Bettman (1979) believes humans have the memory system described in the previous paragraph and control processes that interact within the system. This memory system is used in two basic ways; information stored in long-term memory is retrieved from memory to interpret incoming information, or, “incoming information is processed and stored in memory for later use” (Bettman, p. 38). Processes in the short-term and long-term memory can occur at the same time and are co-dependent rather than independent systems. Humans have several control processes or strategies to manage the information flowing in and out of memory and this happens either actively or habitually.

3.2.4 Properties of short-term (working) memory

Short-term or working memory holds information currently in processing. The properties of short-term memory are described in two main categories, capacity and information transfer times. Short-term memory capacity is limited with research finding that from four to seven chunks of information are stored at any one time (Bettman, 1979; Miller 1956; Simon, 1974). The capacity to store information is also lowered when other processing demands are made. Despite limited capacity and lack of permanency, short-term memory is a key influence on how people carry out cognitive tasks; it is a resource that “retrieves and maintains information during cognitive processing” (Daily, Lovett & Reder, 2001, p. 315; Stocchi, 2011).

3.2.5 Properties of long-term memory

Long-term memory holds factual knowledge. New information is integrated into long-term memory by forming links between the new and existing concepts. Inferences are made by following paths of links and nodes that allows the construction of responses, and tests the consistency of information with what is already known (Bettman, 1979). The network models proposed by researchers are crucial for understanding that consumers have organised systems of concepts (associations) stored in memory: knowing “what concepts are in consumers’ memories and exactly how they are linked is important for understanding consumers’ responses to products” (Bettman 1979, p. 42).

Bettman (1979) describes long-term memory as an infinite semantic storage resource with a capacity for some audio and visual information. Its key function is storing semantic concepts and the associations between them (Anderson & Bower, 1973). Long-term memory stores concepts such as events, objects, and their attributes. World experiences in the form of memory schemata are stored in long-term memory and help organise incoming information, thus schema influence people's perceptions of events and objects. Bettman and other researchers (Anderson & Bower, 1973; Collins & Loftus, 1975; Reder, 1987) agree the structure of semantic information in long-term memory is organised as a network of concept nodes (ideas) with varied numbers of interconnecting links or associations. The associations between the concept nodes vary in strength according to how often the associations are encountered or used. Associations that are not often used diminish in strength, suggesting that the activation of nodes and the networks between them is crucial for efficiency in information retrieval (Reder, 1987; Stocchi, 2011). Later work by Meyers-Levy (1989) pointed out that "consumers are more likely to remember a brand name when it is interconnected with a large number of concepts already held in memory" (p. 197). In marketing, this knowledge led to the implementation of strategies for strengthening consumers' associations with brands to increase the likelihood of retrieval in brand choice decisions (Romaniuk & Sharp, 2016).

3.2.6 Memory activation effects

Retrieving information stored in long-term memory is reliant on two activation factors: the level of activation and the strength of activation (Reder, 1987). When external or internal stimuli activate a concept the activation spreads quickly, cascading through related concepts or nodes (East, Wright & Vanhuele, 2008; Reder, 1987; Wright et al., 2014). The amount of activity depends on the strength of associations, how many other associations share the activation, and how much activation there is. "The more active the information the easier it is to access" (Reder, 1987, p. 228). Activation, therefore, plays a large role in the retrieval of information from memory as it determines the amount of information available (Stocchi, 2011). However, activation is not the only influencing factor in memory retrieval.

A complicating factor in memory retrieval is that the amount of activation is affected by the relative strength of associations, or as phrased by Anderson (1983a), the 'fan' paradigm. Reder (1987) explains that the more information held in memory about a particular concept the longer a person takes to recognise or reject any statement sharing that concept. Reder terms the fan paradigm interference and points out how strength (of associations) and interference have reverse effects on response times, "practice makes retrieval faster and interference (competition) makes it slower" (1987, p. 230). Reder points out the fan theory is logical, except when considered alongside expertise or knowledge. If more knowledge is held about a concept then intuitively retrieval might be assumed faster; however, Reder insists people are slower to verify a fact when additional facts about that person or topic are already held in memory. Reder argues that slower retrieval times for experts is a plausible phenomenon as experts may draw on several, rather than one particular fact to verify an assertion, thereby taking longer to retrieve information.

3.2.7 Cognitive limitations of working memory performance

Working memory has essential resources that allow people to retrieve and maintain information (Daily et al., 2001). However, there are cognitive limitations that affect working memory performance. One of the main performance inhibitors is that working memory capacity differs among individuals, resulting in different performance outcomes. Another inhibitor is the limited number of items that can be simultaneously maintained, causing decreases in performance, especially in complex tasks (Daily et al., 2001). Anderson, Reder and Lebiere (1996) agree with Daily et al. They believe that if a task is complex, source activation is spread sparingly and each relevant node receives less source activation. In these conditions performance is affected by relevant information being less easy to access and less distinctive (Daily et al., 2001). Levels of activation also decrease over time, reducing and impairing working memory performance (Anderson, 1996; Stocchi, 2011).

Sections 3.2.1 to 3.2.7 explain some of the processes consumers use to retrieve information stored in memory, some of the inherent cognitive biases, and some of the limitations of working memory. These studies helped marketing theorists develop knowledge of the memory network systems consumers utilise in their choice and judgement decisions. This knowledge led marketing academics and practitioners to adopt the associative network theory of memory in much of their brand imaging work. The connection between the ANTM and applications in marketing is described in the next section.

3.3 Associative Network Theory of Memory in Marketing

The Associative Network Theory of Memory as described in section 3.2.1 to 3.2.7 is the foundation for many studies in marketing. Bettman (1979) describes the benefit of adopting a network view of memory as “a framework for systematically exploring the contents and interconnections in consumer memory” (1979, p. 42). Keller (1993) links ANTM to a brand’s image with the following explanation. Links in a consumer’s memory with a particular brand name are created, reinforced and stored in a network of memories. This network of associations with the brand constitutes a brand’s image (Romaniuk & Sharp, 2004). Similarly, the link from theory to applications in marketing is explained by Nenycz-Thiel, Sharp, Dawes and Romaniuk:

> “Associations in human memory are a representation of links and cues, where one piece of information, for example a brand, has links to other pieces of information such as a use situation. Therefore, a link between any two nodes (pieces of information), suggests an association in a consumer’s mind” (2010, p. 1143).

By applying ANTM in marketing, brands can be interpreted in the light of the memory structures that are linked to the brand name, or linked to the cluster of core brand associations (logos, colours, fonts and other imagery). These constructs can be evoked by asking for attribute associations, for example “which of the following brands do you think is good value for money?” However, the key point is that associations are likely to be evoked by the brand as a cue, and vice versa. Therefore, evoked associations provide an indication not only of memory structures associated with a concept, but also with the likely mental reaction to any stimulus that evokes that concept (Wright, Teagle & Feetham, 2014). It is the overall network of information (associations) about a brand or concept in human memory that forms a brand image (Nenycz-Thiel et al., 2010). If associations with a brand or concept’s attributes are identified and measured they provide a way to understand likely public reaction to scientific, as well as commercial, concepts (Wright, Teagle & Feetham, 2014).

A large body of work by Romaniuk and colleagues at the Ehrenberg-Bass Institute in Adelaide, South Australia applies ANTM in their branding research (Driesener & Romanuik, 2006; Nenycz-Thiel & Romaniuk, 2009; Nenycz-Thiel et al., 2010; Romanuik, 2003, 2013; Romaniuk & Gaillard, 2007; Romaniuk & Nenycz-Thiel, 2013; Romaniuk & Sharp, 2004, 2016). Two key studies by Romaniuk (2003, 2013) and a recent study by Hogan, Romaniuk and Faulkner (2016) clearly connect ANTM to brand imaging and provide an approach for measuring and benchmarking a brand’s network of associations (mental market share). The findings of these key studies, along with the role of brand attributes in brand evaluations, are discussed in more depth in the following section.

3.4 The Role of Brand Attributes in Brand Evaluations

Memory associations with a brand or concept are not necessarily holistic, instead, as Romaniuk specifies, brands are made up of attributes: "bits of information linked to the brand name in consumer memory and that, when combined with the brand name, make up a brand image" (2003, p. 75). She elaborates that brand attributes are sourced from experience, marketing communications, and word-of-mouth. Another important point about brand attributes is made by Meyers-Levy (1989) and endorsed by Romaniuk (2003): "the linkages between the brand name, its attributes, and other brands in the marketplace mean that associated attributes can be unique to the consumer, unique to the brand, or shared with other brands" (p. 75).

Brand attributes have many broad definitions in marketing. Often they are described as brand characteristics, or features both physical and imagined. More specifically, brand attributes are defined as associations consumers have with a product or service within a particular category. Importantly, consumers maintain a network of attributes linked to a brand name and these attributes constitute a brand's image (Keller, 1993; Henderson, Iacobucci & Calder, 1998). These brand attribute associations are retrieved from memory to categorise and evaluate brands in a consumer's consideration set, thus they are helpful to both marketers and consumers (Low & Lamb Jr., 2000). While attribute associations are useful in two ways – retrieval of associations and evaluating between options – they are dependent on more than one acceptable option being evoked. They are also dependent on the consumer not using a global heuristic (e.g. I'm familiar with this), or the use of another decision rule not related to attribute information, such as 'first to mind' (Romaniuk, 2003).

Other research describes brand attributes as functional versus representational (De Chernatony & McWilliam, 1990), implicit versus explicit (Biel, 1991) and descriptive or evaluative (Barwise & Ehrenberg, 1987; Hoek, Dunnett, Wright & Gendall, 2000). The work of Hoek et al. (2000) used the previous work of Bird and Ehrenberg (1970) to help distinuguish between descriptive and evaluative attributes. Hoek et al reiterated that descriptive attributes represent observable physical characteristics of a brand , while evaluative attributes are derived from the experience of product use and clearly distinguish between a brand's users and non-users. The advantage of descriptive attributes is that if common to a category they are useful for eliciting associations from non-users of brands or concepts. Hoek et al.'s (2000) study replicated the earlier work of Barwise and Ehrenberg

(1987) to determine whether changes in the brand attribute associations held by consumers result in any changes to purchase behaviour. They determined that while it is possible to predict major descriptive attributes, the relationship with usage behaviour is weak. Evaluative attributes, on the other hand, demonstrated a clear relationship with usage. To account for the fact that the public will not have experience with climate engineering techniques (most are still hypothetical concepts), descriptive attributes were provided for the concept evaluations in this research.

Romaniuk's study in 2003 explains the types and relevance of brand attributes when consumers are required to bring to mind, or evaluate, a brand. In this study, Romaniuk examines different types of image attributes used by consumers in purchasing situations. Romaniuk places importance on Holden's (1993) study that provided evidence of different consideration sets being evoked by different types of attribute cues. At that time, little was known about which types of attributes were best at determining a consumer's brand attribute consideration set. This prompted Romaniuk to research whether attributes should be presented as cues focused on developing links to the brand name and products, or focused on the product's benefits or consumption situations. Romaniuk's study found strong evidence that future behaviour was linked to the number of attributes associated with the brand regardless of which type of attribute is used as a stimulus, leading her to reason that the more attributes associated with the brand the more likely the brand would be purchased, confirming the earlier work of Myers-Levy (1989) that suggested memory of a brand is dependent on the number of relative concepts existing in memory. Based on the study's findings Romaniuk concluded "the quantity of links between the brand name and brand attribute may be more important than the quality of any one link" (p. 85).

3.5 Using Brand Attributes to Quantify Brand Evaluations

Another factor that influences a consumer's ability to retrieve brand associations from memory is linked to the number of associations held in the network and the number of links to competitors' brands (Romaniuk, 2013). Romaniuk believes a larger associative network positively influences brand choice. However, often not accounted for are the inhibitive effects of associations linked to competitors' brands. Strong links with competitors' brands means associations with relevant attributes in the same category are shared. Romaniuk terms a brand's share of the total brand associations in a category its 'mental market share'. To calculate a brand's market share the sum of the number of times all attribute associations with the brand are mentioned is divided by the total number of attribute associations for all brands.

Attribute associations also provide a systematic way to quantify consumers' perceptions of a brand. Cues evoke attribute associations with a brand, or concept, from survey respondents and these are measured relative to total associations. For existing brands most associations are positive reflecting the past success that has led to the brand becoming established. For new concepts negative attribute associations may loom larger and require more explicit consideration (Romaniuk, 2013). A net positive association metric for each new concept is achieved by subtracting the sum of any negative attribute associations from summed positive attribute associations. The aggregated net positive metric reveals the overall perception of the concept (Wright, Teagle & Feetham, 2014). Expected attribute counts are computed by using a chi-square calculation of each cell count of the observed (raw) frequencies. For each cell, observed counts are subtracted from the expected values and percentage point skews (deviations) are achieved. These skews are then graphed to show distinctive images for each brand or concept tested (Romaniuk, 2013; Wright, Teagle & Feetham, 2014).

The images provide brand or concept comparisons and allow targeted communications and strategy planning based on a brand's relative attributes. As a hypothetical example, among several brands, one brand might be highly skewed towards a positive attribute '*well known'*, yet be negatively skewed towards '*competent sales people'*. If these two attributes are rated in the first five to eight most mentioned attributes they are key attributes in the category, and indicate how well known the brand is relative to its competitors (Ajzen & Fishbein,1980) . However in this case, the brand may not perform well in actual sales due to the negative perceptions of the competency of salespeople. This type of specific attribute information is invaluable for marketing brand managers when making their strategy decisions and these metrics are applied in commercial research.

3.6 Limitations of Brand Association Measures

Romaniuk's (2013) study advises on ways to ensure potential confounding factors are minimised when measuring brand associations. To ensure attributes lists are appropriate for assessment of a brand's associative networks, two issues are relevant: there is a need both to ensure the chosen attributes motivate the individual to engage in evaluative processes and to avoid repetitions of constructs. Attributes can have overlapping meanings for individuals, resulting in duplication of memory association counts (Romaniuk). A solution for overlapping memory constructs is to use non-parametric correlations to identify attributes that represent similar constructs and remove one attribute (Romaniuk).

Romaniuk (2013) warns there is also a need to avoid strong evaluations or constructs. For example, superlatives such as '*best at*' or '*better than*' require the consumer to undertake additional processing and if so it is likely conscious evaluations are captured rather than memory links between attributes and brands. As a consequence, brand or concept responses will skew the overall distribution of associations (Romaniuk). The earlier work of Supphellen (2000) supports Romaniuk's view that it is important to avoid conscious evaluations when measuring brand associations.

Supphellen (2000) asserts memory associations have four modes of representation – verbal, visual, sensory, and emotional – and that most brand associations are unconscious. Supphellen also believes that even though large numbers of visual, sensual, and emotional associations are not consciously processed they are still stored in memory networks with verbal associations. Therefore, he contends, only a small proportion of associations stored in memory undergo a deliberative process. This has consequences for brand elicitation methods as there may be a tendency for an individual to retrieve only the associations that are easy to access. To overcome the potential for a biased brand image, brand elicitation techniques need to access the less conscious brand associations (Supphellen, 2000).

Another consideration for minimising bias when using brand associations to evaluate brand perceptions is the number of attributes presented. How many should be used to evaluate a concept? Romaniuk (2013) suggests "the more attributes, the more opportunities to pick any brand, and reveal more accurately the scope of the brand and competitive memory structures" (2013, p. 190). She suggests 30 attributes as a maximum and that presenting only two attributes would fail to obtain an accurate representation of memory structures for smaller brands.

3.7 A Second Model of Associative Memory Theory

ANTM is not the only associative memory model proposed. Van Osselar and Janiszewski believe two models explain how associations with a brand affect consumer's learning and decisions. While they agree "that brand names and product attributes are the links to diagnostic information about the product" (p. 202), in contrast to other research, they propose there are two similar theories involved in decision making that support two distinct ways of learning brand associations. The first class of models, HAM (Human associative memory), fit the concept of ANTM that are discussed in the previous paragraphs. Van Osselar and Janiszewski propose the second class of models involved in associative learning relate to adaptive network models. Adaptive network models propose "association strengths update and evolve as cues interact, and often compete to predict outcomes" (Van Osselar & Janiszewski, p. 202) contrasting with ANTM and HAM models that propose cues are learned independently. HAM models suggest learning is imprecise and stimuli are cross-referenced for later retrieval. By comparison, adaptive network models suggest learning is focused on benefits in competition with features, thereby causing associations with features and benefits to become interdependent. These differences in learning are an important consideration when a product has multiple features. Van Osselar and Janiszewski believe HAM learning is always active but can be over-powered by the adaptive network system when it is available and that consumers' utilise these two learning systems to make predictions about products.

3.8 Brand Attribute Elicitation Methodologies

Brand-image measurement requires identification of relevant attributes. Attributes are elicited by various methods that prompt and identify related concepts from an individual's knowledge structures (Steenkamp & Van Trijp, 1997). Several studies in marketing that have evaluated attribute elicitation methods by comparing method effects, similarities and differences of outcomes, and their various strengths and weaknesses, are reviewed in this section.

Steenkamp and Van Trijp (1997) compared three brand elicitation techniques – free elicitation, hierarchical dichotomization, and Kelly's repertory grid – to find out what type of information they generated, their convergent validity, efficiency for data collection, and participants' reaction to the three techniques. Free elicitation is described by Steenkamp and Van Trijp as a directive intended to trigger existing attribute knowledge relative to the perceptions of the product category under investigation which draws on spreading activation theory (Collins & Loftus, 1975). In hierarchical dichotomization procedures, respondents divide the stimulus set into two subsets of brands based on their dis(similarity) and verbalise which attributes guided this decision until no further separations are possible (Steenkamp & Van Trijp, 1997). This procedure is based on schemata theory, which proposes memory structures are organised by hierarchies (Canton & Mischel, 1979). Kelly's repertory grid, drawn from personal construct theory, presents triads of product alternatives to consumers. This theory proposes that individuals have personal repertoires of constructs they use to interpret a product category by sorting products as similar or different. In marketing, Kelly's repertory grid gained popularity for its ability to "generate aspects on which people differentiate between stimuli such as brands" (Steenkamp & Van Trijp, p. 155).

Steenkamp and Van Trijp (1997) found free elicitation yielded the most attributes, with higher levels of abstraction and articulation than either hierarchical dichotomization, or Kelly's repertory grid. These latter procedures yielded fewer attributes, with proportionally more characteristic attributes and lower levels of articulation. Respondents reported the free elicitation procedure easier for expressing their own opinions. Steenkamp and Van Trijp found a substantial degree of convergent validity across the three procedures, as overall the three procedures tapped into the same information. Therefore, Steenkamp and Van Trijp concluded the choice of attribute elicitation procedure depends on the relative importance placed on each of the performance criteria.

Piggott and Watson (1992) compared the performance of free-choice profiling and Kelly's repertory grid for their ability to describe sensory properties of 25 different ciders in the UK. In the free-choice profiling the number of descriptors obtained from participants varied from 12 to 32 with an average of 19. By comparison, Kelly's repertory grid provided a range of descriptors from 19 to 42 with an average of 29. Piggott and Watson found both elicitation procedures allowed participants to choose their own vocabulary; however, Kelly's repertory grid elicited a greater number of descriptors and interpretation of the product space was slightly easier. Overall, Piggott and Watson concluded neither elicitation method delivered substantially different results.

Bech-Larsen and Nielsen (1999) compared five attribute elicitation techniques on a low involvement product, vegetable oil. They used the techniques of triadic sorting (Kelly's repertory grid), free sorting, direct elicitation, ranking, and picking from an attribute list. The first two techniques are described in the preceding review of Steenkamp and Van Trijp's research. Bech-Larsen and Nielsen explain sorting is not used in the direct elicitation technique, instead respondents are asked to come up with attributes they consider most important. In ranking, the respondents prioritise attribute preferences and verbalise the reason for the ranking (Bech-Larsen & Nielsen).

Bech-Larsen and Nielsen (1999) identified a number of differences between the five techniques they used. The number of attributes generated by each of the five techniques varied. Triadic sorting and free sorting generated significantly more attributes than an attribute list, with triadic and free elicitation techniques also generating the largest number of concrete attributes. However, the number of abstract attributes generated did not vary across the five techniques. Bech-Larsen and Nielsen also tested attribute importance. Consistent with Ajzen and Fishbein’s (1980) research they found their participants evaluated the first five attributes they mentioned significantly more important than later mentioned attributes. They also found concrete attributes less important than abstract attributes; however, they found concrete attributes are more efficient at differentiating between sets of products.

From their study’s findings Bech-Larsen and Neilsen (1999) concluded that generally the decision of which attribute elicitation technique to use depends on the purpose of the research. They suggest that for low involvement products triadic sorting does not outperform the less complex and less time-consuming free sorting technique; therefore, it should not be given preference. However, if probing further into consumer’s cognitive structure is required then the triadic sorting technique should be given preference. If prediction is the only purpose of the study, the cheaper and less time-consuming attribute list is recommended (Bech-Larsen & Nielsen, 1999).

Breivik and Supphellen (2003) point out the importance of the quality of elicited attributes to predict choice or make evaluations. They believe an elicitation technique should be able to discriminate between alternatives. They warn that the ability of a technique to elicit the most attributes is not necessarily a priority, as greater numbers of attributes may not reflect the pieces of unique information required to avoid small variations of the same dimension. Breivik and Supphellen also believe that unless elicitation techniques resemble the way knowledge is organised in memory, they are likely to elicit irrelevant and less meaningful attribute sets. Other effects in elicitation methods stem from the way information is used, the format of the task, and the respondents’ understanding of the elicitation procedure and how involved they are with the product category (Breivik & Supphellen, 2003).

Breivik and Supphellen (2003) tested three elicitation techniques for method effect comparisons, using two product categories (restaurants and cars), and randomly assigned their respondents to one of four experimental conditions. They used direct elicitation, rank ordering elicitation, and ideal description techniques. The ideal description technique asks respondents to describe an ideal product within a particular category that they would evaluate favourably. Breivik and Supphellen found only marginal elicitation method effects. They found no significant differences on attribute importance or predictive validity across the three techniques tested. Most method effects, they found, were linked to procedures such as task ambiguity, with rank ordering more affected on this dimension than direct elicitation and ideal description. While Breivik and Supphellen found variation across product category results, overall the results did not differ across elicitation techniques, allowing them to conclude that generally the most salient attributes for product evaluation are evoked regardless of the elicitation technique utilised.

In their research Hogan et al. (2016) compared four elicitation techniques – free elicitation, Kelly's repertory grid, metaphor elicitation (ZMET), and projective elicitation with two conditions (face-to-face interviews and on-line), across two product categories, to determine if either condition causes any loss of information, and which method generates the highest number of unique attributes. Describing the differences between the elicitation methods, they agree with Steenkamp and Van Trijp (1997) that free elicitation relies on the researcher to provide cues that will trigger associations stored in semantic memory. Kelly's repertory grid also draws information from sematic memory structures but asks respondents to sort and comment on triads of (dis)similar, pre-determined stimuli in a structured response format. Metaphor elicitation differs from free elicitation and Kelly's repertory grid because it asks the participants to collect stimuli they perceive are representative of a product category in structured steps. This technique allows access to both semantic and episodic memory. Projective elicitation uses imaginative exercises to help respondents recall or project brand interactions and events, explicitly accessing episodic memory. In this technique cues are unstructured. However, probes are used to elicit more information and this introduces structured element into the responses (Hogan et al., 2016).

Hogan et al. (2016) found that in face-to-face interviews the free elicitation technique generated the highest number of attributes and was the technique ranked most positively by participants in their experiments. Face-to-face interviews elicited more attributes than on-line treatments, although Hogan et al. found online elicitation procedures provided a greater geographical reach and cost less. However, to achieve a sufficient representative number of attributes they recommend combining free elicitation and projective elicitation techniques. Hogan et al. found the metaphor elicitation technique a flexible design but resource intensive for participants, who viewed the technique less positively; overall it did not provide information unique to the technique.

Other research makes the distinction between scaling and sorting techniques in the context of brand image measures. Driesener and Romaniuk (2006) assert sorting techniques only determine if there is an association with the brand or concept, whereas scaling methods determine associations and the strength of that association. In their research they use the three measures of ranking, scaling, and 'pick any'. The ranking technique asked respondents to rank statements about which car manufacturers were least or most closely associated with the statement. The scaling technique asked respondents to strongly disagree or agree with the statement, while the 'pick any' technique asked respondents to select as many or as few manufacturers they thought were associated with the statements.

This study by Driesener and Romaniuk (2006) replicated an earlier study by Barnard and Ehrenberg (1990) that established that all three measures provided similar results, therefore they could be considered interchangeable. Barnard and Ehrenberg's study was in FMCG markets with three categories, whereas Driesener and Romaniuk used cars and only two categories, owners or non-owners, in a different country to the original research. Driesener and Romaniuk's findings concurred with the original study, suggesting the three measurement types are measuring the same construct. A second finding was a correlation between the measures and uses, which led Driesener and Romaniuk to conclude, irrespective of the measure, that current and past usage can influence the interpretation of brand image data, although this can be controlled.

Research by Bird and Ehrenberg (1970) established a generalisation that "brand association responses are systematically linked to past brand usage" (Romaniuk, Bogomolova and Dall'Olmo Riley, 2012, p. 243). To confirm this generalisation Romaniuk et al. re-examined the connection between brand image and brand usage across 45 data sets, 30 different categories, 15 different countries, and four different data collection methods, totalling 460 brands and over 1,028 attributes. Bird and Ehrenberg reported the average proportional responses for *current: former: never tried* was 50: 20: 10. Romaniuk et al. report average proportional responses as 37: 20: 10. Romaniuk et al. acknowledge their response level for current users was lower than Bird and Ehrenberg's original study; however, they believe this lower figure is due to the inclusion of a wider variety of smaller brands that lowered the average figure. Overall, Romaniuk et al.'s findings support the generalisation that "former users are more likely to make a brand-image association than those who have never tried the brand" (p. 248). An implication of this generalisation is that higher levels of attribute mentions can be the result of failing to control for past usage (Romaniuk et al.). Given that the climate engineering techniques being tested in this research are mostly hypothetical controlling for ‘use’ is unnecessary.

Another relative empirical finding in Romaniuk et al.’s study (2012) was that the relationship between brand usage and brand image associations was not affected by the selection of a free-choice or a ‘pick-any’ method. The results across the three different brand imaging measurement methods of ranking, rating, and free choice ‘pick-any’ techniques were similar.

Another important consideration in brand association work is priming or inhibition effects. A study by Romaniuk in 2006 reported primed responses on image attributes may lead to under-reporting of brand associations, especially among small brands and non-brand users. Romaniuk compared the types of brand associations elicited by prompted and unprompted methods to see whether either method would be preferable. Romanuik used 12 toothpaste brands to produce a stimulus-based condition and nine insurance brands to produce a memory-based experimental condition and randomly split 199 respondents to each condition. Respondents were asked which brand they associated with a list of 16 attributes. Overall, the prompted scenarios elicited more brands. Other relevant findings from this study were that while there are minimal differences in the number of associations from brand users by each method, the proportion of responses from non-users of each brand showed unprompted methods get almost half the responses elicited by prompted methods. Also, in the unprompted methods brand associations were under-represented for smaller share brands. Romaniuk’s final conclusion is that to completely capture brand associations and avoid priming or inhibition effects, especially if the respondents are non-users of a brand, or the brand has a small market share, elicitation methods that prompt respondents for brands are better than unprompted methods. This finding has relevance for this research as most of the participants used in all four stages are unlikely to have any prior knowledge of climate engineering and will need cues that prompt responses.

These studies have shown the performances of elicitation techniques are not significantly different; therefore, the choice of technique depends on the purpose of the research and that when associated attributes are salient in a participant’s memory they are easily evoked by most attribute elicitation methods. However, in certain situations some elicitation methods perform better than others. Kelly’s repertory grid draws out underlying constructs often not revealed in ‘pick any’ techniques and is likely more useful with unfamiliar concepts such as climate engineering.

3.9 The Effects of Salience on Brand Choice

Another element of importance in brand image measurement is brand salience, given its potential to moderate brand beliefs and buyer behaviour in choice situations (Williams, 1986). In marketing, a brand's ability to stand out, to be easily recognised, or thought about, is referred to as brand salience (Romaniuk & Sharp, 2004). By this definition brand salience is differentiated from 'top-of-mind' that reports which brand a consumer recalls first. Romaniuk and Sharp (2004) present an argument that a brand's salience is not based on the strength of a single link to a cue, as traditionally supposed, but is more likely linked to a range of cues in a buying situation. They make this argument based on the point that consumers use variations of many cues in buying situations (e.g. product category cues, internal influences, and the external environment) and "not all brands are linked to all cues for all buyers" (p. 334). Holden (1993) agrees different types of attribute cues result in different consideration sets being formed.

Romaniuk and Sharp (2004) also believe brand salience is quite different from brand attitudes in that attitudes are about evaluating a brand, whereas salience is about the brand being thought of. If salience is conceptualised as Romaniuk and Sharp convey, it highlights the importance of the size of the network of brand information, and how once it has been thought of, the brand is more likely to be chosen. When measuring brand salience, Romaniuk and Sharp (2004) recommend focussing on the proportion of times a consumer mentions the brand across several relevant cues or attributes, instead of a specific cue or attribute. They also recommend that more than a single survey question should be used to capture overall pictures of memory structures.

3.10 Chapter Conclusion

Chapter three explains human memory processes and how this is conceptualised in the Associative Network Theory of Memory (ANTM). The theory of ANTM supports the idea that consumers use memory associations to evaluate a brand or concept's attributes. This theory proposes associations in human memory are representations of links that interconnect pieces of information stored in nodes. An external stimulus causes an activation effect that spreads through the nodes and retrieves the information associated with the presented concept. Evoked associations indicate the memory structures associated with a concept. If associations with a brand or a concept's attributes are identified and measured they provide a brand's image (Romaniuk, 2013; Wright, Teagle, Feetham, 2014).

The ability for this theory to provide measureable attribute evaluations is evidenced in a large body of academic research and provides the justification for asserting the ANTM theory is an appropriate foundation to evaluate new or hypothetical concepts in fields other than marketing. Marketers have applied ANTM over four decades, replicating and building on work by Barwise and Ehrenberg (1987), Bird and Ehrenberg (1970), Barnard and Ehrenberg (1990), Driesener and Romanuik (2006), Henderson, Iacobucci and Calder (1998), Hoek et al. (2000), Hogan et al. (2016), Keller (1993), Myers-Levy (1989), Nenycz-Thiel and Romaniuk, 2009, Nenycz-Thiel et al. (2010), Romaniuk (2003; 2013), Romaniuk et al. (2012), Romaniuk and Sharp (2004; 2016) Stocchi (2011), Wright, Teagle and Feetham (2014) and others.

Keller (1996) articulated that links with a particular brand are created, reinforced and stored in a network of memories. Dreisener and Romaniuk (2006), Nenycz-Thiel and Romaniuk (2009), Romaniuk et al. (2012) and others used generalisations related to brand equity and patterns of brand market shares (based on the earlier empirical work of Ehrenberg and colleagues such as Barnard, Barwise and Bird) to demonstrate how the ANTM theory conceptualises how brands, or concepts, are stored in memory and how brand information is processed. The recent work of Romaniuk (2013) and Romaniuk and Sharp (2016) applied ANTM to branding data to provide metrics that measure a brand's image. Wright et al. (2014) extend the ANTM theory and brand imaging work from marketing by applying brand imaging metrics to hypothetical science concepts – making a novel and substantial contribution to science communication.

Specifically, the key study by Romaniuk (2013) offered the metrics for systematically measuring a brand's share of total category associations. In this thesis the brand metrics developed by Romaniuk (2013) are applied to climate engineering techniques to determine each technique's share of associations relative to total associations and the relative strength of each attribute. These metrics allow an overall view of the perceptions of climate engineering as well as individual concept images for each of the six techniques tested (Wright et al., 2014).

The reviewed literature also revealed that evaluative and choice decisions are evoked by stimuli that represent a brand, or concept, and require consumers to retrieve the relative associations stored in short- and long-term memory, highlighting the importance of the cues used to stimulate memory nodes and their interconnected links. Memory of a brand is dependent on the number of relevant concepts existing in memory, suggesting the quantity of links is more important than the quality of links. For concept evaluations, presenting a wide range of cues improves the chances that information unavailable on one cue is present in another cue. Consequently, the use of more than one stimulus and a single survey question is required to capture overall pictures of memory structures.

The reviewed research has also illustrated the significance of the cognitive limitations of short- and long-term memory. Short-term memory has storage capacity limits of four to seven chunks of information at one time. The capacity to store information is also reduced when other processing demands are made, and suggests care is needed not to over-burden survey respondents with complex tasks when evaluating concepts. Retrieval of information from long-term memory is reliant on the level and strength of activation. Even though information stored in long-term memory is always available, to remain easily accessible it needs to be active. Accessibility to information varies according to contextual situations, to the amount of competing information, and to what external and self-generated cues are present at the time.

Since one of the main objectives of this chapter is to establish a method for evaluating a brand, or concept, on its common attributes, research that has evaluated methods of attribute elicitation was also reviewed. Attributes are characterised as descriptive or evaluative. Research suggests the latter is relevant for evaluating brands that have users and non-users, while descriptive attributes best represent common characteristics and were the type used in this research.

The chapter reports the findings from several studies that tested various techniques for eliciting attributes. Common techniques tested are free elicitation, hierarchical dichotomization, Kelly's repertory grid, 'pick-any', ranking and picking from a pre-determined list. While there are some differences between the numbers of attributes each method generates, a common conclusion in the research is that most methods have convergent validity, and that the choice of method depends on the performance criteria and purpose of the research.

The brand attribute elicitation research reviewed in this chapter justifies the choice of the two techniques (Kelly's repertory grid and a Pre-determine list of attributes) used to elicit common climate engineering attributes in Stage one of the research.

Chapter Four: Science Communication, Public Engagement and Deliberation

The objective of this chapter is to examine the current models of science communication and approaches used in public engagement to identify their strengths and limitations.

4.1 Introduction

In science communication, there is on-going debate about the appropriateness of the various approaches used to engage the public with science and technology (Chilvers, 2008; Elam & Bertilsson, 2003; Irwin, 2006; Sundqvist, 2014; Wynne, 2005). Previous methods of engaging the public with science and technology were centred on scientists providing the public with knowledge of science (Davies, 2011). Irwin and Wynne believe this approach to public engagement inferred the public lacked knowledge of science and raised concerns that 'misunderstanding' science is the fault of the public (1996). More recent science communication research examines public engagement approaches that are more inclusive of public perspectives. However, empirical research on whether these approaches are improving public engagement and arriving at policy outcomes inclusive of public views on new science and technological innovations is scarce.

Bubela et al. (2009) explain how institutional, social and technological changes have contributed to changes in science communication. Technology, in particular, has brought changes in how science and technological information is disseminated. For those individuals who are interested in science and technology, the Internet and other digital resources have made it easy to obtain information on a global scale. However, Bubela et al. point out the Internet has fragmented information, making it easy for individuals to avoid science completely. In addition, these digital communication channels are likely to reach only a small proportion of the population who are already knowledgeable about science. Unregulated, poor quality on-line sources and on-line comment sections have the potential to foster animosity towards science or technology. Bubela et al.'s research illustrates how digital communication channels are influencing public interaction and subsequent reactions to new science and technologies.

Irwin and Wynne believe scientists make assumptions that disengage the public with science (1996). Often when scientific ideas are resisted, scientists assume the public are incapable of making sense of complex science and technologies. Irwin and Wynne make the point that science is often conveyed as an important force that can solve many of the world's problems such as poverty, disease, starvation, and climate change. They argue that science is often presented as the "only valid way of apprehending nature" (p. 6). This view of the superiority of science and the assumption that the public have an inadequate understanding of science have led to a tenuous relationship between science and the general public. Consequently, there is little agreement on how to effectively inform and engage the public in dialogue on scientific and technological issues (Davies, 2011).

Despite the tenuous relationship between science and the general public, policy makers in democratic societies are bound by democratic principles to consider the views of the general public in their decision making (Rayner, 2003). The need to include public perspectives in science and technology policy decisions led to several advancements away from the deficit model of science communication towards models that are more inclusive of public views (Brossard & Lewenstein, 2010; Bauer, 2009; Davies, 2011; Gregory & Lock, 2008; Wilsden & Willis, 2004).

4.2 Science Communication Models

One of the earliest communication models was developed on the premise that the gap between science and citizens' perspectives was due to lack of knowledge. This school of thought is known as the 'knowledge-attribute' or 'deficit' model of science communication (Besley & Tanner, 2011; Brossard & Lewenstein, 2010; Wilsden & Willis, 2004). In some countries this view led to governments funding programmes to educate their citizens about science-related matters. However, this reasoning presumes the more knowledge a person has about science the more likely they will have favourable attitudes towards scientific issues, or, as described by Gauchat (2011, p. 754) the model assumes "people who know about science love science" (Bauer, Allum & Millar, 2007). The deficit model also relied on the premise that the public who understood scientific facts would be more likely to view the issues the same way as the experts (Bubela et al., 2009).

Brossard and Lewenstein (2010) point out the deficit model assumes scientists are 'literate' and that non-scientists have only residual scientific knowledge. Making the assumption that non-scientists know less than scientists indicates a power imbalance between scientists and ordinary citizens when in reality, a person who has experience of living in a vulnerable eco-system can have just as much knowledge of the eco-system as a scientist whose knowledge is gained from laboratory or field tests.

Wynne (1995) criticised the deficit model on the grounds that when non-scientists are questioned about a particular scientific issue it is often framed without context. Learning theories have shown that when facts and theories have relevance in people's lives learning is enhanced (Bransford & Brown, 1999). If science is framed without context, it is unlikely learning is taking place and consequently the 'gap' in scientific knowledge is unlikely to change.

Another reason for moving away from the deficit model in science communication was a lack of evidence that knowledge of science leads to positive attitudes about science. Few empirical studies demonstrated strong correlations between people's perceptions and acceptance of science and their knowledge of science (Bauer, 2009; Corner & Pidgeon, 2010). However, some studies found a weak relationship between public knowledge of science and positive attitudes towards science (Evans & Durrant, 1995; Sturgis & Allum, 2004). One study found a small positive correlation between general knowledge of scientific facts and general attitudes towards science but, when specific scientific issues such as biotechnology and nuclear energy were examined, the association between knowledge and attitudes did not hold (Allum, Sturgis, Tabourazi & Brunton-Smith, 2008). This lack of empirical support for a strong relationship between knowledge of science and positive attitudes to science identified a major limitation of the deficit model. If attitudes and knowledge of science are not strongly related then providing knowledge of science is unlikely to change attitudes to science.

Brossard and Lewenstein (2010) note the criticisms of the deficit model were partly addressed by a contextual model of science communication that included lay-persons' knowledge. This model acknowledged that individuals shape their responses to questions based on their prior personal experiences, their cultural environment, and their personal circumstances. The contextual model is also thought to recognize that social systems and media messages can positively or negatively influence public concerns (Brossard & Lewenstein).

The contextual model is better able to segment the market into similar groups within populations. This approach attempted to identify populations with similar attitudes to science in order to target messages about science to individuals in similar circumstances. While this model acknowledges individuals have varying levels of scientific literacy, it is criticized for "being merely a more sophisticated version of the deficit model" (Brossard & Lewenstein, 2010, p. 14). The conceptual model also raised concerns that it might be used to manipulate messages to achieve acceptance of science rather than providing an 'understanding' of science (Brossard & Lewenstein).

In summary, the deficit and contextual models of science communication are strongly criticised for not including public perspectives. This lack of consideration of public views led to two further approaches to science communication (Brossard & Lewenstein, 2010). One model is inclusive of the perspectives of lay-persons and the other model allows members of the public to have a say in setting the engagement agenda and attempts to include a wider range of public views in policy decisions.

The lay-expertise model includes information, knowledge and expertise gathered by local communities or indigenous groups. Its supporters argue that scientists fail to appreciate the value of drawing on lay-expertise and that this results in lack of contingency planning in policy decisions (Irwin & Wynne, 1996). Opponents of this model argue that by excluding science knowledge the lay-expertise model is 'anti-science' and that by valuing the views of local communities it is politically driven (Brossard & Lewenstein, 2010). However, a major concern with the lay-expertise model is that there is little evidence the opinions of lay-experts have any significant impact on policy outcomes. Consistent with this criticism, the research of Selin et al. (2016) found that public engagement with science and technology is only weakly connected with policy decisions or with any science regulations. While the lay-expertise model is considered an improvement on the deficit and contextual models, social scientists still called for a model of science communication that is more inclusive of public views (Corner & Pidgeon, 2010: Stirling, 2008).

A more recent approach to science communication is the public engagement model (also known in the UK as the dialogue model). The public engagement model attempts to include more public perspectives than lay-experts. Its aims are to integrate the views of a broader range of citizens into policy-making decisions, shifting the focus from the need for citizens to understand science to AN interactive and 'engaged' public (Brossard & Lewenstein, 2010; Davies, 2011; Wilkinson, 2014). Public engagement activities range from research or public conferences, town hall meetings, citizen juries, deliberative workshops, focus groups, science cafés and other forums where public are included in discussions. Brossard & Lewenstein argue the advantage of these activities is that the discussions are not controlled by scientists or politicians, rather it is the views of the public that drive discussions and, depending on the type of forum, this transfers some of the power to the public (Brossard & Lewenstein).

Overall, the lay-expertise model and the public engagement model are about actively engaging citizens with science. They have superseded the deficit and conceptual models that focused on simply delivering information to the general public (Brossard & Lewenstein; Davies, 2011; Wikinson, 2014).

Three different reasons for engaging the public in scientific and technological debates are offered by Wilsdon and Willis (2004). Their first reason is linked to a normative view: engaging the public is the key to democratic processes – the 'right' thing to do. The second, instrumental, view is linked to the idea that particular interests are being satisfied. For example, companies or governments might want to gauge public reaction to a new innovation or appear conciliatory. The third reason stems from a substantive perspective where the goal is to improve the quality of decision making by ensuring the public are the subjects rather than objects in the process. In the substantive process the public are active in decisions rather than contributors (Wilsdon & Willis, 2004). From the literature reviewed here it would seem public engagement with science and technology is still crossing back and forth on a normative-instrumental-substantive continuum. A consensus on one universal approach to public engagement remains elusive.

Wilkinson (2014) also points out the advantages of public participation in science and technology policy-making. As well as aligning with democratic principles, Wilkinson believes public involvement in policy decisions creates more socially robust knowledge and aids the appropriateness of publicly funded research. However, as Wilsdon and Willis (2004) point out there is a risk that the public is only included in policy-making discussions to off-set potential controversy about emerging fields of interest, for example, energy saving technologies.

Even though there is a movement away from the assumptions of the deficit model of science communication, towards more public engagement in science policy decisions, practical obstacles inhibit progress. Árnason (2012) discusses three of these obstacles. The first obstacle is the pre-framing of agendas which can potentially prevent participants discussing issues in their own terms of reference (Chapter two contains a more detailed framing discussion). The second concern when implementing deliberative public engagement is the institutional context (Árnason 2012; Bickerstaff, Lorenzoni, Jones & Pidgeon, 2010; Gauchat, 2011). The cultural norms of an institution can influence dialogue and raises the question of where public deliberation should take place. The third obstacle mentioned by

Árnason is the value of public deliberations. Do they actually have any real influence on government policy? While these obstacles and questions have not stopped participatory approaches, they have hindered agreement on a single acceptable approach to public engagement with science.

A body of literature is focused on defining and determining the extent of public engagement. Delli-Carpini, Cook and Jacobs (2004) reviewed public engagement literature beginning with an evaluation of several definitions of 'public deliberation'. Broadly, these definitions suggest that "public deliberation sometimes starts with a given set of solutions, but it always involves problem analysis, criteria specification, and evaluation" (Gastil 2000, p. 22). Fishkin (1997) tried to define when public deliberation is complete. He proposed the process is 'less deliberative' in conditions where some participants cannot answer the arguments made by others, or are unwilling to consider the arguments posed, or when the information required to understand a claim is not provided. Improving deliberation depends on "improving the completeness of the debate and the public's engagement in it" (p. 317). Another definition contends that deliberation can occur through the survey process or within an individual's thought process (Lindeman, 2002). Based on these, and other definitions, Delli-Carpini et al., term public deliberation 'discursive participation' and explain it encompasses:

> "citizens talking in public with other citizens to provide an opportunity for individuals to express their views, learn the positions of others, identify shared concerns and preferences, and come to understand and reach judgments about matters of public concern" (p. 319).

This degree of public participation has several interpretations, making it difficult to measure, or compare, the success or failure of outcomes.

Although the public engagement model is widely supported, it is not immune to criticism. As with the lay expertise model, it is thought to have an 'anti-science' bias. A further criticism is that public engagement processes only consider the views of small numbers of people. As a result, the opinions expressed are unlikely to represent the opinions of the wider population under examination. Gauchat (2011) cautions that abandoning public opinion surveys in favour of ethnographic or local interactions between scientists and the public might overemphasise the significance of particular issues. Often small local groups have a direct relationship with the issue and therefore their views are "systematically different from the general public" (p. 756). Gauchat also points out that critics have failed to demonstrate convincingly the inferiority of carefully designed large-scale surveys, compared with alternative methods of gauging public opinions (2011).

The overarching concern about public engagement processes, however, is that the public often become involved too late in the process. If preliminary decisions and research have already taken place, prior knowledge can bias the discussions and decisions. Recognition of these limitations has led to calls for the public to be involved much earlier in the process (Corner & Pidgeon, 2010; Rodgers-Hayden & Pidgeon, 2007).

4.3 Upstream Public Engagement

Deliberative public engagement early in the policy making process is termed ‘upstream’, and proposes that the public should be encouraged to actively participate in discussions on a scientific or technological issue from the time an idea is conceptualised and throughout the total research and development phase (Corner & Pidgeon, 2010; Rodgers-Hayden & Pidgeon, 2007). Corner and Pidgeon argue that genuine ‘upstream’ engagement asks about the impacts of technological innovation and whether that programme is acceptable, rather than telling citizens about an issue. The various approaches to upstream engagement are: direct public engagement through citizens’ juries, panels, focus groups and deliberative workshops; scenario analysis with stakeholders where uncertainties are identified; decision analytic methods where frames and values for classifying risk are identified; and multi-stage methods that encompass the above approaches with different groups of stakeholders at different times (Corner & Pidgeon, 2010).

Additionally, Corner and Pidgeon (2010) believe ‘upstream’ engagement should take place before any significant commercial involvement has occurred. Wilsdon and Willis (2004) believe constructive debate also needs to take place “at a stage when it can inform key decisions and before deeply entrenched or polarised positions appear” (p. 19). Participatory dialogue needs to take place when the views of the public “are still able to influence the trajectories of scientific and technological development” (Wilsdon & Willis, p. 29). Since climate geoengineering dialogue is already appearing in the media, and as research and development of some of the proposed techniques are underway, it is past the conceptualisation phase. Therefore, the need for public engagement is critical and this is a principal motivation for the present research.

Rogers-Haydon and Pidgeon (2007) tested the 'promise and perils' of moving public debate upstream when they carried out 24 interviews relating to nanotechnologies with stakeholders in the UK. Their approach represented a change from discretionary governance, where technical and expert advice is the main input to policy decisions, to deliberative governance where the public have organised and directed the agenda. The research working group included fellows in nanoscience and engineering, and representatives from social scientists, ethics, consumer protection, and environmental communities. The researchers presented written and oral evidence in sessions and workshops to industry representatives, regulators, public engagement specialists, civil society representatives, scientists, and engineers, along with specialist workshops on environmental impacts and implications on health. The research working group also used the views of ordinary members of the public, obtained through surveys and qualitative workshops. The workshops were interactive, with opportunities to ask questions of an expert in nanotechnology.

From the 24 interviews and workshop feedback, Rogers-Haydon and Pidgeon (2007) make the following conclusions regarding upstream public engagement. Upstreaming scientific debate does not guarantee controversy-free discussions; in reality it may foster greater differences of opinion. Previous research on traditional forms of public engagement revealed stakeholders can quickly feel anger and fatigue if their discussions are not considered in policy decisions (Rayner, 2003). Involvement too early in the process may increase participants' anger as policy decisions could be a long way in the future if the science or technology under discussion is only hypothetical. Additionally, opening up early dialogue allows time for perceived risks to intensify. Despite these potential perils, Rogers-Hayden and Pidgeon believe upstream public engagement is an important innovation that reflects a genuine attempt to improve the relationship between the public, scientists and policy-makers. By delivering transparency and more balanced agendas the likelihood of opening up discussions rather than closing them down, is increased.

Other benefits of upstream public engagement are reported by Sturgis (2014) who believes the benefits of upstream public engagement are better decisions, less controversy, and increased trust. Sturgis suggests there are social benefits to politically and economically marginalised groups when they are included and allowed to shape the course of technological governance. If engagement takes place when a new technology is emerging Sturgis believes public controversy is reduced and trust is increased. However, for the benefits to occur, scientists and the public need face-to-face meetings and the exchange of views needs to be equal and respected by all. Contrariwise, Sturgis (2014) points out two main limitations of public engagement in the context of governing technologies. He questions whether public engagement can operate within the bounds of the democratic principles on which it is founded and whether citizens actually want direct participation in science governance.

Another criticism of public engagement with upstream technologies is the belief that lay-persons are unable to reason and debate unfamiliar technologies. However, this is a misconception, according to Corner, Pidgeon and Parkhill (2012). Social scientists have concluded that even with limited familiarity lay-persons are often able to reason and participate in debate about risks in science and technology (Barben, Fisher, Selin & Guston, 2008; Rogers-Haydon & Pidgeon, 2007). Lay-persons may come into a research situation with limited knowledge of the research subject but many participate in discussions whole-heartedly by drawing on shared cultural narratives (Corner et al., 2012). The conclusions of Barben et al. (2008), Corner et al. (2012) and Rodgers-Hayden and Pidgeon (2007) confirm the value of not restricting public participation in scientific policy decisions to highly subject-knowledgeable publics.

Research regarding the successful implementation of upstream engagement is scarce, although a study by, Kurath and Gisler (2009) empirically analysed six public engagement projects in the context of nanoscale sciences and nanotechnologies. They found most of these public engagement projects did not go beyond the traditional approaches that divided participants into two social groups split by intellect. With a cognitive divide in place the engagement is unlikely to meet the upstream condition of creating a forum where there is a mutual exchange of ideas. This demonstrates that the upstream public engagement projects they examined had not yet moved into a more inclusive approach. Kurath and Gisler also found little evidence that the outcomes of the engagement were translated into policy. While upstream engagement has the intention of being more participatory, there appears a lag between the theory and the practical implementation.

4.4 Chapter Conclusion

Approaches to science communication have progressed from one-way communication models through several models of increasing feedback to the point where, in many cases, communication is conceived as a two-way dialogue". Science and technology can develop in parallel with public views through upstream public engagement and deliberation. The perceived benefits of upstream public engagement are better decisions, less controversy, and increased trust. However, there is little empirical evidence that these perceived benefits are realised. There is no guarantee upstream discussions will avert controversy, instead there is potential to increase differences of opinion. Opening up early dialogue before risks and costs are known may well increase public resistance and divide opinions. It is uncertain whether upstream public engagement is meeting the criteria for more democratic processes in science communication as it is difficult to know whether scientific or technological policy decisions are inclusive of public views. Nor is it certain that the public actually want direct participation in science governance. It is not impossible to recruit a discussion group inclusive of members of the public, scientific experts and stakeholders; however, the resulting groups are usually small and may not represent the overall population. The limitations of the current models of science communication contribute to a lack of consensus about an appropriate approach to upstream public engagement.

However, another more pressing and unaddressed concern regarding upstream public engagement underpins the third stage of this current research. Science communication has acknowledged it is desirable to have upstream public engagement that is deliberative, yet research on what constitutes deliberation, and when it occurs, is scarce. Deliberation is broadly defined as a thought process that carefully evaluates options based on logic and reason, compared with an intuitive automatic response. Since deliberation involves the internal thought processes of individuals, it is unlikely group facilitators can easily observe and quantify when deliberation is taking place. Hence, even if a public forum for engagement with science or technology is arranged in the development stage and the agenda is set by the public, when is the engagement deliberative? When is the engagement automatic and intuitive? Do evaluations of new science and technologies vary with deliberation compared with intuitive responses? The next chapter investigates the literature on intuitive and deliberative thinking that has originated mostly in the field of psychology but is of interest to marketing and science communication due to its potential to influence consumers' or citizens' evaluative decisions.

Chapter Five: Intuitive and Deliberative Thinking in Decision Making

The objective of this chapter is to examine information dual-processing theory, another approach that describes the cognitive processes used in decision making, to determine if any of its applications are useful for measuring the extent of deliberation in public engagement with controversial science and technologies. A second objective is to appraise the research that opposes dual-processing theories as this allows an understanding of potential weaknesses in the reasoning used to support these theories.

5.1 Introduction

Chapter three discussed information processing by focussing on how information is stored and retrieved from working memory. It also explained how the associative network theory of memory allows marketers to understand better the decision process that consumers use when they purchase or evaluate new concepts. This chapter focuses on another approach that explains the cognitive systems humans use to process information in choice and decision situations. The discussion critiques a prominent theory in psychology – the dual-system of cognitive processing. The dual-processing theory proposes that one information processing system uses automatic and intuitive thinking (Type 1) and that the other system uses conscious and deliberative thinking (Type 2). The dual-processing theory has relevance for this thesis as it is important to know what effects either mode of thinking may have when the public are asked to provide opinions that will influence policy-makers' decisions.

Many social scientists and science communicators assert that deliberative discourse with the public is necessary for policy-makers to make decisions that accurately reflect the views and concerns of the general public. Knowing whether the information used to make decisions is processed intuitively or with deliberation, and the accuracy of each outcome, is important if reported research on public opinion is to provide a perspective that represents a broad spectrum of public views. If either mode of thinking has an impact on respondents' evaluations of new science or technologies and this is not accounted for when reporting citizen's opinions then there is a strong possibility of misreporting those opinions. Yet, as Chapter four concluded, in the field of science communication there is little consensus on how to engage the public with new science, nor is there agreement on which method of public engagement best reflects a broad spectrum of public view-points. Even less is known about the effects of intuitive and deliberative thinking on evaluations of new science and technologies.

Although there is no one generic model of the dual-theory of information processing, over many decades various models have been proposed. These dual-processing models use a variety of terms to identify each cognitive process (e.g. intuitive and deliberate, associative and rule-based, system 1 and system 2, Type 1 and Type 2 thinking) and there is much argument as to when and how these two processes occur and interact. While consensus is lacking on the relationship and interactions between the modes, there is general agreement on the distinguishing characteristics of each process (Evans, 2008). One process is characterised as fast, automatic, effortless, and intuitive, while the other process is thought to be slow, conscious, and requiring effort and deliberation.

Specifically, this chapter discusses:

- the development of information dual-process models and theories
- the distinguishing characteristics of dual processing models
- the capabilities and interactions of the Type 1 and Type 2 processes
- the accuracy of Type 1 and Type 2 outcomes
- motivating drivers for Type 1 and Type 2 thinking
- the effects of meta-cognition on reasoning outcomes
- arguments against dual-theories of information processing
- a three stage model of dual-processing

Some of the studies discuss various proxies for measuring Type 2 responses and these are identified in section 5.10, the chapter summary. This chapter also considers the arguments of authors who oppose dual-processing theories. In contrast to dual-processing theory proponents, this group of authors claim reasoning occurs within a single cognitive system. A recent and unique study that proposes there are three stages to the dual-processing model is also reviewed.

5.2 The Development of Dual-processing Models and Theories

It is almost a century since Sigmund Freud, introduced the idea that humans use a dual model of cognition to process information (Epstein, 1994). Freud considered humans to have a primary system of thinking that draws on memory associations unconsciously, and a secondary system of thinking that is conscious and rational, with each system leading to different responses (Osman, 2004). Freud believed that unconscious primary thinking constantly undermines people’s rational thinking, inferring the primary process has the controlling role in decision making (Epstein, 1994). When Freud wrote this revolutionary theory of dual processing, it instigated a conundrum among psychologists and social scientists that, although more understood than in Freud's time, is nonetheless still unresolved.

Over the following decades several dual-processing models were proposed and critiqued. These dual-processing models use a variety of terminologies to define the two information processing modes. Epstein (1994), for example, uses the terms experiential and rational systems; Sloman (1996) and Smith and DeCoster (2000) use the terms associative and rule based; Evans (2006) uses the terms heuristic and analytic; and Stanovich (2004) uses the terms System 1 and System 2 (Evans 2008). These various terms have different connotations that influence interpretation, inhibit model comparisons and invite erroneous critique (Stanovich & Toplak, 2012). Lately, the terms Type 1 and Type 2 thinking have supplanted the use of Systems 1 and 2 as the use of 'system' falsely implies the two processes occur in two specific cognitive systems when instead processes can be multiple, intercede, and interact with one another (Stanovich & Toplak, 2012; Evans & Stanovich, 2013).

Despite disagreement over the terminologies that define dual-processing and how and when they interact, there is general consensus that they have qualitatively distinctive characteristics when reasoning occurs (Evans & Stanovich, 2013). Broadly, Type 1 thinking is described as fast and intuitive with little effort or consciousness, while Type 2 thinking is described as slow, more deliberative, and requiring a conscious effort. The outcomes are thought to "produce best-guess answers to problems without discernible effort" if Type 1 thinking is employed and "accurate justifiable representations of the world" if Type 2 thinking is used (Osman, 2004, p. 988). However, empirical evidence on whether Type 2 thinking is more accurate than Type 1 thinking is scarce. The few studies that have addressed the accuracy of each type of thinking are reviewed below in section 5.5.

5.3 Distinguishing Characteristics of Dual-processing Models

This section reviews the distinctions between the two modes of cognitive processing that are proposed by several authors, and replicated or extended by other authors.

Epstein (1994) has advanced Freud and his predecessors thoughts on dual-processing by declaring the existence of two parallel, interacting modes of information processing that he terms experiential and analytic. His supporting argument for this theory is based on cognitive-experiential self-theory (CEST) of personality. Epstein contends when people try to comprehend reality the experiential system is influenced by emotions, typically non-verbal, while the analytical system is rational and typically verbal. His evidence for this claim is anecdotal and based on everyday life, as people demonstrate two different ways of thinking during emotional and unemotional states. Further, he believes conflicts between the head and the heart (metaphor) are by necessity two different cognitive processes as the heart connects to emotions and the head does not.

Another argument Epstein (1994) uses to support the dual processing theory is that people are aware that they 'know' about something either through feelings, experience or intellect. According to Epstein, superstition and religious thinking also commonly demonstrate that people are engaging in non-rational thinking to understand the world instead of a reasoned analytical process. Through these real life examples Epstein (1994) concludes that experiential, non-rational thinking is predominant. He claims that even when people are aware they are thinking irrationally they are more influenced by their experiential processing mode than their rational mode. However, Epstein's work lacks robust evidence for two distinct cognitive systems as it was based only on anecdotal observations (Evans, 2008).

Sloman (1996) contributes to the theory that people use two processing systems by reviewing experiments from previous research. He uses the labels 'associative' and 'rule-based' to distinguish between the processing modes, and describes associative thought as 'empirical thinking'. Basing his argument on the work of William James (1890 – 1950), Sloman elaborates with an example of associative thinking. Constructing a new design requires a person to search the mind for old images to provide ideas and a measure of comparison, thus demonstrating associative thoughts are abstractions from past experience. However, this highlights a limitation of associative reasoning – it is limited to associations already represented in memory. This limitation is likely to influence a respondent's ability to form associations with any stimulus with which they are presented.

Sloman claims associative reasoning or thinking is inherent in associative systems. Stimuli or objects are classified according to the extent to which they are similar or dissimilar to previously held associations. When perceived similarities are used to draw inferences and predictions Sloman likens the mental computation processes to those of a statistician. He explains that a rule-based system is distinct from an associative system in that it requires specific conscious calculations rather than inferred representations.

Sloman (1996) believes each type of reasoning is identifiable by the awareness element. People who use rules to process information are aware of both the process and the result. Conversely, people who use the associative system to reason are aware of the result, but are unaware of the process they used to achieve the result. However, results achieved when using the associative system are not necessarily performed by this processing mode alone, as a person may move from associative thinking to deliberative thinking and back to associative thinking to achieve a final outcome.

Similar to Sloman (1996), Smith and DeCoster (1999, 2000) try to clarify the two modes of information processing, and when they occur, by summarising previous research on dual-processing models. Smith and DeCoster describe the dual-process as either associative (heuristic) or rule-based. The fundamentals of the associative mode of processing are that a salient cue in a stimulus prompts an automatic memory association with that cue. These associations, stored in memory, are learnt through repeated experiences over time and are activated automatically. Rule based processing varies depending on the situation, specifics of the task and levels of motivation. It can involve logic, general knowledge, mathematical or statistical calculations, and is strategic.

Smith and DeCoster (1999) claim the associative mode is used most often as it is simple, relies on previous learning, is easily accessed, and operates by default unless special circumstances intervene. They believe the second, systematic rule-based process activates when people feel accuracy is needed; to defend an attitude; or when they want to portray optimism. In line with the later work of Evans et al. (2009), Smith and DeCoster (1999) agree rule-based processing requires considerable cognitive aptitude because it takes effort to search for relevant information.

Smith and DeCoster (1999) acknowledge that there is no consensus on the relationships between the two processing modes. However, their review of the existing research found support for several different assumptions of this relationship: people process information using either modes but not both; the process is sequential starting with the associative mode and moving voluntarily to the rule-based mode; and both processing modes occur concurrently. Smith and DeCoster assert that rather than replacing associative processing, the rule-based mode takes place additionally and in tandem with the associative mode. Their model, developed by connecting previous research, supports the earlier assumptions of Chaiken (1980), Epstein (1994), and Sloman (1996). However, their evidence in support of this assertion is lacking. The only reasoning they provide is that the automatic function of the associative system means that it will continue to operate even when the rule-based process is activated. Based on this weak assumption, they conclude, “the two processing modes generally occur simultaneously, rather than as alternatives or in sequence” (p. 330).

A large amount of on-going research on dual-processing theories and reasoning is attributable to Evans (1996, 2006, 2007, 2008, 2013), Evans, Handley and Bacon (2009), Evans and Stanovich (2013a, 2013b), Stanovich and Toplak (2012), and Stanovich and West (1998a, 1998b, 1998c, 2000). These authors provide a concentrated body of research that has advanced the understanding of dual-processing theories, and their potential impacts on reasoning outcomes, and has initiated the use of the most recent descriptions of the two processes – Type 1 and Type 2 thinking.

In Evans’ early work (1996), he expressed doubt that the normative model of choice – the theory that before reaching a decision people consider alternative outcomes, evaluate probabilities and the utilities of each choice – is how people process information (1996). Evans’ experiments using the Wason selection task (a method that tests the truth of conditional statements) led him to challenge this notion. Evans recorded the amount of time participants in his experiments spent considering a card before making a choice among them. The most frequently selected cards were viewed for longer time periods and subjects spent little time on the cards they did not select, inferring only cards with relevant information were considered. Evans believes the card choices in these selection tasks were determined by pre-consciously cued relevance. Further, he speculates the time spent thinking is to rationalise the choice that immediately appeared the most relevant. Therefore, thinking takes place after the decision is made (Evans, 1996). This claim contradicts the normative model of choice, which requires an analysis of consequences before a choice is made, and prompted further investigation into the interaction between heuristic and analytical information processing.

In later work, Evans describes his heuristic and analytical theory of reasoning as a “simple two-stage sequential model” (2006, p. 378). In this model the heuristic process activates representations of the object or problem presented while the analytical process uses these representations to form judgements. Since analytical reasoning relied on the heuristic process, bias in reasoning could be explained by the possibility of relevant information being overlooked at the heuristic stage. This highlights the potential weakness in the analytical system in that it is context dependent and relies on the individual’s experience (Osman, 2004). The simplicity of the heuristic-analytical model prompted Evans to revise and extend it by considering three principles of hypothetical thinking.

Evans (2006) defines hypothetical thinking as involving “the imagination of possibilities that go beyond the representation of factual knowledge about the world” (p. 379). He suggests “hypothesis testing, forecasting, consequential decision making and deductive reasoning” are examples of hypothetical thinking (p. 379). Basically, the three principles of hypothetical thinking – singularity, relevance and satisficing – explain how the analytic mode works and interacts with the heuristic (intuitive) mode. Evans claims hypothetical situations are represented in one mental model at a time (singularity), and are prompted by the most relevant cue in the given context (relevance); the most believable solution is then chosen and evaluated (satisficing). The heuristic mode interacts with the analytical mode by providing the content for analytical processing. Evans, therefore, believes in two singular but interactive modes of information processing and rejects the idea that heuristic and analytical processes are parallel thinking styles. These progressions in dual-processing theories are similarly revised and summarised by Evans (2008).

Evans’ 2008 revision led him to several new conclusions on dual-processing theories. His first conclusion is that the terms Systems 1 and 2 are too simple and imply that dual processes are explicit in two distinct systems in the human brain (Stanovich & Toplak, 2012). Instead, he proposes the use of the terms Type 1 and Type 2 as they allow a clearer distinction and interaction between the dual modes of processing. His parameters for Type 2 processing are those processes “that require access to a single, capacity limited central memory resource, while Type 1 processing does not require such access” (Evans, 2008, p. 270). This allows Type 1 processing to include multiple types of processes such as those that provide identification and retrieval of explicit knowledge as well as knowledge that has become automated by experiences repeated over time.

Evan’s second conclusion is that it is a mistake to think of System 2 as a conscious, slow, and sequential process. He believes that if there is a second system not all of its workings are conscious and controlled. Evans proposes it is “perfectly possible that one system operates entirely with Type 1 processes and that the other includes a mixture of Type 1 and 2 processes, the latter being linked to the use of working memory” (2008, p. 271)

5.4 Capabilities and Interactions of Type 1 and Type 2 Processes

Stanovich and Toplak (2012) agree with Evans' distinctions of the dual process theories and their preference for using the labels Type 1 and Type 2 processing. They believe the defining feature of Type 1 processing is autonomy. That is, responses to stimuli are voluntary and independent of high-level control systems. Correlated to autonomy are the Type 1 features of speedy execution and associative responses that do not drain the central processing capacity. However Stanovick and Toplak assert these correlated features are not essential for defining Type 1 thinking, rather it is the autonomous feature that defines Type 1 thinking (2012).

In contrast, the defining feature of Type 2 thinking is its non-autonomous state and two related capabilities (Stanovick & Toplak, 2012). The first capability is that Type 2 thinking can interrupt and overpower Type 1 responses. Second, Type 2 thinking is capable of ensuring representations of the real world are not mistaken for "representations of imaginary situations" (p. 9). Stanovich and Toplak refer to these two capabilities as cognitive decoupling. Pennycook, Fugelsang and Koehler (2015) offer a similar definition of decoupling: "overriding or falsifying an intuitive response in lieu of an alternative" (p. 36). Stanovick and Toplak assert it is the ability to maintain the decoupling of secondary representations that defines Type 2 thinking. Since this cognitive decoupling is a foundational feature of hypothetical reasoning it clarifies how the Type 2 process is related to hypothetical thinking. Other Type 2 features such as effort and slower processing are considered by Stanovich and Toplak as mere correlates rather than defining features.

Thompson (2013) agrees that autonomy is the one condition of the dual-processing theories that is important because outputs from autonomous processes influence the composition of formed representations and the subsequent Type 2 processes. However, Thompson disagrees autonomy is the one condition that clearly distinguishes between the processes. Instead, Thompson argues that Type 2 processes may also be triggered automatically and that the second differentiating feature between the processes is the use of working memory, the depth of which fluctuates continually. Importantly, "this implies that Type 2 processes are defined along a continuum rather than a dichotomy and raises the question how much working memory needs to be engaged to qualify as Type 2 thinking" (p. 254). Despite the large body of work in psychology on dual-processing theories, the question of whether Type 2 processing takes place on a continuum needs further evidence and experimental replications before being a generalizable theory.

Two other prominent authors from psychology who believe dual-processing exists in two separate but interactive modes are Kahneman and Tversky. They devoted many years of study and experiments to testing and examining dual-processing theories and were recognized internationally for this work when Kahneman received a Nobel Prize in Economic Sciences in 2002. Kahneman (2011) provides explanations of how and when Type 1 and Type 2 thinking processes interact and the degree of influence Type 1 thinking has on human judgements and choices. Kahneman asserts that Type 1 thinking is much more influential and controlling than is generally understood. He explains how Type 1 thinking 'jumps to conclusions' to produce the best possible answer from limited information, a phenomenon he names "WYSIATA: what you see is all there is" (p 86). The reasoning process does not go beyond the stimuli or information that are presented and relies rather on what is already familiar or known. WYSIATA is also responsible for biases such as overconfidence in the intuitive outcome, supressing recognition of framing effects, and base-rate neglect where statistical facts are ignored in favour of an intuitive response (Kahneman, 2011). This finding has implications for the outcomes of surveys investigating public reaction and opinions. If framing effects are not recognised and base-rates ignored in calculations then survey responses are unlikely to represent public opinion.

Kahneman (2011) also believes Type 1 thinking often leads to inaccurate outcomes due to the human mind being unduly influenced by recent stimuli. Intuitive Type 1 thinking can also allow the mind to overlook missing information or make easy substitutions for difficult questions. As well as explaining the controlling influence of Type 1 thinking, Kahneman (2011) clarifies when Type 2 thinking is likely to be activated. Kahneman maintains the "main function of Type 2 thinking is to monitor the thoughts and actions suggested by Type 1 thinking" (p. 44). Type 2 thinking is also employed when people are faced with difficult tasks. However, finding analytical solutions requires the use of a scare resource, mental energy. In these circumstances Kahneman believes Type 2 processing becomes busy, depleted and 'lazy' (Stein, 2013). The 'laziness' associated with Type 2 thinking is another reason why intuitive answers are able to dominate people's decisions.

5.5 The Accuracy of Type 1 and Type 2 Outcomes

Although there is uncertainty about when Type 1 and Type 2 thinking is used, several studies support the idea that judgements made using deliberative thinking are more accurate than judgements using intuitive thinking (Evans & Curtis-Holmes, 2005; Kahneman, 2011; Mata, Ferreira & Sherman, 2013; Moxley, Ericsson, Charness & Krampe, 2012; Stanovich et al. 2010).

Some authors in psychology argue that an individual’s cognitive ability has an effect on each type of information processing. Evans et al. (2009) believe unconscious Type 1 thinking processes are not related to general intelligence and working memory capacity, even though they have high computational capacity. In contrast, they suggest the effort required by Type 2 processing draws on central working memory structures and therefore is relative to an individual’s differences in cognitive ability. In their experiments, Stanovich and West (1998) found higher cognitive capacity increases the likelihood of a correct normative response.

Conversely, other studies support the claim that unconscious thought, or intuition can lead to accurate choices. Dijksterhuis, Bos, Nordgren and Baaren (2006) believe their four experimental studies showed that ‘deliberation-without attention’ leads to better choices in complex decisions. Work by Gigerenzer and Brighton (2009) also disputes the logic that deliberative cognitive processing increases accuracy. Instead, they reason it is the use of simple heuristics linked to the environment that provides more accurate cognitive processing. This belief is founded on situations where higher accuracy is achieved with less effort – the ‘less is more’ principle. One longitudinal study found that automatic attitudes showed more predictive power than deliberative evaluations (McNulty, Olson, Meltzer & Shaffer, 2013). These conflicting beliefs suggest further research on whether greater deliberation provides greater accuracy in cognitive processing is vital.

In addition to supporting the existence of dual processing, Evans and Curtis-Holmes (2005) expand on the characteristics that differentiate the two types of reasoning. They believe there is friction between the two processes as each process seeks to control responses in reasoning tasks. They also believe the key difference between the two types of processing is the speed of processing. Type 2 processing is slower than Type 1 processing because the analytical process is limited by the capacity of central working memory, while Type 1 processing does not have this restraint.

Evans and Curtis-Holmes (2005) confirm the effect of belief bias on responses and provide evidence for the dual-process theory of reasoning. They believe belief bias occurs when evaluations of the validity of an argument are based on agreement with the conclusion rather than the logic of the argument. By comparing performance under rapid-response and free-time tasks Evans and Curtis-Holmes demonstrated rapid responses (those made in less than

10 seconds) increased belief bias and reduced logical responses in syllogistic reasoning. These results were expected as the dual process theory posits fast intuitive processes inhibit and "compete with slower analytical processes that can lead to correct logical decisions" (p. 382). Belief bias effects that result from time constraints in the reasoning process, therefore, provide evidence that dual-processing in reasoning occurs and that hasty intuitive responses are less accurate than responses that use a slower more deliberative process.

The research by Evans and Curtis-Holmes (2005), reviewed in the previous paragraph, implies intuitive responses are less likely to be corrected when people respond quickly. Earlier research by Petty and Cacioppo (1991) blamed cognitive load for an individual's failure to recognise their incorrect responses. Other research pointed out that accountability for decisions and the personal relevance of the outcome are more likely to lead to corrected responses (Chaiken, 1980). However, as Alter, Oppenheimer, Epley and Eyre (2007) point out, understanding what influences and limits intuitive responses does not address when deliberative thinking is activated.

Studies on how to encourage and measure deliberative thinking are less prevalent. One established proxy for measuring Type 2 thinking is the time taken to respond to questions. Although the exact point of time when deliberate thinking occurs is unquantifiable, it is possible to observe that greater analytical processing takes place when subjects are given increased time to answer questions, and it is possible to identify an approximated time period where an increase in analytical processing changes respondents' perceptions (e.g. De Neys 2006; Evans & Curtis-Holmes 2005; Kahneman 2011; Thompson et al. 2011).

5.6 Motivating Drivers for Type 1 and Type 2 Thinking

5.6.1 Drivers of Type 1 thinking

Research suggests that Type 1 thinking, or heuristic outputs, is an outcome of fast responses (De Neys 2006b; Evans Curtis-Holmes, 2005; Thompson, Prowse Turner & Pennycook, 2011). When forced to respond quickly reasoners are more likely to respond based on a believable conclusion in contrast to unrestricted response times where there is time to consider all the information and alternatives (Evans & Curtis Holmes, 2005). Also supporting the likelihood that fast responses force Type 1 thinking is research in neuroscience that found brain activity in the interior frontal cortex (the source of belief-based inhibition) was more engaged when participants were forced to respond quickly than when they were not (Tsujji &Watanabe, 2010).

5.6.2 Drivers of Type 2 thinking

Other research suggests the degree of involvement of Type 2 thinking is dependent on clarity and consistency of instructions (Daniel & Klaczynski, 2006), the amount of time allocated to thinking (Evans Curtis-Holmes, 2005), and an individual's characteristics (Stanovich & West, 1998; 2000). Importantly, Pennycook, Fugelsang and Koehler (2015) suggest that separating the lower level actions that lead to Type 2 processing helps understand the dynamic relationship between the types of processing.

5.7 The Effects of Meta-cognition on Reasoning Outcomes

The effects of cognition on reasoning outcomes is the focus of several studies in psychology and has shown that humans frequently make unexpected judgements that are contrary to normative standards. In reasoning tasks, the law of probability posits that a conjunction of two events cannot be greater than either of its components. In their experiments, Tversky and Kahneman found 80% of university students disregarded the conjunction rule and gave incorrect responses.

Much of the work undertaken by Stanovich and West (1998a, 1998b, 1998c, 2000) examined the impact of an individual's cognitive capacity when responding to traditional reasoning problems (De Neys, 2006b). Their studies assessed participants using standard cognitive ability tests and found those with higher cognitive capacity were more likely to provide the correct response (De Neys, 2006b). However, a large working memory might cause both correct responses and higher cognitive capacity. Stanovich and West reasoned that in some cases correct responses could be expected as "the more resources that are available, the more likely that the analytic system will be successfully engaged and the correct response calculated" (De Neys, 2006a, p. 1072). De Neys, however, points out a weakness in Stanovich and West's findings by challenging their assumption that correlations with higher cognitive capacity result in correct responses. Correlations do not establish causality. Instead, De Neys believes that Stanovich and West's findings indicate that choosing the correct analytical response is linked to having a large working memory capacity. However, this does not confirm working memory is a requirement for the calculation of correct responses. Other factors might be responsible for positive associations (De Neys, 2006a).

To test the claim that burdening working memory capacity affects cognitive performance De Neys (2006b) ran a series of experiments that required participants to undertake secondary tasks. De Neys took a secondary task approach based on the previous arguments of Sloman (1996) that cognitive load should differentiate between reasoned and automatic responses. Therefore, De Neys rationalised, correctly reasoned responses would decrease under cognitive loading as fewer resources would be available; and, conversely if the heuristic system operates automatically, heuristic responses would not decrease under secondary cognitive loading. One of the ways De Neys tested this claim was to impose a secondary tapping task while participants reasoned a primary problem solving task. Participants were asked to use their non-dominant hand and tap a sequence with their index, middle, and little finger while problem solving. The results confirmed burdening memory resources while solving problems decreased participants correct scores on problem solving tasks.

De Neys (2006a) believes his consistent findings over many similar experiments support dual-processing claims that the analytic (Type 2) system draws on working memory resources, while the heuristic system operates automatically. Further, De Neys' work supports the claim that when analytic reasoning becomes too difficult, reasoners do not make a random guess, rather their responses will be overpowered by the more dominant heuristic system (Type 1). Other secondary tasks participants in De Neys' experiments were required to undertake included asking them to remember visual dot patterns with different manipulations for different groups, and recording the time taken to give a response after reading italicised text. This latter experimental condition established that making correct analytic responses required more processing time than making heuristic inferences (De Neys, 2006a).

Some studies suggest meta-cognitive difficulty is a cue that activates analytical reasoning or more deliberation. Alter et al. (2007) used Frederick's (2005) Cognitive Reflection Test (CRT) on a sample of 40 university students as a pilot to test the difficulty of their proposed research tasks. Frederick had previously established, through 35 studies with 3,400 subjects, that CRT scores were highly correlated with various measures of analytical thinking. Participants in Alter et al.'s next three experiments received information in degraded font, difficult to read lettering, and a third condition of maintaining a furrowed brow while reasoning. Control groups in each experiment did not experience the test conditions. In all experiments those participants who were given more difficult tasks scored more highly on the CRT test than those without the difficult tasks. These findings suggest that if meta-cognitive difficulty is experienced when people are reasoning, they are more likely to engage in deeper evaluations and “overcome invalid intuitions to answer more questions correctly” (p. 570).

A study by Thompson et al. (2011) also investigated the effects of meta-cognitive difficulty in reasoning tasks. However, the main purpose of their work was to determine when more deliberative engagement takes place in the reasoning process and when does reliance on the first intuitive response suffice. By drawing on metacognitive reasoning theory, Thompson et al. posit people have the ability both to retrieve information from memory and to monitor that information. Importantly, these are two distinct processes. Monitoring information involves a cognitive self-assessment or a feeling of rightness about an answer. Thompson et al. claim this feeling of rightness can determine the depth of Type 2 thinking. The feeling of rightness that accompanies Type 1 processing is an indicator of whether or not the Type 2 output is sufficient or whether more deliberation (Type 2) time is needed.

Over four experiments, Thompson et al. (2011) used item-specific cues to trigger Type 2 thinking and asked participants for an initial response, and then asked them to evaluate how confident they were that the initial response was correct. The first two experiments tested that the relationship between the feeling of rightness and Type 2 engagement was not attributable to the task parameters of the experiment. The results showed that that when a feeling of rightness accompanied an initial intuitive answer, further deliberation is less likely to take place. However, if the feeling of rightness of an intuitive answer is low, then further deliberation and a change of answer is more likely. Even when encouraged, engagement with Type 2 thinking is not guaranteed. Thompson et al. observed that when there was an opportunity to alter answers in many cases respondents’ first instinctive answers remained unchanged. Nonetheless, Thompson et al.’s study suggests that no matter how reasoning is processed a feeling of rightness about the outcome determines the quality and extent of Type 2 thinking.

While a great deal of the research reported in this chapter uses different terms to describe dual-processing theories – showing there is dissent on when and how these systems interact – there is some agreement among these same researchers about the existence of two distinct memory systems and a general consensus on their distinguishing characteristics. However, several researchers do not agree with dual-processing theories and their arguments are presented in section 5.8.below.

5.8 Arguments Against Dual-theories of Information Processing

Reder, Park and Kieffaber (2009) argue that the unconscious characteristic of implicit (Type 1) memory does not justify it being treated as a separate system of human memory. They explain that the dual-processing theory proposes that performance on implicit (stored experiences that subconsciously affect behaviour) and explicit (stored experiences that can be consciously recalled) memory tasks are thought to be an indication of two distinct memory systems. Reder et al. believe this is a fallacy and reason that the unconscious characteristic of implicit memory does not require a separate system of memory to operate. They also assert that “some implicit and explicit memory tasks share the same memory representations” (p. 23) therefore the key distinction between implicit and explicit memory is whether the required task demands a new association.

Evans and Stanovich (2013b) acknowledge and counter-argue five key criticisms made against dual-processing systems. The first criticism is that there are multiple and ambiguous definitions of dual-processing systems. The most obvious is the systems’ distinguishing characteristic of conscious/unconscious making it difficult to test empirically. Evans and Stanovich agree consciousness is difficult to define and that both Type 1and Type 2 processes can have non-conscious or conscious elements; however, there is insufficient rationale to say there are not two systems of cognitive processing. In further defence of this criticism, Evans and Stanovich point out their work is often misunderstood. This misunderstanding is caused by authors who have not recognised the distinction between the defining and the correlated features of the two processes.

A second criticism made against the dual-system of processing, is that if there are two cognitive systems with a group of defining attributes, the different features of the group definitions are not always seen collectively, implying there is not two systems (Keren & Schul, 2009). Evans and Stanovich (2013b) counter-argue that not all the features used to define dual-processing systems have to be present in order to distinguish each system and assert it is highly unlikely all the various published distinguishing features would be observable at the same time. Evans and Stanovich refer to the Type 1 and Type 2 terms and reiterate that these terms indicate qualitatively different forms of processing; however, they also contend that numerous cognitive systems may underlie them.

A third criticism of dual-processing systems is that they are not discrete types instead there is a continuum of processing and therefore only one system (Osman, 2004). Evans and

Stanovich (2013b) counter this argument by explaining the differences between the terms mode and type to show there is a continuum of processing styles that should not be confused with types. According to Evans and Stanovich, modes vary continuously and are actually different cognitive styles used in Type 2 processing. For example, an analytical processing style could be slow and careful, or quick and casual, or somewhere in between (Evans & Stanovich). In contrast, types do not vary, although they are different from one another. The implication that cognitive processing continues in some contexts is not a reflection of type; instead it is likely a reflection of different cognitive styles (Evans & Stanovich).

The fourth criticism about dual-processing theories relates specifically to the rule-based definition of cognitive processing that led Kruglanski and Gigerenzer (2011) to assert that information is processed using a 'uni' or single cognitive system. Their argument to support the existence of only one system is that "both intuitive and deliberative judgments are rule-based opposed to the dual-systems approach of qualitatively different processes" (p. 106). Evans and Stanovich (2013b) dispute this logic. They believe the assertion that both systems use the same rules for information processing does not have any bearing on whether the systems are distinct cognitive mechanisms.

The fifth criticism of dual-processing models relates to concerns that the evidence for dual-processing is weak as well as ambiguous. To provide supporting evidence for dual-processing Evans and Stanovich refer to other studies. In an experimental approach, under time pressure, or simultaneous working memory load, participant's belief bias increased and logical accuracy decreased (Evans & Curtis-Holmes, 2005; De Neys, 2006a). An expected reaction to time pressure and working memory overload might be guessing and random error. However, Evans and Curtis-Holmes' study reported they observed opposite effects on accuracy and beliefs.

Evans and Stanovich's second reason for supporting dual-processing is the work in neuro-science. They refer, in particular, to the work of Lieberman (2007) and De Neys, Vartanian and Goel (2008) that used neural imaging to show that different brain activation takes place when reason-based and belief-based responses occur. Evans and Stanovich believe these neuroscientific findings are entirely consistent with the dual-process theories that propose Type 2 thinking often defaults to Type 1 thinking. Evidence for this claim is also provided by Greene, Nystrom, Engell, Darley and Cohen (2004) whose study found that when moral consequential reasoning overrode the 'right action' participants took longer to respond.

Similar to De Neys et al., they observed that the area of the brain associated with emotion displayed more activity, suggesting the individuals in these trials were using Type 2 processing to override Type 1 processing via the area of brain that produces emotion.

To conclude on their reasons for supporting two types of cognitive information processes Evans and Stanovich (2013b) acknowledge that the definitions and characteristics suggested in the past need amending. They now believe only the two characteristics shown in Table 2 are necessary to make the distinction between dual-processes and that these characteristics will avoid the ambiguity and confusion over whether or not there are two distinct information processes.

Table 2: Type 1 and Type 2 processing characteristics

Type 1 process (intuitive)	**Type 2** process (deliberative**)**
Does not require working memory	Requires working memory
Autonomous	Cognitive decoupling: mental stimulation

Source: Evans and Stanovich, 2013b, p. 225.

5.9 Three Stages of Dual-processing

A recent study adds another perspective to the dual-processes described in the previous sections by speculating there are three stages of dual-processing (Pennycook, Fugelsang & Koehler, 2015). Pennycook et al. investigate the issue of determining when an individual thinks analytically or is relying on intuition. They propose a three-stage model that explains the factors that encourage Type 2 thinking. Stage 1 involves motivating Type 1 thinking with a stimulus that leads to potential conflict detection (Stage 2). Once thinking starts conflict detection leads to Type 2 processing (Stage 3). By using base-rate problems with short response times in conditional experiments Pennycook et al. claim they separated conflict detection and decoupling processes. This allowed separation and identification of failed analytic engagement and failures due to response inhibition – two conditions that are often used as explanations for the biases found in reasoning and decision making (Pennycook et al., 2015).

Pennycook et al. (2015) acknowledge that bias can arise from both sources depending on contextual or individual difference factors; however, their interest centred on which type of failure is most common in which situations. Their experiments suggest that complex reasoning problems are influenced by failures of analytical engagement because competing intuitions are low. Conversely, in less complex reasoning problems bias appears to be the result of inhibition failures rather than failure of analytic engagement (Pennycook et al., 2015). Overall, Pennycook et al. concede more testing of this model is required; however, they are confident the model predicted Type 1 outputs are linked to speed of processing, and that these Type 1 outputs partly determine what happens later in the reasoning process. If replicated, this model could help explain further the influence of Type 1 thinking on Type 2 processing, a gap in knowledge that remains unresolved.

5.10 Chapter Conclusion

The dual-theory of information processing has developed over many decades. The processes are characterised by a variety of terms that are ambiguous and confusing. However, there is general agreement that the two processes can be broadly described as one type that is fast, automatic, effortless, and intuitive and a second type that is slow, conscious, requires effort, and is deliberative. Research by Evans (2008) concluded it is possible one system operates using Type 1 processing and the second system may operate using a mixture of Type 1 and Type 2 processing. Stanovich and Toplak (2012) believe the difference between the systems is that Type 1 responses to stimuli are voluntary and independent of high-level control systems (autonomous). In contrast, Type 2 processing is non-autonomous and has two capabilities. The first capability is cognitive decoupling – the ability to override Type 1 thinking – and the second capability is that type 2 processing can ensure the representations of the real world are not imaginary. Thompson (2013) agrees with the autonomy distinction but proposes that a second distinguishing characteristic between the processes is that, unlike Type 1 processing, Type 2 processing needs to draw on working memory, the depth of which continually fluctuates. Critically, this implies Type 2 processes take place along a continuum rather than as a dichotomous process and raises the question of how much engagement with working memory constitutes Type 2 thinking.

While there is strong support for two types of cognitive processing it is still unclear when either mode of processing is taking place. Some research agrees Type 1 thinking can override Type 2 thinking especially if the task is too difficult (Kahneman, 2011). A number of studies claim that the Type 2 reasoning produces more accurate outcomes than than Type 1 reasoning, although other studies do not support this finding and argue it is an individual's cognitive ability that has an effect on each type of processing. Similarly, some authors argue unconscious intuitive thinking can lead to accurate choices, and that simple heuristics linked to an individual's environment provides more accurate cognitive processing. One study found higher accuracy is achieved with less effort, and another found automatic attitudes showed more predictive power than deliberative evaluations. Other research has posited inaccuracies in information processing occur because the reasoning process does not go beyond what is known or presented in the stimuli, particularly recent stimuli which may have undue influence of information processing (Kahneman, 2011). The accuracy of either type of cognitive processing on outcomes is still an uncertain area of research.

Some authors dispute the existence of dual-processing. Instead, these authors argue information processing is carried out in a single cognitive system. One belief is that the unconscious characteristic of implicit memory does not necessitate a separate system of memory to operate. Another claim used to support a single system is that as there is a continuum of processing, only one system exists. These and other criticisms of dual-processing are strongly countered, based on the reasoning that some researchers have treated the definitions used to explain the processes as correlates rather than as defining features. Another counter-argument is provided by neuroscientific findings that suggested individuals took longer to decide and displayed more activity in the emotional area of the brain during trials where subjects were using moral consequential reasoning to override the ‘right action’.

Several studies have used various techniques as proxies to measure deliberative thinking; however, none of these has successfully or irrefutably established the exact point in time when deliberate thinking occurs; although some authors assert it is possible to approximate the time period when greater analytical processing takes place if subjects are allowed increased time to answer questions (De Neys, 2006; Evans & Curtis-Holmes; Kahneman, 2011; Thompson et al, 2011). Some of the reported measures of deliberative thinking consist of loading working memory with difficult or secondary tasks when seeking a response; for instance, tapping while solving a problem, remembering manipulated dot patterns, presenting information in degraded font, or maintaining a furrowed brow. Recording the time taken to perform these tasks and comparing subjects with those who were not subjected to secondary loading provides a measure of deliberation. Other research has separated Type 2 thinking by forcing rapid responses. The time taken to provide responses to questions is, therefore, used as a measure of deliberative responses in Stage 3 of this research, the online surveys.

A recent study proposed a three-stage model of dual-processing (Pennycook et al., 2015). This work disentangled conflict detection the second stage proposed in their dual-processing model (Stage 1 involves the use of a motivating stimulus) and decoupling processes (a defining feature of Type 2 processing). Type 2 processing is considered stage 3 in Pennycook et al.'s model. While further work on this model is required, Pennycook et al. believe that it predicted Type 1 outputs are linked to the speed of processing which partly determines what happens later in the reasoning process.

While much work on defining the distinctive properties of the dual-system of information processing has taken place, there is still a major gap in knowledge of how the processes interact and the point of time when deliberative responses are taken place. The accuracy of outcomes from deliberative (that they are more accurate than heuristic or intuitive thinking) is both supported and refuted. Work in this very important area of research continues.

5.11 Relevance of the Literature Findings to the Research Questions and Approaches

To answer the question of whether marketing research methods can improve upstream science communication, the literature reviewed in Chapters two to five investigates two key areas of research. These are science communication, particularly in the context of climate engineering, and marketing methods that have the potential to allow an assessment of public perceptions at a concept's development stage (upstream rather than when research and development decisions have taken place, or social representations are already formed).

An appropriate scientific context to investigate this question is global warming and its environmental impacts. Past solutions to global warming have included mitigation and adaptation. Recently, climate scientists have proposed various solutions under the umbrella term, 'climate engineering'. A majority of the proposed climate engineering solutions are still hypothetical concepts, untested outside laboratories, relatively unknown to the general public and with unknown side effects, making them an appropriate science communication topic and upstream context to use in this research.

Providing the appropriate information to the public and involving them early in the process requires constructive debate through engagement processes and the literature in Chapter four revealed that among social scientists and experts in science communication there is little consensus on which method best engages the public, and little empirical evidence that shows outcomes from public engagement with new science and technology is included in policy decisions. These findings reveal a gap in the science communication literature and the need for methodologies that allow upstream engagement with hypothetical concepts.

A second gap in the science communication literature was also revealed in Chapter four. Social scientists are recommending not only that public engagement should be upstream but it might also be desirable for it to be deliberative. The few studies that have engaged the public with climate engineering were reviewed in Chapter two. Some of these studies were described as deliberative workshops but it is unclear what constitutes deliberation as no measures of deliberation were applied to responses in these workshops, rather it is assumed that the discussions in the workshops were deliberative because they took place over a period of more than one day and on more than one occasion. The purpose of chapter five, therefore, was to investigate whether the theory of dual processing of information could provide a method for determining if intuitive or deliberative thinking has any effect on concept evaluations. The literature on the theories of dual-processing demonstrated several researchers have used time, or secondary tasks, and cognitive overload to determine whether intuitive or deliberative thinking is taking place. Subsequently, this research used time and the number of commenters as a proxy for investigating whether greater deliberation has any effect on concept evaluations.

To summarise, the science and climate engineering literature provided in Chapters two and four revealed that public perceptions of climate engineering is very recent, limited in amount, and restricted to a few countries, mainly in the northern hemisphere. This research fills that gap of knowledge by measuring and benchmarking public perceptions of climate engineering in New Zealand and Australia, the first climate engineering research to take place in the southern hemisphere (reported in Chapters six and seven).

The research also contributes to filling another highlighted gap in the science communication literature – the uncertainty of which method is appropriate to encourage public engagement in the concept generation phase by providing novel qualitative and quantitative methods (reported in Chapters six and seven) that allow upstream engagement with hypothetical concepts. The findings reported in Chapter eight have explored the issue of whether evaluations of concepts use intuitive or deliberative thinking, and importantly whether these evaluations change with greater deliberation. However, the findings on the effects of intuitive and deliberative thinking on concept evaluations reported in Chapter eight are exploratory and will require replication along with the use of a wider variety of measures than the time taken to form responses, and testing across a variety of conditions before becoming substantiated research.

To answer the second part of the overall research question of how marketing research methods can help facilitate upstream science communication, the literature in Chapter three examines specific marketing methodologies. Marketing academics have long used the Associative Network Theory of Memory (ANTM) to conceptualise how brands, or concepts, are stored in memory and how this information is processed. The literature demonstrated how applications of this theory have been developed and extended in marketing and how associations with concepts can be measured to form conceptual images. The ATNM research and applications justify the use of concept imaging as an appropriate approach to measure hypothetical scientific concepts.

As concept imaging requires a list of common attributes to evaluate the literature in Chapter three also investigated the strengths and weaknesses of methods of attribute elicitation. The reviewed literature provided strong evidence that most methods of attribute elicitation have convergent validity, and that the choice of elicitation method is dependent on the purpose of the research. The two elicitation methods chosen are discussed in Chapter six and the use of the two methods confirm the robustness of each method. The chosen methods were useful for eliciting attributes in a scientific, rather than marketing context, confirming their convergent validity across disciplines.

The thesis now proceeds with four chapters and a final concluding chapter. The following four chapters are separate stages of research but are structured in corresponding sections consisting of: specific research questions; justification for the methodology; the specific method; results; discussion; and a limitations and future research section.

Chapter Six: Stage One – Qualitative Attribute Elicitation

6.1 Stage 1 – Research Question

To explore public perceptions of climate engineering the first step is to elicit the most salient attributes associated with climate engineering as Stage two of this research uses attribute association counts to evaluate some potential climate engineering concepts. The specific questions to answer in stage one are:

- What is the most salient set of attributes naturally evoked by the concept of climate engineering technologies for members of the public?
- Are there common perceptions of climate engineering techniques?

6.2 Justification for Stage One Methodology

Stage one of this research uses qualitative methodologies to explore the public's perceptions of climate engineering and develop a list of the concept's salient attributes. As qualitative research is considered exploratory and insightful, rather than a specific measure of human behaviour (de Ruyter & Scholl, 1998) it is deemed a suitable approach at this first exploratory stage. On the other hand, a weakness of qualitative research is that it usually has insufficient sample numbers to allow representative claims, and the opinions expressed are therefore unlikely to represent the opinions of the wider population under examination. However, careful target group selection and a classified sample can ensure a wide range of views and opinions are given consideration. "Representativeness of the results in accordance with the subject of investigation, not in the research population, is what counts" (de Ruyter & Scholl, p. 8).

A second reason why this approach is appropriate for stage one is that qualitative research is flexible. Qualitative research allows the researcher to respond during the interaction and, if appropriate, alter the direction of the conversations with participants to uncover new or unexpected insights (de Ruyter & Scholl, 1998). The researcher can confirm answers, seek elaboration, and probe the reasoning behind responses, thus allowing richer insights than quantitative methods. As this first stage seeks to elicit attributes naturally evoked by a new and controversial science, the flexibility of qualitative research makes it an appropriate methodology.

In this stage of the research the objective of attribute elicitation is to obtain personally relevant attribute sets. Attributes are elicited by various methods that prompt and identify related concepts from an individuals' knowledge structures (Steenkamp & Van Trijp, 1997). Previous research suggests that if instructions are held constant and focussed on choice then method effects are minimised regardless of which attribute elicitation method is used (Breivik & Supphellen, 2003). Breivek and Supphellen believe associated attributes are salient in participants' memories and easily evoked by all methods of attribute elicitation. Research has suggested there are two types of attributes. One type is evaluative because consumers draw on previous brand experience. Obviously, evaluative attributes make the distinction between past users and non-users of a brand. The second type of attribute is descriptive, and if common to a category such attributes are used to elicit associations from users and non-users of brands or hypothetical concepts (Hoek, Dunnett, Wright & Gendall, 2000). Since the purpose of this research is to determine public perceptions of relatively new scientific concepts, descriptive attributes and two elicitation methods that identify perceptual attributes were selected. A Pre-determined List of Attributes and Kelly's Repertory Grid were used to validate the most common attributes associated with the climate engineering techniques presented in semi-structured face-to-face interviews (Breivik & Suphellen, 2003; Fransella, Bell & Bannister, 2004).

Pre-determined lists of attributes require the researcher to generate a list of attributes. While this lessens the chance of idiosyncratic wording, it increases the risk that the attributes will reflect the language of the researcher rather than the respondent. The task is easy to administer and relatively easy for the respondent to complete (Bech-Larsen & Nielsen, 1999).

Kelly's repertory grid is built on personal construct theory. This theory advances the idea that individuals personalise objects or brands as a construct. The construct is evoked by asking the respondent to choose a pair from three brands or concepts and say why the pair is alike yet different from the third. The process is repeated with all the brands or concepts until no new attributes are generated (Bech-Larsen & Nielsen, 1999; Rogers & Ryals, 2007; Steenkamp & Van Trijp, 1997).

This method was chosen to counter the weaknesses of Pre-determined lists by identifying gaps in the terminology not listed, and allowed final language choices to reflect the respondent's vocabulary. Previous research has shown most brand associations are at the sub-conscious level (Supphellen, 2000). Attribute associations may not emerge if they are at a respondent's subconscious level; however, a second advantage of Kelly's repertory grid is that it allows underlying constructs to surface when brands, or concepts', similarities and differences are examined.

Focus groups were considered as a method of attribute elicitation but rejected for this first stage as the interest is in exploring individuals' underlying cognitive constructs. Climate engineering techniques are controversial, with many associated risks and unknown side effects, and are likely to produce robust group debate where dominant individuals may supress the views of others. Individual semi-structured interviews were adopted for data collection in this phase as they overcome the bias inherent in focus groups and allow for the depth of discussion required to identify cognitive associations.

6.3 Stage 1 Method

6.3.1 Sample Recruitment

Stage one used a convenience sample of 30 participants who were recruited from contacts known to the researcher during June and July 2012, in a region of the lower North Island of New Zealand. During recruitment care was taken to ensure there were an equal number of men and women, and a wide range of age, education, and occupations. Each elicitation technique was randomly assigned to 15 participants in face-to-face interviews with the order of the four presented concepts randomly rotated.

6.3.2 Field Work Procedures

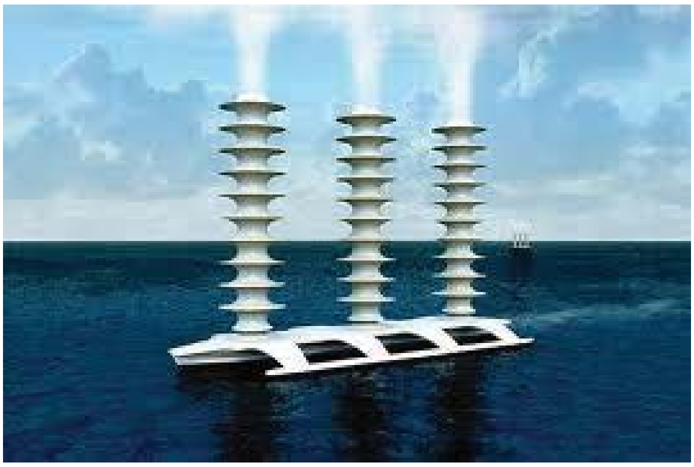
Participants in both methods were given a verbal introduction to climate warming and climate engineering, and then presented examples of climate engineering techniques on laminated concept boards, typically used for assessment of new products (Lees & Wright, 2004). Each concept board displayed a colour image, a brief description of the concept on one side and a list of known advantages and disadvantages on the other side. An example of the two sides of the concept board is shown below (the other three concepts boards are placed in Appendix A).

6.3.3 Side 1-Cloud Brightening Description and Image

Cloud Brightening

- Clouds appear brighter when they are made of tiny droplets than of fewer, bigger droplets

- By spraying small seawater droplets into the air over the sea, it is possible to create more cloud and so increase the reflectivity of clouds
- One idea is to use specially designed automated ships to spray the seawater
- The most effective places in terms of cooling are over the west coast of North and South America and the west coast of Africa



Adapted from Vaughan & Lenton (2011).
Image source: MacNeill, J. 2011

6.3.4 Side 2 Cloud Brightening Pros and Cons

Pros

Could start reducing temperatures in a short time period.
Easy to turn off if there is a fault.

Cons

It may not be as effective at reducing temperatures as predicted.
Effects may only last a few days or weeks so it would need to be carried out repeatedly which would cost money and take time.
It would cause a lot of cooling in a very localized area.
It may have unwanted effects on the weather and sea life.
It may reduce or change the patterns of rainfall in other areas.
Other impacts of rising carbon emissions still remain e.g. increasing ocean acidification.

The descriptions drew on the climate engineering techniques presented in the Experiment Earth deliberative workshops (2010) and later work in this area (Parkhill & Pidgeon, 2011; Vaughan & Lenton, 2011). Four climate engineering techniques – Biochar, Air Capture, Cloud Brightening, and Stratospheric Aerosols – were chosen to represent two Carbon Dioxide Removal techniques and two Solar Radiation Management techniques; however, the classifications were not revealed to the participants. These techniques have continued to be to be subject to discussion, criticism and refinement; for example, Latham et al., (2012) noted several major problems for marine cloud brightening which may or may not be capable of resolution. The subsequent refinement of scientific concepts is to be expected when engagement is moved upstream.

6.3.4 Pre-determined List of Attributes Method

The list of 30 attributes used in this method was derived from a content analysis of citizen dialogue reported in the Experiment Earth deliberative workshops (2010). The final list of attributes was peer reviewed by independent experts and the questions were pre-tested on three volunteers. The presentation order of the concept boards was rotated amongst the 15 subjects who were asked: "Which of these attributes do you personally think are associated with <x>". Subjects were able to select as many attribute descriptors as they wished. The freedom to pick any attribute that is associated with the presented technique is a form of sorting task. Nenycz-Thiel et al. (2010) believe this approach best replicates the cognitive retrieval process compared with forced-choice techniques such as ranking and rating. The selected attributes were then totalled across all 15 interviews. The list of 30 attributes used in this process can be viewed in Appendix B.

6.3.5 Kelly's Repertory Grid Method

Presentation in this method differed in that the 15 participants were shown three concept boards at a time (four combinations in all) with the order randomised and asked the following questions: "Which two techniques are different from the third?"; "What qualities do the two techniques have in common?"; "What are the opposite qualities the third technique has?" If few, or no new, descriptors of the techniques were specified this fourth question was asked: "Imagine that you could donate $40 dollars to support research on one of these techniques. What are the important qualities you would look for to help you choose which technique to support?" The answers were written down by the researcher and then read back to the subject for confirmation. After 10 completed interviews, no new attributes were generated, thus the attribute list was deemed exhaustive. The attributes from individual subjects were then collated into groups and totalled across all 15 interviews.

6.4 Stage One Results

6.4.1 Qualitative Sample Demographics

The stage 1 sample demographics were closely matched between the samples for age and gender. Overall gender was evenly split 47% males and 53% females with ages ranging between 18 and 77 years. Occupations varied with education levels spread from no formal school qualification to post-graduate degrees. A full demographic table for this sample is found in Appendix C.

6.4.2 Predetermined List of Attributes

Table 3 shows the top 24 associations from in-depth interviews using a Pre-determined list of attributes, ranked in order of popularity. This gives a sense of the memory structures most readily evoked by climate engineering, and thus a guide to the most likely public reactions.

Table 3: Pre-determined list attribute associations

Attribute	**Number of Associations**
Good for the planet	22
Risky	22
Ingenious	21
Beneficial	20
Engineered	19
Artificial	18
Controversial	18
Unpredictable	18
Too expensive	17
Feasible	17
Understandable	16
Visually Cumbersome	15
Interfering	13
Reversible	12
Constructive	12
Effective	12
Quick fix	12
Necessary	11
Unbalanced	11
Band-aid	11
Harmless	11
Unrealistic	11
Dangerous	10
Not easy to regulate	10

The maximum number of possible associations for each attribute is 60 (15 respondents × 4 techniques). No attribute has more than 22 associations, indicating a reasonable spread of perceptions across attributes. Positive and Negative attributes show mixed popularity.

Table 4 breaks the attributes down by the general class of climate engineering technique. Biochar and Air Capture are classified as Carbon Dioxide Reduction (CDR) techniques, and Cloud Brightening and Stratospheric Aerosols are classified as Solar Radiation Management (SRM) techniques. To enhance readability, Table 2 reports only the 12 most popular associations for each class of technique.

Table 4: Comparison of associations across climate engineering techniques

Carbon Dioxide Reduction		Solar Radiation Management	
Good for planet	18	Risky	19
Controllable	17	Unpredictable	17
Beneficial	16	Artificial	14
Feasible	15	Too expensive	11
Ingenious	14	Controversial	11
Understandable	12	Engineered	11
Effective	10	Unbalanced	10
Constructive	9	Dangerous	10
Harmless	9	Unrealistic	10
Visually cumbersome	9	Interfering	9
Necessary	8	Quick Fix	9
Engineered	8	Band-aid	8

This shows a striking result – that the most popular associations for CDR are predominantly positive, while the most popular associations for SRM are all negative.

6.4.3 Kelly's Repertory Grid

Table 5 shows 22 associations from the interviews using Kelly's repertory grid, ranked in order of popularity. The memory structures most readily evoked by climate engineering are similar to the pre-determined list associations in that there is a mix of positive and negative associations. However, while many of the attributes may have had similar meanings for the subjects across the two methods, some language terms used are different. For instance, 'visually cumbersome' was a term chosen from content analysis by the researcher, but in the Kelly's repertory grid method subjects used the term 'eyesore'. What is more, Kelly's repertory grid allowed underlying constructs to be disclosed. Themes that emerged from this method that were not stimulated in the pre-determined list of attributes method were 'local benefit', long-term sustainability', and 'potential environmental impacts'. Since the predetermined list of attributes method restricted the subject's choice of language, the terminology in the Kelly's repertory grid method along with the language common across both methods was used in the next phase of the quantitative research involving on-line surveys.

Table 5: Kelly's repertory grid attribute associations

Attribute	**Number of Associations**
Sustainability long-term	32
Natural	30
Risky	21
Artificial	21
Proven	20
Potential environmental impacts	18
Least risk	17
Environmentally friendly	12
Most beneficial	12
Cost effectiveness	12
Unknowns	11
Quick fix	10
Eyesore	7
Recyclable by-product	6
Most likely to succeed	6
Local benefit	6
Treats source	6
Understandable	6
Drastic	6
Slow	5
Time Effective	5
Ambitious	5

Table 6 presents the top eight associations common to both attribute elicitation methods. Some of the attributes selected for the subsequent quantitative stage seem similar; for example *unknown effects, unpredictable,* and *risky*. However, these attributes were maintained to reflect the various possible perceptions and levels of uncertainty about the effects of global warming and the reversibility of some of the proposed climate engineering techniques.

Table 6: Common attribute associations across two elicitation methods

Pre-determined List of Attributes	Number of Associations		Kelly's Repertory Grid Attributes
Good for the Planet	22	32	Sustainable Long-term
Risky	22	21	Risky
Beneficial	20	24	Beneficial
Artificial	18	21	Artificial
Unpredictable	18	11	Unknowns
Quick-fix	12	10	Quick-fix
Understandable	16	6	Understandable
Visually Cumbersome	15	7	Eyesore

6.5 Stage One Discussion

Stage 1 of the research identifies the frequency with which different adjectives are associated with climate engineering techniques. It provides a ranked list of attributes to consider for inclusion in the next, quantitative, phase of the research, to be conducted with a much larger sample size. The least popular of these attribute associations can now be omitted from future work, although it is clearly important to ensure that a balanced mix of positive and negative associations is included.

The use of two attribute elicitation methods validated the most common attributes associated with the climate engineering techniques presented. It also identified any gaps in terminology not tested and allowed language choices to be refined based on the choice of vocabulary of the lay persons, rather than that of the researchers.

6.6 Stage One Limitations and Future Research

Stage One of this research is reliant on the methods of attribute elicitation providing the most salient set of attributes relevant to climate engineering, and phrased in language that is relevant to members of the public. However, as discussed above the use of two elicitation methods, particularly the Kelly's repertory grid technique that evokes underlying cognitive constructs and embraces participants own language increases the likelihood that the most salient set of attributes was identified. Future research could use other combinations of attribute elicitation techniques and a wider span of interviewees from more than one geographical area.

Respondents known to the researcher may have given socially desirable responses, however it is likely minimised in this instance as the topic of climate engineering was not known to the interviewees and the author of this thesis has no connections to any environmental or conservational organisations.

Commercial branding theory indicates that substitutable brands competing within a product category tend to have highly similar rankings of attribute associations. As Carbon Dioxide Reduction (CDR) and Solar Radiation Management (SRM) have highly dissimilar rankings, they may be perceived as different product categories, or non-substitutable activities as far as these respondents are concerned. It is therefore important to continue to examine a wider range of climate engineering techniques to see whether they continue to fall into these two categories, and if so whether these are best described as CDR and SRM techniques, or whether there is some other unidentified discriminatory variable that better classifies them.

The following chapter justifies and explains the second quantitative stage of the research, provides results, and discusses the relevance of the outcomes of stage two.

Chapter Seven: Stage Two – Quantitative On-line Surveys

7.1 Stage Two – Research Questions

To quantify how widely and how strongly the climate engineering associations in stage one are held, and to identify if there are any differences between the techniques, or individual and group perceptions, the research questions in Stage two are:

- Can marketing methodologies quantify the attributes associated with climate engineering?
- How do public perceptions of individual climate engineering techniques vary?
- How do public perceptions of CDR and SRM approaches vary?
- Are there any differences in perceptions of climate engineering techniques between individuals or groups?

7.2 Justification for Stage Two Methodologies

Qualitative research methods are exploratory and insightful; however, one of their major criticisms is that they lack population representativeness (de Ruyter & Scholl, 1998). Consequently, quantitative methods are often used due to their inductive-statistical orientation that enables defendable generalisations (Hanson & Grimmer, 2007). Characterised by their logical positivism these methods embody the idea that the extent of reality can be determined and described objectively, implying the observer and the subject being observed are independent (Amaratunga, Baldry, Sarshar & Newton, 2002). Quantitative methodologies usually involve experiments and surveys where observed or intended behaviour is reported numerically in data sets that allow statistical validation.

Quantitative methods are not without criticism, particularly surveys, due to their potential for sampling error and common method bias. Common method bias relates to "variance that is attributable to the measurement method rather than the constructs the measures represent" (Podsakoff, MacKenzie, Lee & Podsakoff 2003, p. 879). However, both these issues can be minimised with considered recruitment, careful survey design, pre-testing, procedure checks, randomising questions, and testing the robustness of results statistically (Podsakoff, MacKenzie & Podsakoff, 2012). On-line surveys, in particular, are criticised as they provide self-reported answers, respondents may receive incentives that influence participation and responses, and regular participation may lead to respondent complacency and manufactured answers (Couper, 2000; Van Ryzin, 2008). The respondents in this research volunteered for membership in a commercial panel used only for research. The self-reported answers rely on participants' willingness to respond truthfully, and it is not expected that respondents who volunteered membership would deliberately provide information that is not true. Van Ryzin (2008) points out that much of the bias in on-line surveys is attributable to the characteristics of the panels and the survey topics. Van Ryzin believes that diverse sources of recruitment when forming panels can help alleviate self-selection and learned response behaviours. He cites several studies that have found results from "on-line panels can produce estimates of various attitudes and behaviours that are quite similar to telephone or other probability sampling methods, although sometimes these similarities depend on the use of weighting schemes and adjustments for mode effects" (2008, p. 240).

The use of surveys for gauging public opinions is also defended by Gauchat (2011). Gauchat cautions that abandoning public opinion surveys in favour of ethnographic or local interactions between scientists and the public might overemphasise the significance of particular issues (Gauchat, 2011). Often small local groups have a direct relationship with the issue and therefore their views are "systematically different from the general public" (p. 756). Gauchat also points out that critics have failed to demonstrate convincingly the inferiority of carefully designed large-scale surveys, compared with alternative methods of gauging public opinions (2011).

7.3 Stage Two Method

As noted in section 7.2, surveys are subject to criticism, especially on sampling error and common method bias. These potential biases can be controlled by careful survey design, participant recruitment methods, and considered implementation procedures. The stability of data and accuracy of results can be measured and benchmarked against appropriate statistical tests. The corrective actions for sampling error and common methods bias taken in this stage of the research are discussed throughout the sections in this chapter and summarised in Table 15, section 7.4.9.

7.31 Sample Recruitment

Survey respondents were supplied by a commercial on-line panel provider, ResearchNow. The provider issues invitations to panel members continuously until demographic quotas are filled. Setting quotas ensures demographic groups are not under-represented. To help avoid response bias, the participation invitations referred to social research rather than specifying climate engineering. Recruitment bias is lessened by the substantial size of the commercial panels (n = 75,000 in New Zealand, and n = 189,000 in Australia). Coverage bias is likely reduced by 92% of New Zealanders in 2012 – 2013 claiming they have Internet usage (Gibson, Millar, Smith, Bell & Crothers, 2013), while in 2014 Australia had 86% percent of their population connected to the Internet, an increase from 83% in the previous year (Australian Bureau of Statistics, 2015).

7.3.2 Survey design

The survey was built in a Qualtrics' platform and activated over weekdays and weekends in early December, 2012. The survey began with three broad warm-up, Likert-style questions on global warming. These three questions were phrased negatively so that participants were forced to deconstruct the questions in working memory and activate relevant memory networks (Wright et al., 2014a). Following the warm-up questions were six blocks containing the climate engineering techniques: Biochar, Air capture, Enhanced weathering (CDR), Cloud brightening, Stratospheric aerosols, and Mirrors in space (SRM). However, to minimise fatigue, each respondent saw only four of the six techniques in blocks in randomised order. Table 7 lists the three treatments for the six concepts.

Table 7: Climate engineering technique treatments

Block	**Concept Treatments**			
1	Stratospheric aerosols	Biochar	Cloud brightening	Enhanced weathering
2	Biochar	Air capture	Cloud brightening	Mirrors in space
3	Stratospheric aerosols	Air capture	Enhanced weathering	Mirrors in space

The techniques were displayed on screen in pictorial content using the best available public images, or artist's impressions, reviewed by experts, rather than self-constructed images. These were followed by a brief description. This ensured the images were as similar as possible to the images the public were likely to see at that time, maximizing external validity (Wright, Teagle & Feetham, 2014b). Concept pictures were also included to reduce the risk of some semantic elements of the concept statements becoming over salient (Wright, Gendall & Lewis, 1999).

The brief descriptions of each of the six climate engineering techniques were formatted in the same way. Particular care was taken to ensure consistent content to avoid framing effects.

Each technique was matched for pictorial content, degree of elaboration of the content and the positive and negative aspects of the description, in line with Lees and Wright's work on new product concept testing (2004).

Other measures implemented to avoid framing effects and bias included avoiding self-generated validity effects by making sure the concept descriptions did not use any of the adjectives identified in Stage 1. Instead, the attributes identified in Stage 1 were used as outcome variables in line with Romaniuk's (2013) recommendations for evaluating brands. To minimise item order effects, both the order of the concepts and the adjectives were randomly rotated. An example of the Enhanced weathering technique block is shown in Figure 3. A copy of the complete survey is placed in Appendix E.

For each technique, respondents were asked which adjectives they associated with the concept. Respondents could choose from a randomised list of six positive and six negative adjectives, developed in Stage 1 of this research; a 'pick any' association task approach. A balanced list of adjectives helps avoid primed responses through stimulus frequency (Wright et al., 2014a). Respondents were also asked several questions, adapted from new product research in marketing which involved problem-solving ability, believability, perceived risk, likely support, and whether they could understand the description. The latter question checks the adequacy of the concept descriptions (see results in tables 13 and 14). In total, participants answered 11 Likert style questions, 7 multi-choice style questions, and 1 rating scale question, as well as undertaking four of six possible climate engineering concept evaluations. An optional, open-ended question with a limit of 255 characters was provided for participants to comment on global warming or climate change.

Figure 3: On-line survey concept block – Enhanced weathering

Enhanced weathering

Copyright: Dave Craw

Enhanced weathering involves increasing the rate that carbon dioxide dissolves minerals to form limestone. This can be achieved through greater exposure to the atmosphere, fine grinding or heating of the minerals, and could be applied to volcanic ash, sand or mine tailings. The resulting limestone traps the carbon dioxide for thousands of years. Enhanced weathering can be implemented locally, increased gradually, and stopped at any time. It could take decades to lower global temperatures. It will produce large amounts of limestone and could use a lot of water. It has similar environmental impacts to mining.

Which of the descriptions in the list below do you think applies to Enhanced weathering?
Please select as many as apply.

☐ Risky	☐ Environmentally friendly
☐ Understandable	☐ Quick-fix
☐ Cost effective	☐ Eyesore
☐ Artificial	☐ Beneficial
☐ Unpredictable	☐ Controllable
☐ Long-term sustainability	☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think Enhanced weathering could help reduce global warming.	○	○	○	○	○
I think Enhanced weathering is practical with modern technology.	○	○	○	○	○
I think Enhanced weathering is a technique most people would support.	○	○	○	○	○
I think Enhanced weathering might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain Enhanced weathering to somebody else.	○	○	○	○	○

7.4. Stage Two Results

7.4.1 Sample Characteristics

Rather than pool all 2028 respondents, results are reported by country which helps avoid aggregation bias and provides built-in replication checks.

In both Australia and New Zealand the participants are broadly spread across demographic groups and comparable to census data for gender and age. Comparable census data were not available for education, income, and location. Gender was balanced, 54% female, 46% male in Australia; 49% female, 51% male in New Zealand. With the age demographic, it should be recognized there were slight skews away from the census figures: the New Zealand sample had slight skews in the over 55 – 64 and 65 –82 year ages, whereas Australia had slight skews for the over 65 years.

As expected, there were demographic differences in population locations between the countries. The Australian sample had more respondents from large cities (more than 1 million). By comparison, New Zealand had more respondents in small cities (60,001 – 300,000). New Zealand has only two cities with a population over 300,000 and one city with a population larger than one million. This difference was expected as Australia has five cities with populations over one million that account for just over 60% of Australia’s total population.

This sample composition is acceptable for the purposes of this research. A table of the demographic characteristics of both countries compared with consensus age and gender figures is provided in Appendix D.

7.4.2 Knowledge of climate engineering

Less than 18% of respondents in either country knew about climate engineering techniques before they participated in the survey. However, more than half the respondents, 61% in New Zealand and 53% in Australia, said they would be likely, or very likely, to search for more information on climate engineering techniques. These results confirm the results of earlier studies carried out in other countries that found low levels of knowledge on climate engineering. A survey in the US, UK, and Canada (Mercer et al., 2011) found only 8% of the participants could correctly define the term ‘geoengineering”, although 45% accurately defined the term ‘climate engineering’. In a survey in the UK, 28% of the participants said they had heard about the term ‘geoengineering’ before (Corner & Pidgeon, 2014). Focus groups held in Sweden in 2013 reported 13% of the 45 participants had heard of geoengineering (Wibeck, Hansson & Anshélm, 2015). An on-line survey conducted in Germany in 2012 reported 20% of their sample had heard of spraying sulphate particles into the atmosphere (Merk, Pönitzsch & Rehdanz, 2015). These findings signal the low levels of public awareness of climate engineering technologies up until 2013. However, these figures are likely changed in 2016 as climate engineering is featured more in academic publications, media outlets, climate change summits, conferences, talkback discussion, and science blogs (see section 2.2 for figures).

7.4.3 Attribute Associations

The primary outcome measures are frequency counts of attribute associations for each technique. These counts are analysed using metrics developed by Romaniuk and colleagues at the Ehrenberg – Bass Institute, South Australia (discussed in sections 3.5, 7.4.7, and 7.4.9).

Table 8 shows the top 12 climate engineering attribute associations, ranked in order of most to least attribute associations in Australia and New Zealand. The attributes show considerable variation in popularity when measured as each attribute's share of all associations.

Table 8: Attribute association by percentage of all attribute mentions

		Australia	New Zealand
Ranking	**Attribute**	%	%
1	Unknown effects	19	20
2	Unpredictable	14	15
3	Risky	13	13
4	Artificial	9	11
5	Eyesore	6	7
6	Quick-fix	7	6
7	Understandable	6	6
8	Beneficial	6	5
9	Controllable	6	6
10	Environmentally friendly	6	5
11	Long-term sustainability	5	5
12	Cost-effective	4	2

The ordered ranking revealed that the three attributes mentioned most account for almost 50% of total attribute associations. Clearly they are all negative attributes, linked to respondent concerns over unknown effects, predictability and risk. In both countries 29 – 33% of associations are attributed to positive attributes that are mentioned with similar frequency, ranging from 5 – 6%. The cost-effectiveness of techniques ranked the lowest, 4% in Australia and only 2% in New Zealand. The predominance of negative attribute mentions is again a striking finding.

7.4.4 Reduced Attribute Set

Further statistical tests are carried out to identify any potential overlapping memory structures. This is assessed using Kendall Tau-b correlations. Matrixes of non-parametric attribute correlations for the Australian data are provided in Appendix F. The table in Appendix F is the average of six correlation matrixes, one for each climate engineering technique. To assist grouped analysis of the negative and positive attributes the table is divided into quadrants. Not one of the reported correlations for the Australian data is high – all are less than .50. Three correlations, however, are above .37, which substantially exceeds the average correlations for the attributes involved. The related attributes meet the condition necessary for elimination to reduce overlapping memory structures (Romaniuk, 2013). The results for the New Zealand data are similar, allowing consistent treatments across both samples. The attributes *unpredictable* and *beneficial* were removed to avoid over-representation of duplicate attributes (Wright et al., 2014a).

Table 9 shows the set of reduced attributes ranked by order of popularity.

Table 9: Attribute association rankings reduced attributes

		Australia	New Zealand
Ranking	**Attribute**	%	%
1	Unknown effects	24	25
2	Risky	16	16
3	Artificial	12	13
4	Eyesore	8	9
5	Quick-fix	8	7
6	Understandable	7	8
7	Controllable	7	7
8	Environmentally friendly	7	6
9	Long-term sustainability	6	6
10	Cost-effective	5	3

Of these ten attributes the most frequently chosen are the five negative attributes. The three negative attributes, *unknown effects, risky* and *artificial* account for over 50% of all associations. Positive attributes account for approximately one third of all associations. The attributes show substantial variation in popularity and have a correlation between countries of *r* = 0.99 (Wright et al., 2014a).

7.4.5 Raw Attribute Counts

Table 10 shows the raw frequency counts after elimination of the overlapping attributes in New Zealand. Table 11 displays the Australian raw frequency counts on the reduced data set of 10 attributes.

Table 10: Attribute counts after elimination of overlapping attributes (New Zealand)

New Zealand	Biochar	Air capture	Enhanced weathering	Cloud brightening	Stratospheric aerosols	Mirrors in space	**TOTAL**	%
Unknown effects	426	314	405	506	543	555	2749	**25%**
Risky	200	140	291	316	381	472	1800	**16%**
Artificial	118	259	180	274	314	323	1468	**13%**
Eyesore	42	385	173	114	116	114	944	**9%**
Quick-fix	48	134	67	201	255	91	796	**7%**
Understandable	173	210	151	109	94	91	828	**8%**
Controllable	168	279	153	99	67	44	810	**7%**
Environmentally friendly	225	173	75	112	51	45	681	**6%**
Long-term sustainability	202	170	133	42	37	44	628	**6%**
Cost effective	118	66	60	30	37	21	332	**3%**
TOTAL	**1720**	**2130**	**1688**	**1803**	**1895**	**1800**	**11036**	
%	16%	19%	15%	16%	17%	16%		

Note: The chi-square value for the test of independence are $X^2 = 1312$. This exceeds the critical value for statistical significance at $p = .001$, $X^2_{(.999,\ 45)} = 80$.

Table 11: Attribute counts after elimination of overlapping attributes (Australia)

Australia	Biochar	Air capture	Enhanced weathering	Cloud brightening	Stratospheric aerosols	Mirrors in space	**TOTAL**	%
Unknown effects	371	254	352	448	448	460	2333	**24%**
Risky	193	136	263	273	310	376	1551	**16%**
Artificial	120	194	144	226	235	240	1159	**12%**
Eyesore	48	323	118	113	104	68	774	**8%**
Quick-fix	81	136	81	174	233	96	801	**8%**
Understandable	143	169	120	107	106	81	726	**7%**
Controllable	131	204	135	99	90	52	711	**7%**
Environmentally friendly	189	171	87	103	74	63	687	**7%**
Long-term sustainability	163	160	136	59	55	54	627	**6%**
Cost effective	117	92	88	57	69	65	488	**5%**
TOTAL	**1556**	**1839**	**1524**	**1659**	**1724**	**1555**	**9857**	
%	16%	19%	15%	17%	17%	16%		

Note: The chi-square value for the test of independence are $X^2 = 2361$. This exceeds the critical value for statistical significance at $p = .001$, $X^2_{(.999,\ 45)} = 80$.

7.4.6 Percentage Point Deviations from Expected Attribute Counts

The row, column, and total count in Tables 10 and 11 are used to calculate a chi-square expected cell count. Tables 12 and 13 show the percentage point deviations from expected attribute counts as a result of chi-square calculations for New Zealand and Australia, respectively.

Table 12: Percentage point deviations from expected attribute counts (New Zealand)

New Zealand	Biochar	Air capture	Enhanced weathering	Cloud brightening	Stratospheric aerosols	Mirrors in space
Unknown effects	0%	-10%	-1%	3%	4%	6%
Risky	-5%	-10%	1%	1%	4%	10%
Artificial	-6%	-1%	-3%	2%	3%	5%
Eyesore	-6%	10%	2%	-2%	-2%	-2%
Quick-fix	-4%	-1%	-3%	4%	6%	-2%
Understandable	3%	2%	1%	-1%	-3%	-2%
Controllable	2%	6%	2%	-2%	-4%	-5%
Environmentally friendly	7%	2%	-2%	0%	-3%	-4%
Long-term sustainability	6%	2%	2%	-3%	-4%	-3%
Cost effective	4%	0%	1%	-1%	-1%	-2%

Table 13: Percentage point deviations from expected attribute counts (Australia)

Australia	Biochar	Air capture	Enhanced weathering	Cloud brightening	Stratospheric aerosols	Mirrors in space
Unknown effects	0%	-10%	-1%	3%	2%	6%
Risky	-3%	-8%	2%	1%	2%	8%
Artificial	-4%	-1%	-2%	2%	2%	4%
Eyesore	-5%	10%	0%	-1%	-2%	-3%
Quick-fix	-3%	-1%	-3%	2%	5%	-2%
Understandable	2%	2%	1%	-1%	-1%	-2%
Controllable	1%	4%	2%	-1%	-2%	-4%
Environmentally friendly	5%	2%	-1%	-1%	-3%	-3%
Long-term sustainability	4%	2%	3%	-3%	-3%	-3%
Cost effective	3%	0%	1%	-2%	-1%	-1%

These point deviations (skews) are used to create the concept images throughout section *7.4.9.*

7.4.7 Net positive metrics all techniques

To evaluate overall perceptions of each climate engineering techniques the negative attribute counts are subtracted from the positive attribute counts to give a net positive association count for each technique. These metrics are approximately normally distributed. Histograms and plots illustrating the distribution can be viewed in Figures 1 – 4 in Appendix G.

Table 14 displays the positive and negative memory associations by climate engineering techniques, and by CDR and SRM approaches, for the Australian and New Zealand samples. The correlation between New Zealand and Australian net positive metric is again $r = 0.99$ (Wright, et al., 2014a).

Table 14: Memory associations for climate engineering techniques

	Biochar	Air capture	Enhanced weathering	Cloud brightening	Stratospheric aerosols	Mirrors in space	Total
New Zealand							
n*	670	691	683	670	683	691	1,022
Count of associations	1,774	2,130	1,780	1,860	1,917	1,800	11,188
Positive associations	52%	42%	34%	22%	15%	14%	30%
Negative associations	48%	58%	66%	78%	85%	86%	70%
Net positive associations	3%	-16%	-32%	-57%	-70%	-73%	-40%
Australia							
n*	672	674	666	672	666	674	1,006
Count of associations	1,600	1,885	1,581	1,706	1,789	1,594	10,155
Positive associations	48%	43%	37%	26%	23%	20%	33%
Negative associations	52%	57%	63%	74%	77%	80%	67%
Net Positive Associations	-4%	-13%	-26%	-49%	-54%	-59%	-34%

*Each participant evaluated four of six techniques to minimise fatigue.

Table 14 shows that, on average, respondents had predominately negative associations with climate engineering techniques, with negative attributes at 70% of all associations in New Zealand. In Australia negative associations are slightly less, at 67% of all associations. Association varied by climate engineering classification; CDR techniques had substantially more positive associations and fewer negative associations than SRM techniques, although overall the negative associations are still in the majority (Wright et al., 2014a).

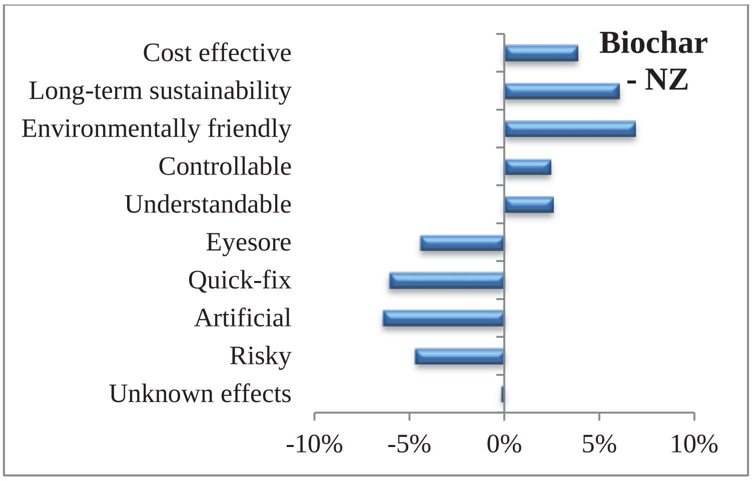
7.4.8 Data Management – Normalised Data Sets

One further calculation was made with both data sets. Within each survey there were three treatments. Respondents saw either of three blocks, randomly rotated. Each block contained four of six possible climate engineering techniques which were also rotated randomly. This resulted in minor sample size variation. To account for this variation, the data for the concept images are normalised to the value in the largest sub-sample. However, all reported statistical tests are conducted on unadjusted numbers (Wright et al., 2014a).

7.4.9 Concept Images-New Zealand

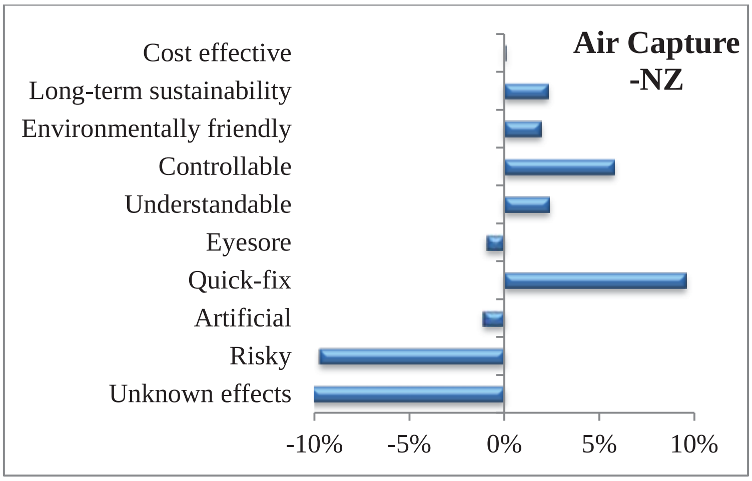
Concept image maps are created by considering the number of associations with each technique compared with the expected level of attribute associations, based on the relative popularity of each attribute. Expected cell counts are the result of a chi-square calculation explained in section 7.4.6 (Romaniuk, 2013; Romaniuk & Sharp, 2000). The concept image is then visualised as skews (the positive and negative deviations shown in Tables 12 and 13) away from the expected benchmark level, showing the relative strengths or weaknesses of each concept on its attributes after controlling for the overall level of attribute associations for the technique. In branding, concept images are useful for showing distinctive attributes to guide advertising and promotional communications (Romaniuk, 2013). In this case, they signal probable public reaction to each technique, as well as what attributes are of most, or least, concern to participants. The following charts illustrate the New Zealand concept images for the six climate engineering techniques tested. The charts are presented with the attributes in the inverse order of popularity, placing the positive attributes at the top.

Chart 1: Biochar Concept Image – New Zealand



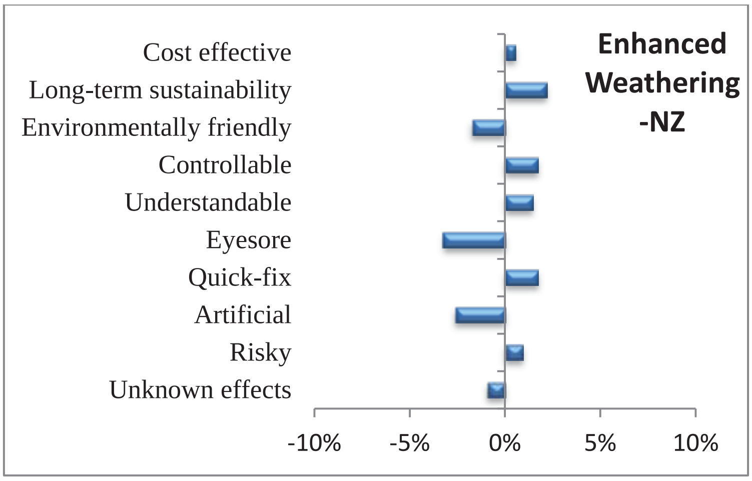
The concept image for Biochar shows notable positive associations with the attributes of *long-term sustainability* and *environmentally friendly*; however, these are not key category attributes (see Table 5 for the key category attributes). The important insight here is that Biochar has less than expected associations with the key negative attributes *eyesore*, *quick-fix*, *artificial*, and *risky*.

Chart 2: Air Capture Concept Image – New Zealand



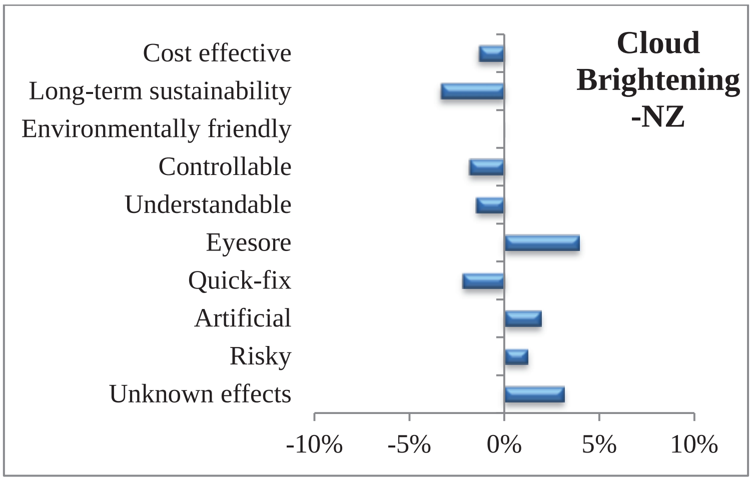
The concept image for Air capture is skewed away from the key negative attribute *quick-fix* therefore it is not considered a short-term solution. Air Capture is negatively skewed with the key attributes *risky* and *unknown effects*, meaning it has much less than expected negative associations with these two attributes.

Chart 3: Enhanced Weathering Concept Image- New Zealand



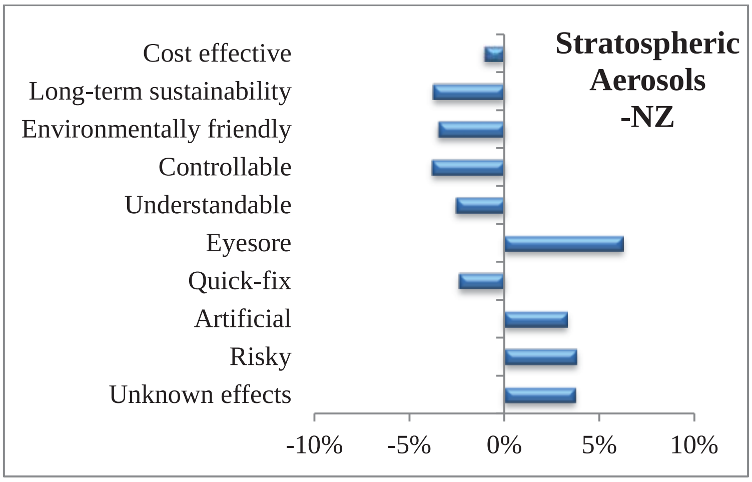
The concept image for Enhanced weathering demonstrates slight skews towards the negative attributes *eyesore* and *artificial*; however, overall this technique does not hold strong associations with any key climate engineering attributes.

Chart 4: Cloud Brightening Concept Image – New Zealand



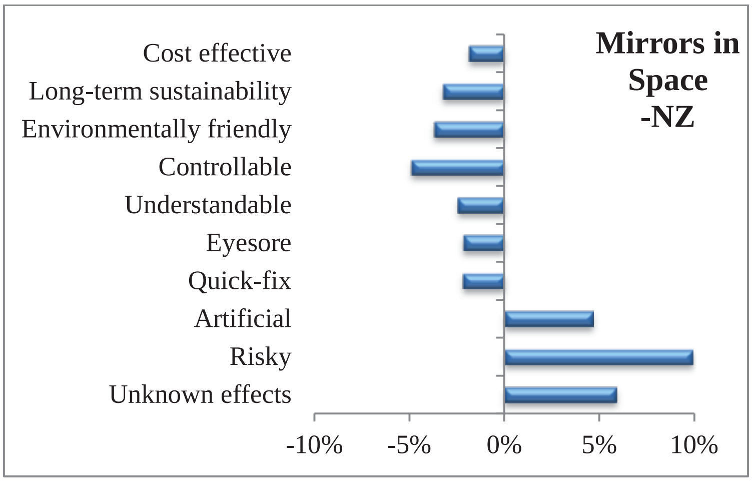
The concept image for Cloud brightening skews away from the negative attributes *eyesore* and *unknown effects* and skews negatively towards the positive attribute *long-term sustainability*.

Chart 5: Stratospheric Aerosols Concept Image – New Zealand



The concept image for Stratospheric aerosols skews away from all the five key positive attributes and towards the negative attributes, but is not perceived as a quick-fix.

Chart 6: Mirrors in Space – New Zealand

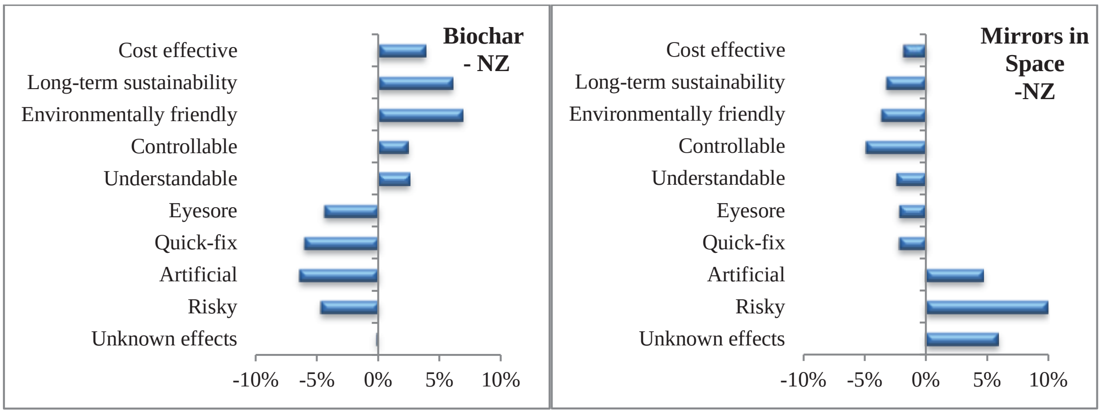


The Mirrors in space concept image has very distinctive skews towards the negative attributes *artificial*, *risky*, and *unknown affects* – the largest negative skews of all the techniques.

In summary, these concept images vary in distinctiveness. The techniques Biochar and Air Capture have distinctive and positive concept images. In comparison, Stratospheric aerosols and Mirrors in space have distinctive and more negative concept images, while Enhanced weathering and Cloud brightening are not very distinctive; their skews are small (Wright et al., 2014, p. 108).

Overall the concept images confirm greater negativity for SRM techniques than for CDR techniques. The difference between the CDR technique, Biochar, and the SRM technique, Mirrors in Space is particularly large. Chart 7 compares how the individual techniques of Biochar and Mirrors in Space reflect memory associations that are almost polar opposites. While Biochar skews towards the positive attributes of *environmentally friendly* and *long-term sustainability*, Mirrors in Space skews away from the positive attributes and towards the negative attributes *artificial*, *risky*, and *unknown effects*.

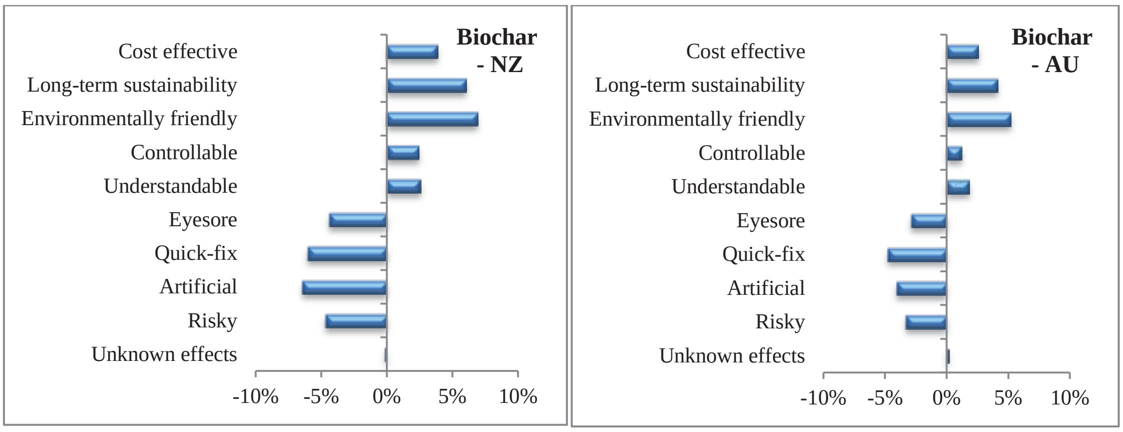
Chart 7: Biochar – Mirrors in Space Concept Comparison New Zealand



While the concept images varied among the climate engineering techniques, overall the perceptions of individual climate engineering techniques were similar in both Australia and New Zealand. To avoid repetition, the Australian concept images are not displayed in this section, instead they are compared technique by technique with the New Zealand concept images in the next section.

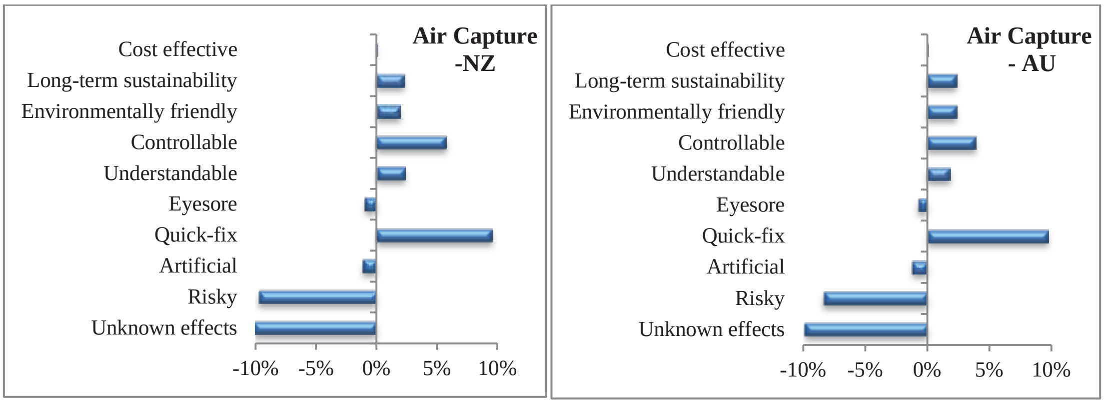
7.4.10 New Zealand and Australia Concept Image Comparisons

Chart 8: New Zealand and Australian Comparison – Biochar



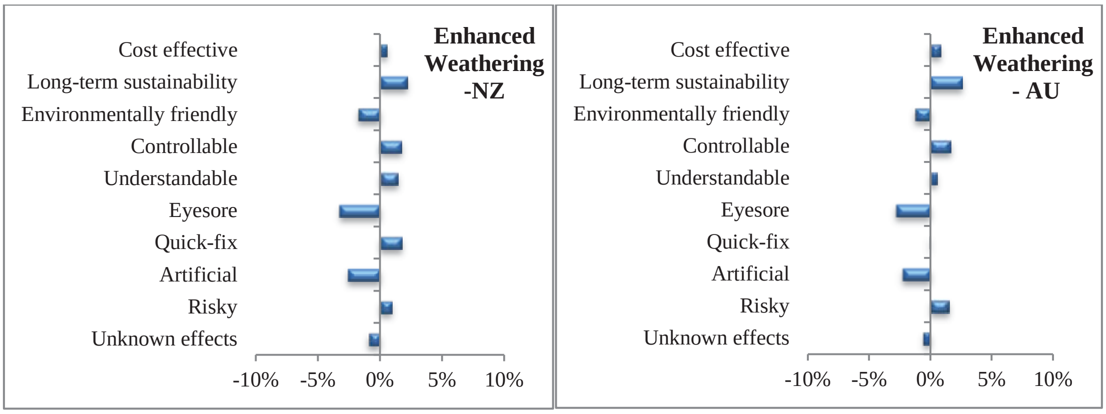
The attribute skews of the Australian Biochar demonstrate the same distinctive pattern, but are slightly less skewed than the New Zealand skews on all attributes. In both countries, the Biochar techniques skew in the same direction: positively towards *long-term sustainability* and *environmentally friendly*, and negatively towards *eyesore*, *quick-fix*, *artificial*, and *risky*.

Chart 9: New Zealand and Australian Comparison – Air Capture



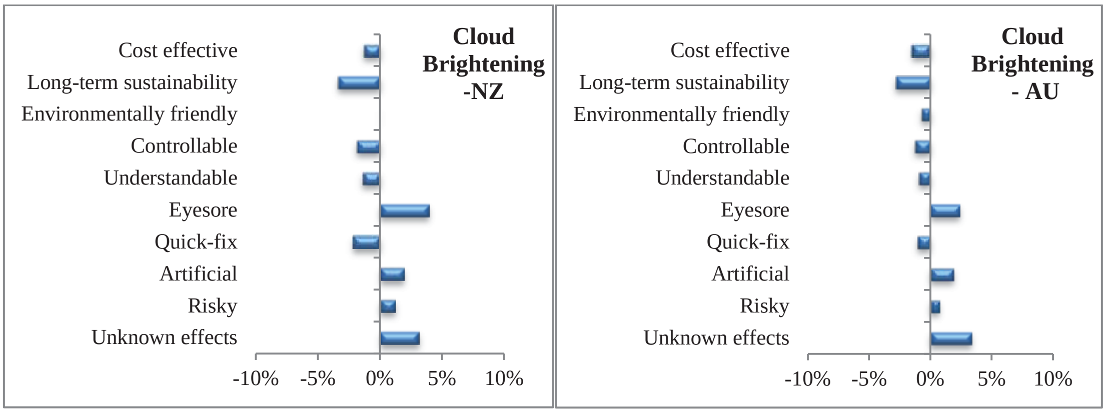
The Air Capture technique demonstrates a markedly similar pattern across both countries. Air Capture is positively skewed towards the *controllable* attribute and negatively skewed towards *risky and unknown effects*. Air Capture skews towards the negative attribute *quick-fix*, indicating it is perceived more positively than expected.

Chart 10: New Zealand and Australian Comparison – Enhanced Weathering



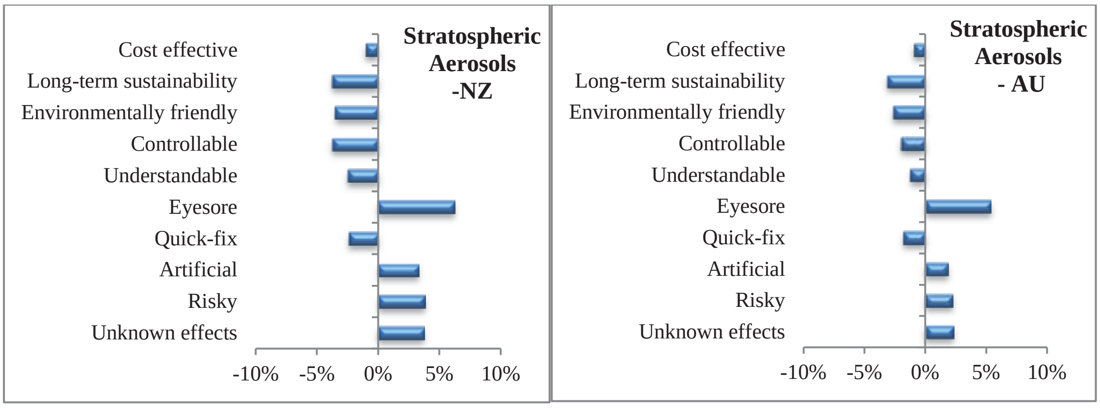
The Enhanced Weathering techniques show almost identical patterns across both countries, with a slight variation on the attribute *quick-fix*. Overall, the enhanced weathering concept associations are indistinct and public reaction to this climate engineering technique is likely to be low-key.

Chart 11: New Zealand and Australian Comparison – Cloud Brightening



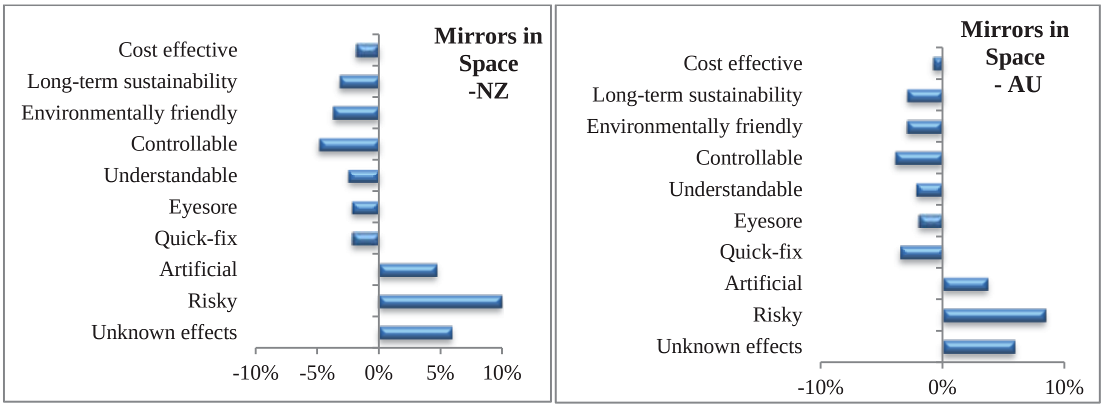
The Cloud Brightening techniques illustrate similar patterns across both countries with only slight variations on the *eyesore* and *quick-fix* attributes. As with Enhanced Weathering, this technique has an indistinct concept image that is unlikely to evoke much attention.

Chart 12: New Zealand and Australian Comparison – Stratospheric Aerosols



The Stratospheric aerosol techniques display noticeably similar patterns of deviations across both countries. The Stratospheric aerosol techniques skew away from the key positive attributes of *long-term sustainability*, *environmentally friendly*, *controllable*, and *understandable,* and towards the negative attributes. However, an exception is the negative attribute *quick-fix* which skews in the opposite direction, revealing the Stratospheric aerosol technique is slightly less negative than expected for the *quick-fix* attribute.

Chart 13: New Zealand and Australian Comparison – Mirrors in Space



Across both countries the skew patterns for Mirrors in Space are strikingly similar. Mirrors in space generally have the most negative concept images, skewing away from the positive attributes and towards the negative attributes (Wright, Teagle & Feetham, 2014).

Overall, the similarities between the techniques across the countries indicate the stability of the data and its robustness to different contexts, a finding typical of brand image data (Romaniuk, 2013).

7.4.11 Support for climate engineering techniques

Support for the individual techniques was gauged by asking respondents whether they agreed or disagreed with the statement that 'most people would support the technique' on a scale of 1-5 with 1 = strongly agree and 5 = strongly disagree. The levels of agreement and disagreement in Tables 15 – 18 were combined to three categories. Table 15 displays the level of support for each of the climate engineering techniques in the Australian sample.

Table 15: Support for individual climate engineering techniques – Australia

Most people would support this technique	Mean	% Agree	% Neutral	% Disagree
Biochar	2.9	34	42	24
Air Capture	2.9	32	42	26
Enhanced Weathering	3.1	23	42	35
Cloud Brightening	3.2	23	41	37
Stratospheric Aerosols	3.3	20	40	40
Mirrors in Space	3.4	16	38	46

In Australia support for The CDR climate engineering approaches of Biochar and Air Capture is higher with more respondents agreeing with the statement than disagreeing. However, only one third of the sample agreed other people would support these two techniques. The trend reverses for Enhanced Weathering, Cloud Brightening, Stratospheric Aerosols, and Mirrors in Space. Almost half the sample disagreed there would be support for Mirrors in Space. Overall, 38 – 42% of the sample remained neutral on whether they would support any of the four climate engineering techniques they saw.

Respondents' levels of agreement and disagreement of support for climate engineering techniques in New Zealand are presented in Table 16.

Table 16: Support for individual climate engineering techniques – New Zealand

Most people would support this technique	Mean	% Agree	%Neutral	% Disagree
Biochar	3.0	31	41	28
Air Capture	3.0	32	38	31
Enhanced Weathering	3.3	15	42	43
Cloud Brightening	3.4	14	38	49
Stratospheric Aerosols	3.5	11	36	53
Mirrors in Space	3.6	10	32	57

In New Zealand support for Air Capture was a little ahead of Biochar, but overall still similar to Australian's support for these two techniques. However, New Zealanders' degree of support for Enhanced Weathering and the three SRM techniques was much less. Only fifteen percent or less of the sample agreed that most people would support any of these four techniques. Between 32 and 41% of the sample were neutral about supporting the climate engineering techniques they saw.

Understanding of the climate engineering techniques was tested by asking respondents to agree or disagree with the statement, 'I could explain this technique to someone else'. Results across the two countries are very similar and are displayed in Tables 17 and 18.

Table 17: Understanding of climate engineering techniques – Australia

I could explain this technique to someone else	Mean	% Agree	% Neutral	% Disagree
Air Capture	2.6	51	35	14
Mirrors in Space	2.7	48	34	19
Cloud Brightening	2.7	46	36	17
Biochar	2.7	45	37	19
Stratospheric Aerosols	2.7	43	38	20
Enhanced Weathering	2.8	40	41	19

In Australia understanding of the six climate engineering techniques presented in the online survey is quite high with 37 – 50% of participants agreeing they could explain each concept to someone else. A range of 14 – 24% of participants disagreed they could explain the technique to someone else, and 32 – 41% remained neutral.

In the case of Air Capture, at least half of the sample agreed they could explain this technique to someone else, while just under half of the sample agreed they could explain Mirrors in Space to someone else. Enhanced Weathering was the least understood technique.

Table 18: Understanding of climate engineering techniques – New Zealand

I could explain this technique to someone else	Mean	% Agree	%Neutral	% Disagree
Air Capture	2.7	49	34	18
Mirrors in Space	2.7	49	32	20
Cloud Brightening	2.7	48	34	18
Biochar	2.8	42	38	20
Stratospheric Aerosols	2.8	43	37	21
Enhanced Weathering	2.9	37	39	24

In New Zealand the understanding of the six climate engineering techniques is similar to Australia, although the Enhanced weathering technique is slightly less understood by New Zealanders than by Australians.

The understanding of techniques does not separate into the two classifications of climate engineering as the techniques most understood were the Air capture (CDR) and Mirrors in space (SRM).

7.4.12 Summary of Steps Taken to Minimise Sampling and Common Method Bias

Table 19 summarises the steps taken in Stage two to minimise recruitment bias, sampling errors and common method biases.

Table 19: Summary of sampling and common method bias controls

Issue	Control Action	Section
Demographic representation	Set quotas and census comparisons	7.3.1
Response bias	Topic blind recruitment	7.3.1
Recruitment bias	Respondents drawn from very large panels	7.3.1
Coverage bias	<10% of populations are without the Internet	7.3.1
Un-activated working memory	Warm-up questions were negatively phrased	7.3.2
Respondent fatigue	Reduced the number of concepts to evaluate	7.3.2
External validity	Professionally constructed images, expert reviews	7.3.2
Framing effects	Matched pictorial content, degree of elaboration and balanced number of negative and positive elements	7.3.2
Self-generated validity	Concept descriptions differ to adjectives used for attribute measurement	7.3.2
Item-order effects	Random rotation of concepts and descriptors	7.3.2
Primed responses	Used a balanced list of adjectives	7.3.2
Understanding of concepts	Pre-testing and evaluative question in the survey	7.3.2
Aggregation bias	Analysed the countries separately and tested independence with correlation coefficient *r*	7.4.1
Memory structure overlaps	Kendall Tau-b correlations	7.4.4 & Appendix F
Normal Distribution of data	Kolmogorov-Smirnov tests and histograms	Appendix K
Independence of variables	Univariate and multivariate tests between net positive variables, survey treatment and demographics	Appendix K

7.5 Stage Two – Discussion

This stage of the research determined that public response to the six climate engineering techniques tested is predominantly negative, although the degree of positive and negative memory associations varied between climate engineering approaches and individual techniques. The ranked attribute associations revealed that the negative associations are mostly linked to concerns over uncertainty and risk. This indicates the need for uncertainty over climate engineering techniques to be reduced. However, given that many of the technologies are in the early stages of development, any reassurances of uncertainty and risks are unlikely to be offered in the immediate future. Additionally, as climate engineering is a new and relatively unknown science this reaction is not unexpected.

The CDR methods of Biochar, Air Capture, and Enhanced Weathering had markedly more positive associations and less negative associations than the SRM methods of Stratospheric Aerosols, Cloud Brightening and Mirrors in Space. This was also evident when individual techniques were graphed to show attribute skews. In the concept images shown in this report the Biochar attribute associations skewed towards positive attributes and the Mirrors in Space attribute associations skewed towards the negative attributes, demonstrating that positive and negative attribute associations vary significantly between the six techniques tested.

Support for the individual techniques of Biochar and Air capture was higher compared with Enhanced Weathering and the three SRM techniques tested. Although only a third of the sample agreed there would be support for Biochar and Air Capture, it does indicate that the public are likely to be more receptive towards the use of these two techniques. However, it is clear the public are highly unlikely to advocate the use of Enhanced Weathering or the three SRM techniques tested in this research.

Although less than one fifth of both the Australian and New Zealand respondents had any knowledge of climate engineering before taking the survey, they understood the climate engineering techniques presented in the Stage 2 on-line survey. With the exception of Enhanced Weathering, almost half of both samples believed they could explain the individual techniques to someone else. This suggests that the basic concept description with some advantages and disadvantages of climate engineering techniques presented in this research, were well understood. This is an important finding as it indicates that similarly framed information on climate engineering techniques is likely to be understood by much of the public.

7.6 Stage Two Limitations and Future Research

As discussed in sections 7.2 and 7.4.12 there are several criticisms of survey methodologies, particularly on-line surveys. The numerous specific actions taken to minimise the potential limitations of the survey implemented in Stage two is clearly outlined in these sections and not repeated here.

As noted earlier the neutral framing used in this study is a fortuitous choice, given the potential for framing to affect outcomes. However, future work could systematically investigate the effect of non-neutral framing on outcomes in the context of the concept statement and brand evaluations methodologies used in this research.

Future research could also test other climate engineering techniques. Research could investigate in more depth the effect of previously held attitudes on perceptions of climate engineering and investigate in more depth whether gender, age, education, ethnicity, or occupation are drivers of reactions to climate engineering. It will be important to also ensure that a wide variety of both small and large, and northern and southern hemisphere, countries are included in future climate engineering research. In particular, the countries in the South American continent, and South-East Asia, seem under-represented in climate engineering research.

While this stage of the research quantified likely public reaction to several climate engineering techniques it does not suggest how the public would react should the need for climate engineering become urgent or come to have more personalized relevance. This stage of the research did not consider climate engineering alongside other solutions to global warming, such as mitigation and adaptation. Stage two also does not determine whether respondents' answers were hasty, intuitive thinking or more engaged and deliberative thinking, a topic that is under-investigated in science communication and marketing.

The following chapter reports the next stage of the research that investigates specifically whether the evaluations of climate engineering in Stage two vary with more deliberation.

Chapter Eight: Stage Three – Intuitive and Deliberative Analysis

8.1 Stage Three – Research Question

To determine whether intuitive and deliberative responses differ in fundamental ways the research questions in Stage three are:

- How do citizens' evaluations of climate engineering vary with more deliberation?
- Is deliberative thinking a dichotomous or continuous mental process?

8.2 Stage Three – Justification for Methodology

The literature reviewed in Chapter five discussed how humans apply a dual-theory of processing information when making choices and decisions. Nowadays the two processes of thinking are described as intuitive, Type 1 thinking, or deliberative, Type 2 thinking. While there is no clear consensus about the accuracy of either type of thinking, or whether the processes are interactive, or dichotomous, or take place on a continuum, several researchers have used various techniques as proxies to measure deliberative thinking. Some research supports the idea that deliberative decisions are generally more accurate than intuitive decisions when completing specified tasks (Kahneman, 2011; Mata, Ferreira & Sherman, 2013; Moxley, Ericsson, Charness & Krampe, 2012; Stanovich et al. 2010). Other research asserts it is possible to approximate the time period when greater analytical processing takes place if respondents are allowed increased time to answer questions (De Neys, 2006a; Evans & Curtis-Holmes, 2005; Kahneman, 2011; Thompson et al, 2011).

The Dual-theory of information processing provides a theoretical foundation for examining whether responses to questions about new scientific concepts or technologies differ if they are made using hasty, automatic, intuitive (Type 1 thinking), or made using a more effortful, slow, conscious and deliberative process (Type 2 thinking). Therefore this stage of the research extends previous approaches that have measured deliberation by using the time taken to complete responses in various situations and examines the times taken to complete questions in the on-line survey used in Stage two as a proxy for whether deliberative thinking is occurring. Given the dual-processing theories discussed in Chapter 5 indicated some agreement among researchers that Type 1 thinking occurs hastily without conscious effort it is expected there may be different evaluations between short and long responses times when discussing or thinking about contentious environmental or scientific issues. Using question response times enables an assessment of whether increased thinking times is associated with differing evaluations, in the context of upstream scientific engagement for climate engineering concepts.

8.3 Stage Three – Method

The data used to measure the extent of deliberative thinking and whether it affects evaluations of climate engineering is drawn from the same samples used in Stage two of this research (Australia *n* = 1006, New Zealand *n* = 1022).

As Stage three is particularly concerned with the time to completion for the questionnaire, the data is further trimmed 5% at each extreme to remove outliers, leaving a final sample of *n* = 904 in Australia and *n* = 920 in New Zealand. The sample is then split in two different ways, quartiles and halves. If Type 1/Type 2 thinking is conceptualised as a dichotomy, then it is most appropriate to compare the means of the fastest and slowest time-to-completion quartiles, as this will maximise the chances that respondents have flipped between intuitive and deliberative thinking. If Type 1/Type 2 thinking is instead conceptualised as a continuum, then is it most appropriate to compare the means of the fastest and slowest halves, as this will use all the information available to estimate the effect of moving along the intuitive/deliberative continuum. The dependent variable, repeated from Stage 2, is the net positive count of associations for each climate engineering method and for all the methods combined.

The difference in the net positive measure between quartiles or halves is therefore a proxy for the differences in evaluations that occur with intuitive versus deliberative thinking. Should patterns be stronger in quartiles than halves this would provide some evidence to indicate that deliberative thinking was occurring more through a dichotomous switch rather than a continuum of mental effort.

8.4 Stage Three – Results

The association between Type 1 and Type 2 thinking and negativity towards climate engineering is presented in the following tables. Tables 20 and 21 show the Australian quartiles and half comparisons respectively.

Table 20: Australian time comparisons in quartiles

Quartile	**1 (n=226)**	**4 (n=226)**
Time Period	**3 – 6 minutes**	**11 - 24 minutes**
	Net Positive Associations	
Biochar	21	-26
Air Capture	-35	-97
Enhanced Mineral Weathering	-48	-99
Cloud Brightening	-118	-227
Stratospheric Aerosols	-110	-285
Mirrors in Space	-120	-298
Total Associations	-410	-1032

Table 21: Australian time comparisons in halves

Half	**1 (n=452)**	**2 (n=452)**
Time Period	**3 – 8 minutes**	**8 - 24 minutes**
	Net Positive Associations	
Biochar	-24	-31
Air Capture	-98	-119
Enhanced Mineral Weathering	-152	-203
Cloud Brightening	-289	-465
Stratospheric Aerosols	-331	-545
Mirrors in Space	-343	-525
Total Associations	-1237	-1888

This decomposition reproduces the original result of Wright et al. (2014); that is, the overall evaluation is negative, the evaluation of SRM methods (cloud brightening, stratospheric aerosols and mirrors in space) is more negative than the evaluation of CDR methods (biochar, air capture and enhanced weathering), and the order of the evaluations of the individual techniques is virtually identical to that found in the original research.

Also, the decomposition shows that greater deliberative thinking is associated with more negative evaluations, indicating that intuitive and deliberative thinking do give different results in *magnitude*, if not in *direction* for this data. The two methods of comparison (quartiles in Tables 20 and halves in Table 21), yield similar patterns of results, so no conclusions can be drawn about whether deliberative thinking tends towards dichotomous or continuous mental processes.

Tables 22 and 23 display the New Zealand comparisons of quartiles and halves, respectively.

Table 22: New Zealand time comparisons in quartiles

Quartile	**1 (n=230)**	**4 (n=230)**
Time Period	**5 – 8 minutes**	**16 -37 minutes**
	Net Positive Associations	
Biochar	-9	35
Air Capture	-79	-90
Enhanced Mineral Weathering	-122	-132
Cloud Brightening	-237	-244
Stratospheric Aerosols	-297	-306
Mirrors in Space	-288	-279
Total Associations	-1032	-1016

Table 23: New Zealand time comparisons in halves

Half	**1 (n=460)**	**2 (n=460)**
Time Period	**5 - 10 minutes**	**10 – 37 minutes**
	Net Positive Associations	
Biochar	-18	46
Air Capture	-164	-160
Enhanced Mineral Weathering	-267	-254
Cloud Brightening	-454	-503
Stratospheric Aerosols	-595	-638
Mirrors in Space	-639	-576
Total Associations	-2137	-2085

The decomposition for the New Zealand data also reproduces the original result of Wright et al. (2014); the overall evaluation of climate engineering is negative, the evaluation of SRM methods is more negative than the evaluation of CDR methods, and the order of the evaluation of the individual climate engineering techniques is virtually identical to that found in the original research. Again, the two methods of comparison (quartiles in Table 22 and halves Table 23) yield very similar patterns of results, so no conclusions can be drawn about whether deliberative thinking tends towards dichotomous or continuous mental processes.

However, in this case, greater deliberative thinking is not associated with more negative evaluations. Rather, in contrast to the Australian results, the evaluations are virtually identical. This suggests that the effect of deliberative thinking on the evaluation of climate engineering concepts is moderated by the country of study.

Statistical tests for the derived net positive variable are not defined. However, tests can be undertaken for differences in the *proportions* of all given associations that are negative. The results of these tests are reported here using Z-scores.

For New Zealand	H2 v H1	Z = 1.24
For New Zealand	Q4 v Q1	Z = 1.57
For Australia	H2 v H1	Z = -2.57
For Australia	Q4 v Q1	Z = -4.38

These results show that for New Zealand, z-scores are below the critical value of z = 1.96 for a difference at the 95% confidence level. Thus, there is no detectable difference in respondent evaluations using either method of comparison. For Australia, either method of comparison results in a difference that is both statistically detectable and large in magnitude.

Alternative measures of Type 2 thinking are the number of characters used by commenters and the number of commenters in the final open-ended question of the on-line surveys. These measures are examined by the same time quartiles.

In Australia, the average number of characters used for commenting in each quartile from the fastest to slowest time taken to complete the survey is 35, 67, 100, 171. As expected, when the time taken to complete the questionnaire increased the average number of characters used to comment also increased. This pattern is repeated in the New Zealand data. The average number of characters used by New Zealand participants from the fastest to slowest quartiles is 77, 124, 154, 189.

The number of commenters also shows a monotonic increase over successive quartiles (Chart 14). The same pattern is present in New Zealand (Chart 15).

Chart 14 : Australian commenters in time quartiles.

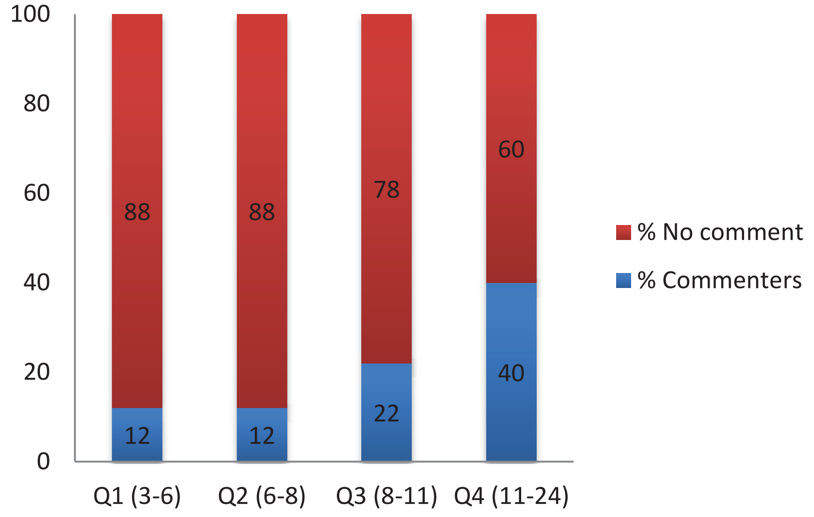
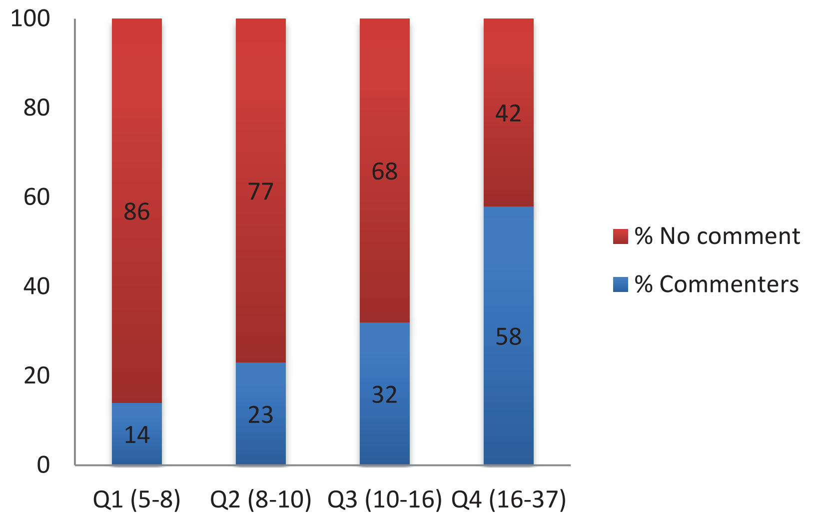


Chart 15 : New Zealand commenters in time quartiles.



An interesting outcome is the number of participants in each quartile who did not comment on global warming or climate change. In the longest Australian time quartile (11 – 24) minutes) 60% of the quartile did not make any comment (Chart 14). In the longest New Zealand time quartile (16-37 minutes) the number of participants who chose not to comment is 43% (Chart 15). Although the percentage of commenters follows the expected pattern of becoming fewer in number as the time taken to complete the survey decreases, the percentage of non-commenters in the longest quartiles indicates time taken to complete the survey is driven by something other than time taken to write comments. The high number of non-commenters in these longer quartiles indicates it is not simply the time taken to write comments that is driving the time taken to complete the survey. While some of the longer times recorded could be attributed to an interruption during the participant's time on-line, this is unlikely to explain the behaviour all non-commenters used in the third and fourth quartiles.

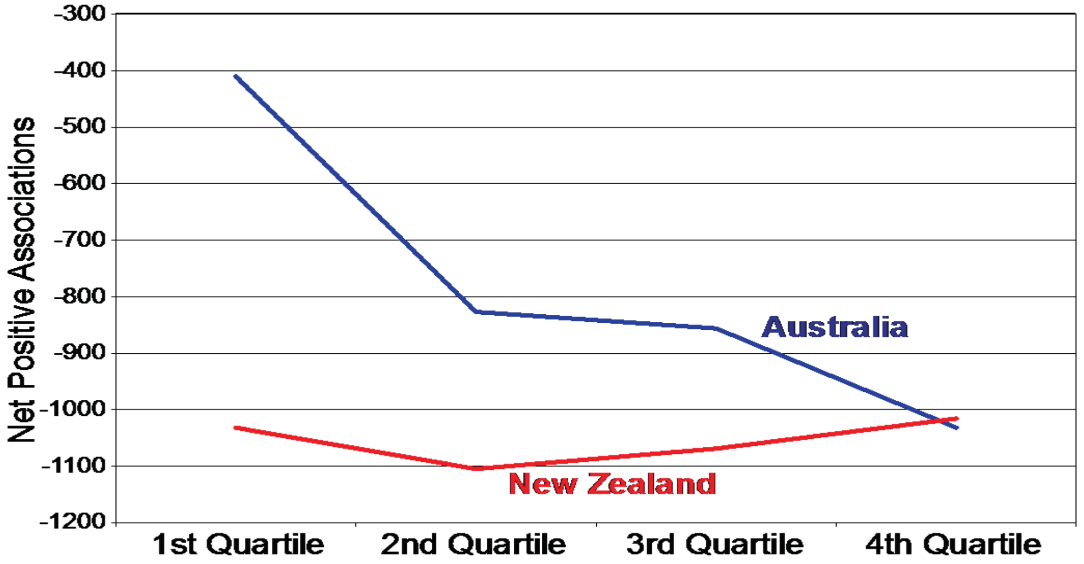
8.5 Stage Three – Discussion

Australia and New Zealand might be expected, a priori, to react quite differently to climate engineering proposals, due to their different views on the closely related issues of mineral exploration and mining. The Australian economy is heavily mineral-dependent, while mining is more restricted in New Zealand. When proposals were made to allow mineral exploration in some New Zealand national parks in 2010, they were hastily withdrawn after 40,000 protestors took part in an anti-mining march. Surprisingly, Wright et al. (2014a) did not find any differences in the reaction to climate engineering between these two countries. Nor, using a multifactor random effects general linear model, did they identify any important demographic correlates of the net positive variable.

The present results are therefore quite suggestive, as country-differences have now become detectable as a moderator of the effect of deliberative thinking on the net positive evaluations. Australians who took longer to think about the questions were more negative in their evaluations of climate engineering concepts. New Zealanders who took longer to think about the questions made substantially similar evaluations to those who took less time.

Figure 6 presents this analysis in graphical form, and extends it across all four quartiles. This shows how the number of net positive evaluations varies with time taken to answer the questionnaire. It is noteworthy that the results for each country converge by the 4^{th} quartile.

Figure 4: Changes in net positive associations by quartile.



Source: Feetham, Wright, & Teagle (2015).

This unexpected result invites further investigation. It offers a promising line of enquiry for an old problem; the correlation between attitudes and behaviour (or behavioural intention). These correlations have long been known to be weak (Kraus 1995) and this has also been demonstrated for environmental attitudes in particular (Wright and Klÿn 1998). The results of the present research imply that this weak relationship may be because attitudes do not operate directly through their effect on cognitive evaluations, but rather have an effect by moderating the impact of cognitive effort (deliberation) on evaluation (net positive in this case). So those with stronger attitudes may simply reach the same conclusions more quickly than others. For now this is a tentative comment, but it does suggest an interesting line of future research.

An inter-country difference is also shown in the number of people who opted to comment on global warming or climate change. In all quartiles New Zealanders made more comments than their Australian counterparts and on average used more characters to express their opinion. This may reflect a cultural difference between the countries. New Zealanders have a long history of protesting environmental issues of concern. As early as the nineteen seventies they demonstrated their concerns about the harmful environmental effects of nuclear waste by denying American nuclear-armed naval vessels entry to New Zealand ports and have continued to speak out against countries of greater economic power on environmental and other major global issues.

The high number of non-commenters in the longer third and fourth quartiles in both countries indicates it is not simply the time taken to comment that is driving the time taken to complete the survey. However, as respondent behaviour while answering the surveys is unobserved, it is not possible to conclude the non-commenting participants in the longest quartiles were all applying deliberative thinking. Some participants in these quartiles may have taken longer to complete the surveys due to interruptions. Yet it is highly unlikely the longer time taken by non-commenters in these quartiles is attributable solely to interruptions to their responses. The results suggest more than just intuitive responses were used. However, the uncertainty as to the degree of non-intuitive consideration highlights the difficulties of identifying and measuring when deliberative thinking is taking place.

The convergence of views shown in Figure 6 also implies that through clear public engagement, education and explanation of complex issues such as environment change or new technology, it may be possible to generate a wider public response (i.e. the Type 1 response) closer to that given by well-informed individuals undertaking deliberative thinking. This gives promise for an entirely new approach for upstream deliberation based on giving more weight to the views of respondents who take the longest to answer.

8.6 Limitations and Future Research

This stage of the research used the time taken to complete the survey in Stage two and as a proxy for measuring deliberative thinking. This single measurement needs extending. Follow-up research should check these initial results on new datasets, and extend the tests from cross-sectional to experimental data. Aside from considering the moderating effects of attitudes on the relationship between cognitive effort and evaluations, future research could investigate whether there are personal characteristics that are associated with greater deliberative thinking, and also test a variety of methods for encouraging more deliberative thinking.

The previous three stages of research in Chapters six, seven, and eight quantified public perceptions of climate engineering as predominately negative, and suggested the effect of deliberative thinking on the evaluation of climate engineering concepts is moderated by the country of study, as the results in Australia indicated that intuitive and deliberative thinking do give different results in magnitude if not direction. In both countries the quartiles and halves show similar patterns of results, therefore whether deliberative thinking is dichotomous or takes place on a continuum is unconfirmed. The impact of demographics on degrees of negativity towards climate engineering is not detectable in these first three stages of this research, other than a slight tendency for older people to be more positive about climate engineering. Also, the three stages compared public perceptions of individual climate engineering techniques, but did not evaluate perceptions of climate engineering in the context of other solutions for global warming. To address these unanswered questions Chapter nine reports the findings of five focus groups held in New Zealand during 2015.

Chapter Nine: Stage Four – Qualitative Focus Groups

9.1 Stage Four – Research Question

To understand how social representations of climate engineering relative to other solutions for global warming are formed the research questions in Stage four are:

- Do public perceptions of climate engineering change when considered among alternative solutions for global warming?
- How are social representations of climate engineering formed?
- Do climate engineering perspectives vary among individuals or relatively homogenous groups?

9.2 Stage Four – Justification for the Methodology

The qualitative method of face-to-face depth interviews used in Stage 1 was chosen rather than focus groups because the interest was to explore individuals' underlying cognitive constructs and avoid the influence of dominant individuals on group participants. In face-to-face interviews there is the flexibility to probe for further reasons for a particular response and this was appropriate as the aim of Stage one was to elicit attribute associations from memory constructs. However, in this fourth stage of research the interest is in understanding how shared representations are formed among individuals and to draw out the common themes of climate engineering in relatively homogenous, societal groups. In this situation, focus groups are an appropriate method for examining common themes, and to identify how shared representations are formed and negotiated in social interactions between individuals (Wibeck et al., 2015). Focus groups will also allow another assessment of whether demographic differences influence climate engineering perspectives as this was not detectable in Stages one and two of the research. This stage of the research also delays introducing the 'emergency climate framing' or 'insufficient mitigation framing' as the reason for climate engineering until as late as possible in the discussions.

Focus groups are also considered in this stage because open-ended questions can be explored by issues of importance to the participants, and questions that arise are framed in the participants' own vocabulary. The communication is interpersonal and this is thought to highlight (sub) cultural values or group norms (Kitzinger, 1995). Despite these advantages in focus groups the moderator needs to control dominant individuals who may intimidate other group members. Encouraging group members to contribute may also be required if the expression of group norms inhibits an individual who opposes the group norm (Kitzinger, 1995).

9.3 Stage Four – Method

9.3.1 Sample Recruitment

The participants were recruited by contacting community groups and asking for volunteers to join a discussion group on global environmental problems (i.e. topic blind). Recruiting community groups allows relatively homogeneous groups as the individuals have common interests. The five community groups used in Stage four were classified as young professionals, creative professionals, young parents from a kindergarten committee, retirees, and an ethnic group chosen because they had indigenous Māori or Pacific Island heritage. Some community groups were given a donation for their organisation and the members of one group were given petrol vouchers for travel to the university campus. The groups contained 6-7 participants with an overall total of 33 people.

9.3.2 Focus Group Procedure

The groups were led by one moderator, and an assistant, and lasted between 55 and 70 minutes. Discussions were recorded, transcribed verbatim and each speaker's input was coded for later thematic content analysis. The thematic content and analysis of how social representations were formed was carried out by this author. A copy of the topic guide used by the moderator (this author) is presented in Appendix I.

9.3.2 Focus Group Discussion Content

The format and content of the group discussions replicates focus group research carried out in Sweden in 2013 and published in *Energy Research & Social Science, 2015* (Wibeck, et al., 2015). The discussion topics were semi-structured and began with a broad discussion on environmental issues, then proceeded through discussions on climate change to an explanation of climate engineering technologies by the moderator. This was followed by a discussion on how participants would be affected if climate engineering was considered as a real alternative to mitigation and adaptation in the future. A final topic asked what types of actions participants saw as most important to tackle climate change.

9.4 Stage Four – Results

9.4.1 Focus Group Sample Demographics

The sample as a whole displays an even gender split, males 52% and females 48% and a wide span of age, education and occupation. Ages ranged from 19 to over 65 years. Educational backgrounds varied from school only qualifications to post-graduate degrees. Occupations were also widely varied. Other than gender, demographic details were not collected from the group of retirees to avoid any undue pressure on their retirement status. Some community groups were given a donation for their organisation and members of one group were given petrol vouchers for their travel to the university campus. A table of demographic characteristics is presented in Appendix H.

9.4.2 Thematic Content Analysis

Common environmental concerns across all focus groups were global warming, rising oceans, more natural disasters, pollution and animals becoming extinct. With the exception of one group, all participants didn't think much about these issues unless prompted by the media, or the weather. The indigenous group on the other hand did think about these problems in their everyday lives.

Example 1 "We used to plant by the moon and fish by the tides but that's been affected by temperatures and water changes."

Views of climate change problems were varied among the groups. Three groups did not see climate change as a major problem in their everyday lives suggesting spatial proximity is an influence on perceptions of climate change. The young creatives and the indigenous groups thought climate change is a major problem that should be addressed.

When introduced to climate engineering all participants were sceptical. Some participants were openly scared, other common themes were comparing it to science fiction, climate engineering is not addressing the cause of climate change, and that it was unnatural.

Example 2 "Scares the heck out of me. Some of those are really quite scary."
"It freaks me out a bit. What are the side effects of those things?"
"It makes me nervous about what effects it will have."
"They're very weird…..they sound just like sci-fi."
" They all seem a bit far-fetched

"Addressing the symptoms not the cause."
"None of it sounds very natural. It's all very interfering."

Knowledge of climate engineering varied across the groups. Among the young professionals (aged 23 – 27 years) and the young parents (aged 29 – 43 years) groups no one had previously heard about climate engineering. In the indigenous group (aged 19- 53 years), one person knew of ocean fertilisation but not in the context of climate engineering. In the retiree group (65 years and over) all except one person had heard about climate engineering. In the creative professionals (aged 21 -57 years) half of the group had heard 'something' about climate engineering but were only vaguely familiar with carbon dioxide removal techniques and had not heard of solar radiation management.

Generally across the groups risks and unknown side effects were mentioned for individual climate engineering technologies.

Example 3 "How do we know that brightening crops isn't going to lead to weird types of cancers?"
"*sulphate poisoning us….or if it* (mirrors in space) *blocks out too much sunlight*"
"ocean fertilisation is messing with the natural food chain"
"painting the roofs white would cause retinal degeneration from the glare"

Except for the indigenous group who were aware of rising ocean waters (Pacific Islands) reclaiming land, none of the groups could think of any ethical concerns until the moderator explained it in the context of climate engineering. The moderator provided the example of how using cloud brightening to cool the icecaps could alter the monsoon cycles over India or Africa thereby affecting people's livelihoods and lifestyles. On the topic of ethics the responses were more individual than group consensus.

Example 4 "Painting roofs white well that's taking away freedom of choice"
"it's us messing with the world"
"what does it do to the sea life"
'where's the ethics for Pacific Islanders now? They are sinking and we are doing nothing"

With the exception of the indigenous group all the other groups expressed the responsibility for addressing climate change lay with the government. There was some agreement that

United Nations should govern climate engineering but some scepticism towards the United Nations achieving anything as nations do not get along.

Example 5 "almost impossible because the super powers are the biggest producers of pollutants"

Some participants thought that New Zealand was too small to be successful in addressing climate change (see also example 9).

Example 6 "Tin-pot countries like New Zealand doing it is a waste of time"

The indigenous group on the other hand did not want the government taking responsibility, mostly because they did not trust politicians. Instead the majority within this group thought everyone is responsible. This is not surprising given that Māori have an inherent connection and attachment to the land 'the tangata whenua' (ancestors are buried in the land), and the sea-beds through their Treaty of Waitangi rights.

Example 7 "Everyone's responsible so everyone should address it. I trust the people in the community in the grass roots."

"*our belief system is that we are 'kaitiaki of the whenua'* (translation – caretakers of the land, a guiding principle of Māori culture)…… *so we naturally have an automatic responsibility to the land."*

When the moral hazard argument was explained (i.e. the use of climate engineering would cause people to reduce their mitigation actions such as energy saving and recycling) nearly all participants in all groups said it was unlikely this would happen, instead they expressed it was more likely people would be motivated to recycle more.

When the groups were asked what type of actions (mitigation, adaptation or climate engineering) were most important to tackle climate change 45% chose mitigation only, 33% chose mitigation along with adaptation. Four participants chose adaptation only. Two participants thought all three actions were needed to combat climate change, and one person thought the action should be based on what was accessible to each country as it was not appropriate for some countries to mitigate if they do not have the infrastructure.

9.4.3 Social Representations

In these focus groups social representations and 'sense making' are examined through the participants use of analogies and metaphors, the use of 'we' and 'them' to express they are representing the group, and affective reactions versus logical reasoning.

When asked if climate change is a problem some participants tried to influence others by minimising the problem *" it's a drop in the water"*, referred to themselves as 'civilisation', and used the analogy "*that's the nature of the beast."*

Example 8 "Civilisation as we know it we've put up with it. There's always going to be floods and there's always going to be um typhoons or hurricanes because that's the nature of the beast."

"Even if you did do something it's a drop in the water."

When participants were asked, 'how should climate engineering be addressed?' logical reasoning were provided in the following conversation from the retiree group.

Example 9 "We're all talking little things in NZ the biggest thing we can do is work together and put pressure on countries that are doing the major polluting e.g. China, America, Mexico and Indonesia. In NZ individuals can make a little bit of difference but if we have a joint voice we can be effective against the major polluter
we can't lean on China no…. but we can we can yell at them we've got a big say in the UN at the moment
How many of you purchased products from China last month….
How can you not……..we all have
but by stopping purchasing thing from China that's one of the ways it will affect China……………
can't bite the hands that feed you can you?

The conversation turned from a local frame of farming in New Zealand needing to be 'cleaner' and using rail freight more than trucks to save energy and lessen pollution to the quoted conversation (Example 8) that blamed the bigger global nation of China as the problem, and then provided reasons why it would not be possible to stop purchasing products from China, New Zealand's main trading partner. Through this line of reasoning the group reached an inferred consensus that someone else is to blame for global warming and that even though New Zealand could voice these concerns it would have little effect because New Zealand is economically dependent on the main polluter. *"Tinpot countries like New Zealand doing it is a waste of time"*

As a response for how climate chance should be addressed another participant used the metaphor "*this beast is impossible"* to compare the magnitude of the problem to a 'beast'.

When asked their thoughts on climate engineering as a solution if there was an emergency a respondent expressed the following analogy:

Example 10 "I was going to say it's like in my industry (health) *you don't immediately go for the big gun antibiotics when you can do the lesser things first and see. You've got to keep your big stuff for your absolute final shot, so we do what we can but we do it down here. Softly, softly, you don't go in and start firing off your 25 pounder guns."*

The analogy compares antibiotics to weapons and more broadly uses this comparison to say use only small weapons to attack the climate change problem and slowly lead up to bigger weapons of attack.

9.5 Stage Four – Discussion

The focus group findings revealed that overall the participants were sceptical and a little afraid that climate engineering is being considered as a solution to climate change and global warming. Generally there were concerns about the risks, side effects and unknowns. Knowledge of climate engineering was limited, although an exception was the retiree group as all but one person had heard of climate engineering. The majority of most groups did not believe as individuals they could make a difference to prevent climate change and that it was the government's responsibility; however, for the indigenous group this was reversed. They believed it was everyone's responsibility, that they had an inherent responsibility to protect the land, and that their efforts could make a difference to global temperatures. All groups were unaware of any ethical concerns as a result of climate engineering deployment and needed an explanation of ethical issues from the moderator. In contrast to some research, these participants disagreed with the moral hazard argument, rather they thought the need for climate engineering would make society more motivated to reduce emissions – not less motivated to take remedial actions. Out of the 33 participants only two thought all three actions, mitigation, adaptation and climate engineering were most important to tackle climate change. Almost half of the participants thought only mitigation should be used and a third of the participants thought mitigation and adaptation should be used. Many participants used a variety of analogies, metaphors, logical reasoning and the terms we and them to form social representations. The main social representations inferred were New Zealand is too small to have any effect in addressing climate change problems and New Zealand is powerless against its main trading partner who is one of the major 'polluting' nations to blame for climate change. There was also little belief that such a big problem could be solved.

Overall, the focus groups confirmed many of the themes that emerged in Stage one of the research. However, it allowed an illustration of some of the differences among social groups as the indigenous group felt they were responsible for helping solve climate change and that individual mitigation efforts could make a difference, in contrast to the other groups who did not believe it was their responsibility or that they could make a difference.

9.6 Limitations and Future Research

The key findings in the five focus groups revealed some differences in how individuals and relatively homogenous groups perceive climate engineering, and how some social representations of climate engineering are beginning to be formed. However, the focus groups were few in number, from only one geographical area of New Zealand and therefore under-represent the many diverse lifestyles and cultural backgrounds of New Zealanders. The indigenous group identified some different perspectives of climate engineering than the perspectives of the other non–Māori groups. However, to provide a more representative sample of all Māori, group discussions would need to incorporate larger hui style interactions, rather than the small group format of focus groups, as huis are how Māori make community-wide decisions. Forming a wider range of groups to investigate different perspectives could include farmers, white collar workers, and separated gender groups.

The following final chapter concludes the dissertation by discussing the relevance of the outcomes of the four stages of research and their important theoretical and methodological contributions to marketing and science communication.

Chapter Ten: Conclusions

The main objective of this dissertation is to investigate whether marketing research methods facilitate upstream public engagement with contentious science issues . In doing so the research also extends the validity and the robustness of the methods in marketing through transferability into science communication and their convergent validity. The ways that marketing theories and methods facilitate upstream public engagement with contentious science issues are investigated using four different methodologies applied in four different independent stages of research.

Stage one of the research contributed to marketing theories by confirming the findings of previous work that has applied and tested attribute elicitation techniques. Earlier work determined that most methods of attribute elicitation have convergent validity (Bech-Larsen & Nielsen, 1999; Brevik & Supphellen, 2003; Steenkamp & Van Trijp, 1997). Both of the elicitation methods used in this research provided a set of similar salient attributes. The pre-determined list of attributes and the Kelly's repertory grid methods of attribute elicitation used in Stage one of this research confirm the convergent validity of the two techniques. However, practitioners in marketing who need to uncover underlying memory constructs and identify consumer' own language associations with brands should in the first instance use Kelly's repertory grid as this method performs better on these aspects.

The two attribute elicitation techniques demonstrate their usefulness for science communicators wishing to provide descriptors to new science, technologies, or hypothetical concepts as they revealed underlying climate engineering concepts that were unfamiliar to most participants in the study. One of the concerns about obtaining public views on hypothetical issues is that lay public may be unable to form associations with an unknown concept. This belief often delays early pubic engagement with new science or technologies. Stage one of this research demonstrated that public involvement need not be delayed due to unfamiliarity with a hypothetical science issue and confirms that public can be included even when a new concept is only at the hypothetical stage of the research and development process as participants were able to provide verbal descriptors of little known climate engineering technologies.

Overall, the stage one research highlighted the robustness of the independent qualitative research by illustrating that perceptions of climate engineering techniques are predominately negative, and that there is a clear separation between the participants' perceptions of CDR and SRM technologies. These results were confirmed in Stage two of the research.

The methodologies applied in Stage two used associative network theory of memory, widely applied in branding evaluations, and the latest methods of brand metric imaging to quantify the extent of negative and positive perceptions of the six climate engineering technologies tested. The results of this Stage demonstrate that participant's perceptions of climate engineering vary on the key attributes associated with the techniques (*unknown effects*, *risky*, *artificial*, *eyesore,* and *quick-fix*), and confirmed Stage one's findings that there is a clear separation between the broad classifications of climate engineering, CDR and SRM. Only a minor variation was found between climate engineering evaluations and demographic groups – a slight tendency for the net positive variable to increase a little with age in Stage two of the research. The close similarity of the results in a cross-country comparison provided further evidence of the convergent validity of these techniques.

These imaging metrics have practical significance for science communicators as they provide a unique, systematic method to address the lack of upstream public engagement when new science or technologies are still only hypothetical concepts. In the past, new science and technologies that remain in the hypothetical stage have delayed public involvement at the conceptual design stage. This stage of the research provides a tangible, representative, systematic, and quantitative methodology that enables upstream engagement (before the concept is real). It also allows between technique comparisons and benchmarks for evaluating changes in concept evaluations over time.

Stage three of the research addresses the issue of lack of knowledge of when deliberative thinking is taking place and whether evaluations of new science and technologies vary with deliberation compared with intuitive responses. Stage three results indicated that the more time taken to respond to survey questions increased the negativity of the participants' evaluations of climate engineering techniques in Australia and similar to the findings in Stage two, evaluations of the SRM methods were more negative than the evaluations of CDR methods. However, the result was different in New Zealand. New Zealanders who took longer to think about the questions made substantially similar evaluations to those who took less time. In this case, greater deliberative thinking is <u>not</u> associated with more negative evaluations. Rather, in contrast to the Australian results, the evaluations are virtually identical. This suggests that the effect of deliberative thinking on the evaluation of climate engineering concepts is moderated by the country of study. The present results are therefore quite suggestive, as country-differences are now detectable as a moderator of the effect of deliberative thinking on the net positive evaluations.

While the results in Australia and New Zealand show greater deliberative thinking is associated with more negative evaluations and indicates that intuitive and deliberative thinking give different results in *magnitude,* they do not signal *direction* for this data. Both countries yielded similar patterns of results across quartiles and halves, therefore no conclusions can be drawn about whether deliberative thinking tends towards dichotomous or continuous mental processes.

Drawing any further conclusions from this initial stage of research on the effects of intuitive and deliberative thinking would be premature as a variety of other methods for encouraging more deliberative thinking need applying to more data sets and in a variety of contexts before any generalisations can be made. However, the method has potential for an entirely new approach for upstream deliberation based on giving more weight to the views of respondents who take the longest to answer.

The results of Stage three of the research are indicative and thought provoking, providing a new perspective and theoretical direction for a long-standing problem – are responses provided in public engagement activities hasty and intuitive, and consequently less accurate than responses that are more deliberative? More replication is required to answer this critical question; however, grounded in the theoretical foundation of information dual-processing (Chapter 5), the method used in stage three of this research provides a practical starting point for other researchers to follow and extend.

Stage four reverts to a more traditional approach of engaging the public with the topic of climate engineering through focus groups. The focus groups add to the previous three stages by considering climate engineering alongside other solutions for global warming mitigation, rather than in isolation. Focus groups are not a new methodology in social science as they are widely used in public health sectors, in science communication, marketing, and other fields of study to help understand public perceptions of various issues. However, the findings of the focus groups in Stage four bring more detailed insights that were not revealed by the earlier qualitative individual interviews and on-line surveys. The analyses of these focus group discussions goes beyond the traditional focus group reporting of content themes by taking into account how sense-making of the unknown occurs, and identifying how participants form social representations in their arguments, counter-arguments and negotiations with others' viewpoints (Wibeck et al., 2015). The findings of thematic analysis uncovered similar concerns present in Stage one that is, participants were concerned about the risks and the unknown side effects on the Earth's eco-systems. Additional concerns were that an international consensus on regulations would be impossible to achieve. Analyses of these focus groups discussions showed that social representations were beginning to form and involved the use of metaphors, analogies and local reasoning. Through social representation inferences were made that as a nation New Zealand was too small to have any effect on addressing climate change problems and powerless against their larger trading partner who make a substantially larger contribution to global warming.

Overall, the results in this dissertation indicate that public evaluation of scientific concepts is not a simple matter. Even when deliberative thinking takes place responses are complex and varied. Thus, unless a multi-layered and multi-method evaluation of communication is used, a full picture of public perceptions of scientific concepts is unlikely to be achieved. To avoid misleading communication, science communicators and policy-makers should seek diversity in their methods of public engagement. Stirling (2008) agrees that a divergence of perspectives is crucial in science communication, "crucially the emphasis is not in building a final consensus but exploring systematic divergences of perspectives" (p. 282). The outcomes of this research provides a systematic divergence of perspectives, demonstrating that theories and methods from marketing can improve upstream public engagement with science through the novel application of marketing metrics to science communication.

Concurrently, this research extends the validity of marketing metrics by using the associative network of memory theory outside of branding in a specific scientific context, climate engineering, confirming the robustness of the associative network of memory theory. The research also contributes to marketing theory by investigating the effects of intuitive and deliberate thinking on concept evaluations and provides a better understanding of the relative impact of intuitive and deliberative processing of stimuli under different circumstances.

The results fill a major gap in the science communication literature on perceptions of climate engineering, demonstrating and benchmarking the extent of negative and positive associations with the overall climate engineering concept and six potential climate engineering techniques. In science communication and marketing the results of this research also break new ground by suggesting new methodologies to address important contemporary issues and providing cross-validity, thereby making more than just an incremental contribution to both areas.

References

African Academy of Sciences and Solar Radiation Management Governance Initiative. (2013) *Governance of research on solar geoengineering: African perspectives.* Consolidated report of three workshops in Senegal, South Africa and Ethiopia. Nairobi, Kenya.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*: Englewood Cliffs, N.J.: Prentice-Hall, c1980.

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. *Public Understanding of Science, 17*(1), 35-54.

Alter, A. L., Oppenheimer, D. M., Epley, N., & Eyre, R. N. (2007). Overcoming intuition: metacognitive difficulty activates analytic reasoning. *Journal of Experimental Psychology: General, 136*(4), 569-576.

Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: application of “mixed” research approach. *Work study, 51*(1), 17-31.

Amelung, D., & Funke, J. (2013). Dealing with the uncertainties of climate engineering: Warnings from a psychological complex problem solving perspective. *Technology in Society, 35*(1), 32-40.

Amelung, D., & Funke, J. (2015). Laypeople's risky decisions in the climate change context: Climate engineering as a risk-defusing strategy? *Human and Ecological Risk Assessment: An International Journal, 21*(2), 533-559.

Anderson, J. R. (1983a). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behaviour, 22*(3), 261-295.

Anderson, J. R. (1983b). Retrieval of information from long-term memory. *Science, 220*(4592), 25-30.

Anderson, J. R., Reder, L. M., & Lebiere, C. (1996). Working memory: Activation limitations on retrieval. *Cognitive Psychology, 30*(3), 221-256.

Anderson, J., & Bower, G. (1974). *Human Associative Memory*. Washington: John Wiley & Sons.

Anshelm, J., & Hansson, A. (2014). The Last Chance to Save the Planet? An Analysis of the Geoengineering Advocacy Discourse in the Public Debate.

Árnason, V. (2013). Scientific citizenship in a democratic society. *Public Understanding of Science, 22*(8), 927-940.

Asilomar Scientific Organising Committee. (2010). *The Asilomar conference recommendations on principles for research into climate engineering techniques*. Retrieved from Washington DC: http://www.climate.org/PDF/AsilomarConferenceReport.pdf

Australian Bureau of Statistics. (2016). 8146.0 - Household Use of Information Technology, Australia, 2014-15. Retrieved from http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8146.0Main+Features12014-15?OpenDocument

Barben, D., Fisher, E., Selin, C., & Guston, D. H. (2008). 38 Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration. *The handbook of science and technology studies*, 979.

Barnard, N. R., & Ehrenberg, A. S. (1990). Robust measures of consumer brand beliefs. *Journal of Marketing Research*, 477-484.

Barwise, T. P., & Ehrenberg, A. (1987). Consumer beliefs and awareness. *Journal of the Market Research Society, 29*(1), 88-94.

Bauer, M. W. (2009). The evolution of public understanding of science—discourse and comparative evidence. *Science Technology & Society, 14*(2), 221-240.

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Understanding of Science, 16*(1), 79-95.

Bawden, T. (2016). *COP21:Paris deal far too weak to prevent devastating climate change, academics warn*. Retrieved from: http://www.independent.co.uk/environment/climate-change/cop21-paris-deal-far-too-weak-to-prevent-devastating-climate-change-academics-warn-a6803096.html

Bech-Larsen, T., & Nielsen, N. A. (1999). A comparison of five elicitation techniques for elicitation of attributes of low involvement products. *Journal of Economic Psychology, 20*(3), 315-341.

Bellamy, R. (2013). Framing Geoengineering Assessment. *Opinion article, Geoengineering our climate working paper and opinion article series*. Oxford University, Institute of Science, Innovation and Society.

Bellamy, R., Chilvers, J., Vaughan, N. E., & Lenton, T. M. (2012). A review of climate geoengineering appraisals. *Wiley Interdisciplinary Reviews: Climate Change, 3*(6), 597-615.

Bellamy, R., & Lezaun, J. (2015). Crafting a public for geoengineering. *Public Understanding of Science*, 0963662515600965.

Besley, J. C., & Tanner, A. H. (2011). What science communication scholars think about training scientists to communicate. *Science communication, 33*(2), 239-263.

Bettman, J. R. (1979). Memory factors in consumer choice: A review. *The Journal of Marketing*, 37-53.

Beyerl, K., & Maas, A. (2014). *Perspectives on climatic engineering from Pacific small island states* (IASS working paper). Institute for Advanced Sustainability Studies. Potsdam, Germany.

Bettman, J. R., Luce, M. F., & Payne, J. W. (1998). Constructive consumer choice processes. *Journal of Consumer Research, 25*(3), 187-217.

Bickerstaff, K., Lorenzoni, I., Jones, M., & Pidgeon, N. (2010). Locating scientific citizenship: The institutional contexts and cultures of public engagement. *Science, Technology & Human Values, 35*(4), 474-500.

Biel, A. L. (1991). The brandscape: converting brand image into equity. *Admap* (October), 41-46.

Bird, M., & Ehrenberg, A. S. (1970). Consumer attitudes and brand usage. *Journal of the Market Research Society, 12*(4), 233-247.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*: National Academy Press.

Breivik, E., & Supphellen, M. (2003). Elicitation of product attributes in an evaluation context: A comparison of three elicitation techniques. *Journal of Economic Psychology, 24*(1), 77-98.

Brossard, D., & Lewenstein, B. (2010). A critical appraisal of models of public understanding of science: using practice to inform theory. In L. Kahlor & P. Stout (Eds.), *Communicating Science* (pp. 11-39). New York: Routledge.

Bubela, T., Nisbet, M. C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., . . . Hyde-Lay, R. (2009). Science communication reconsidered. *Nature Biotechnology, 27*(6), 514-518.

Buck, H. (2012). Geoengineering: remaking climate for profit or humanitarian intervention? *Development and Change, 43*(1), 253-270.

Buck, H. J. (2013). Climate engineering: spectacle, tragedy or solution? A content analysis of news media framing. *C. Methmann, D. Rothe, & B Stephen, eds*. (De-)constructing the greenhouse: interpretive approaches to global climate governance. Routledge: London

Caldeira, K., Bala, G., & Cao, L. (2013). The science of geoengineering. *Annual Review of Earth and Planetary Sciences, 41*, 231-256.

Cantor, N., & Mischel, W. (1979). Prototypes in person perception1. *Advances in Experimental Social Psychology*, 3.

Carpini, M. X. D., Cook, F. L., & Jacobs, L. R. (2004). Public deliberation, discursive participation, and citizen engagement: A review of the empirical literature. *Annu. Rev. Polit. Sci., 7*, 315-344.

Carr, W. A., Preston, C. J., Yung, L., Szerszynski, B., Keith, D. W., & Mercer, A. M. (2013). Public engagement on solar radiation management and why it needs to happen now. *Climatic Change, 121*(3), 567-577.

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology, 39*(5), 752.

Chilvers, J. (2008). Deliberating competence theoretical and practitioner perspectives on effective participatory appraisal practice. *Science, Technology & Human Values, 33*(2), 155-185.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*(6), 407.

Corner, A., Parkhill, K., & Pidgeon, N. (2011). Experiment Earth? Reflections on a public dialogue on geoengineering *Understanding Risk Working Paper 11-02*: Cardiff, School of Psychology.

Corner, A., Parkhill, K., Pidgeon, N., & Vaughan, N. E. (2013). Messing with nature? Exploring public perceptions of geoengineering in the UK. *Global Environmental Change, 23*(5), 938-947.

Corner, A., & Pidgeon, N. (2010). Geoengineering the climate: The social and ethical implications. *Environment, 52*(1), 24-37.

Corner, A., & Pidgeon, N. (2014). Geoengineering, climate change scepticism and the 'moral hazard' argument: an experimental study of UK public perceptions. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, 372*(2031), 20140063.

Corner, A., & Pidgeon, N. (2015). Like artificial trees? The effect of framing by natural analogy on public perceptions of geoengineering. *Climatic Change, 130*(3), 425-438.

Couper, M. P. (2000). Web surveys a review of issues and approaches. *Public Opinion Quarterly, 64*(4), 464-494.

Daily, L. Z., Lovett, M. C., & Reder, L. M. (2001). Modeling individual differences in working memory performance: A source activation account. *Cognitive Science, 25*(3), 315-353.

Daniel, D. B., & Klaczynski, P. A. (2006). Developmental and individual differences in conditional reasoning: Effects of logic instructions and alternative antecedents. *Child Development, 77*(2), 339-354.

Davies, S. R. (2013). The rules of engagement: Power and interaction in dialogue events. *Public Understanding of Science, 22*(1), 65-79.

De Chernatony, L., & McWilliam, G. (1990). Appreciating brands as assets through using a two-dimensional model. *International Journal of Advertising*, *9*(2), 111-119.

De Neys, W. (2006a). Dual processing in reasoning two systems but one reasoner. *Psychological Science*, *17*(5), 428-433.

De Neys, W. (2006b). Automatic–heuristic and executive–analytic processing during reasoning: Chronometric and dual-task considerations. *The Quarterly Journal of Experimental Psychology*, *59*(6), 1070-1100.

De Neys, W., Vartanian, O., & Goel, V. (2008). Smarter than we think: When our brains detect that we are biased. *Psychological Science*, *19*(5), 483-489.

De Ruyter, K., & Scholl, N. (1998). Positioning qualitative market research: reflections from theory and practice. *Qualitative Market Research: An International Journal*, *1*(1), 7-14.

Dijksterhuis, A., Bos, M. W., Nordgren, L. F., & van Baaren, R. B. (2006). On Making the Right Choice: The Deliberation-Without-Attention Effect. *Science, 311*(5763), 1005-1007

Dilling, L., & Hauser, R. (2013). Governing geoengineering research: why, when and how? *Climatic Change, 121*, 553-565.

Driesener, C., & Romaniuk, J. (2006). Comparing methods of brand image measurement. *International Journal of Market Research, 48*(6), 681-698.

East, R., Wright, M., & Vanhuele, M. (2013). *Consumer behaviour applications in marketing* (2nd ed.). London: Sage.

Effiong, U., & Neitzel, R. L. (2016). Assessing the direct occupational and public health impacts of solar radiation management with stratospheric aerosols. *Environmental Health, 15*(1), 1-9.

Elam, M., & Bertilsson, M. (2003). Consuming, engaging and confronting science the emerging dimensions of scientific citizenship. *European Journal of Social Theory, 6*(2), 233-251.

Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist, 49*(8), 709.

European Union Climate Action (2015). Retrieved from

http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm

Evans, J. S. B. (1996). Deciding before you think: Relevance and reasoning in the selection task. *British Journal of Psychology, 87*(2), 223-240.

Evans, J. S. B. (2006). The heuristic-analytic theory of reasoning: Extension and evaluation. *Psychonomic Bulletin & Review, 13*(3), 378-395.

Evans, J. S. B. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annu. Rev. Psychol.*, *59*, 255-278.

Evans, J. S. B., & Curtis-Holmes, J. (2005). Rapid responding increases belief bias: Evidence for the dual-process theory of reasoning. *Thinking & Reasoning*, *11*(4), 382-389.

Evans, J. S. B., Handley, S. J., & Bacon, A. M. (2009). Reasoning under time pressure: A study of causal conditional inference. *Experimental psychology, 56*(2), 77-83.

Evans, J. S. B. T. (2013). Two minds rationality. *Thinking & Reasoning, 20*(2), 129-146

Evans, G., & Durant, J. (1995). The relationship between knowledge and attitudes in the public understanding of science in Britain. *Public Understanding of Science, 4*(1), 57-74.

Evans, J. S. B., & Stanovich, K. E. (2013a). Dual-process theories of higher cognition advancing the debate. *Perspectives on Psychological Science*, *8*(3), 223-241.

Evans, J. S. B., & Stanovich, K. E. (2013b). Theory and metatheory in the study of dual processing reply to comments. *Perspectives on Psychological Science, 8*(3), 263-271.

Experiment Earth: Report on a public dialogue on Geoengineering (Ipsos Mori, 2010). Retrieved from http://www.nerc.ac.uk/about/consult/geoengineering-dialogue-final-report.pdf

Feetham, P., Wright, M., Comrie, M., & Teagle, D. (2012). Public reaction to climate geoengineering: An exploratory study. In R. Lee (Ed.), *Proceedings of the Australian and New Zealand Marketing Academy [ANZMAC] Conference* (pp. 1-7). Ehrenberg-Bass Institute for Marketing Science, Edith Cowen University: Ehrenberg Bass Institute for Marketing Science, Edith Cowen University, Adelaide, South Australia.

Feetham, P., Wright, M.J., Teagle D.A. (2015). Intuitive and deliberative responses in science communication – potential to mislead? (*working paper*).

Fishkin, J. S. (1997). *The voice of the people: Public opinion and democracy*: Yale University Press.

Fox, T. A., & Chapman, L. (2011). Engineering geo-engineering. *Meteorological Applications*, *18*(1), 1-8.

Fransella, F., Bell, R., & Bannister, D. (2004). *A manual for repertory grid technique*: John Wiley & Sons.

GAO. (2011). *Climate engineering technical status, future directions, and potential responses* (GAO-11-71). Retrieved from Washington DC: http://www.gao.gov/search?q=GAO-11-71

Gastil, J. (2000). *By popular demand: Revitalizing representative democracy through deliberative elections*: University of California Press.

Gauchat, G. (2011). The cultural authority of science: Public trust and acceptance of organised science. *Public Understanding of Science, 20*(6), 751-770.

Gibson, A., Miller, M., Smith, P., Bell, A., Crothers, C. (2013). *The Internet in New Zealand 2013*. Auckland, New Zealand: Institute of Culture, Discourse & Communication, AUT University.

Gigerenzer, G., & Brighton, H. (2009). Homo heuristicus: Why biased minds make better inferences. *Topics in Cognitive Science*, *1*(1), 107-143.

Gordijn, B., & ten Have, H. (2012). Ethics of mitigation, adaptation and geoengineering. *Medicine, Health Care and Philosophy*, *15*(1), 1-2.

Greene, J. D., Nystrom, L. E., Engell, A. D., Darley, J. M., & Cohen, J. D. (2004). The neural bases of cognitive conflict and control in moral judgment. *Neuron, 44*(2), 389-400.

Gregory, J., & Lock, S. J. (2008). The evolution of 'public understanding of science': Public engagement as a tool of science policy in the UK. *Sociology Compass, 2*(4), 1252-1265.

Hanson, D., & Grimmer, M. (2007). The mix of qualitative and quantitative research in major marketing journals, 1993-2002. *European Journal of Marketing, 41*(1/2), 58-70.

Harré, R., & Moghaddam, F. M. (2003). *The self and others: Positioning individuals and groups in personal, political, and cultural contexts*: Greenwood Publishing Group.

Hoek, J., Dunnett, J., Wright, M., & Gendall, P. (2000). Descriptive and evaluative attributes: what relevance to marketers? *Journal of Product and Brand Management, 9*(6), 415-435.

Hogan, S., Romaniuk, J., & M, F. (2012). *A purpose-based classification of brand attributes.* Paper presented at the Australian and New Zealand Marketing Academy, Adelaide.

Hogan, S., Romaniuk, J., & Faulkner, M. (2016). Comparing approaches to elicit brand attributes both face-to-face and online. *International Journal of Market Research, 58*(1), 4.

Holden, S. J. (1993). Understanding Brand Awareness: Let Me Give You a C (I) ue! *Advances in Consumer Research, 20*(1).

Huttunen, S., & Hildén, M. (2014). Framing the Controversial: Geoengineering in Academic Literature. *Science communication, 36*(1), 3-29.

IPCC. (2012). *Meeting report of the intergovernmental panel on climate change expert meeting on geoengineering*. Retrieved from Potsdam, Germany: http://www.ipcc.ch/pdf/supporting-material/EM_GeoE_Meeting_Report_final.pdf

Irvine, P. J., Schäfer, S., & Lawrence, M. G. (2014). Solar radiation management could be a game changer. *Nature Climate Change, 4*(10), 842-842.

Irwin, A. (2006). The politics of talk coming to terms with the 'new' scientific governance. *Social Studies of Science, 36*(2), 299-320.

Irwin, A., Jensen, T. E., & Jones, K. E. (2013). The good, the bad and the perfect: criticizing engagement practice. *Social Studies of Science, 43*(1), 118-135.

Irwin, A., & Wynne, B. (1996). *Misunderstanding science?: The public reconstruction of science and technology*: Cambridge University Press.

Jasanoff, S., Markle, G. E., Peterson, J. C., & Pinch, T. (2001). *Handbook of science and technology studies*: Sage publications.

Kahan, D. M., Jenkins-Smith, H., Tarantola, T., Silva, C. L., & Braman, D. (2015). Geoengineering and Climate Change Polarization Testing a Two-Channel Model of Science Communication. *The Annuals of the American Academy of Political and Social Science, 658*(1), 192-222.

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Straus and Giroux.

Keith, D. W. (2000). Geoengineering the climate: History and prospect 1. *Annual Review of Energy and the Environment, 25*(1), 245-284.

Keller, K. L. (1993). Conceptualizing, Measuring, Managing Customer-Based Brand Equity. *Journal of Marketing, 57*(1), 1-22

Keren, G., & Schul, Y. (2009). Two is not always better than one a critical evaluation of two-system theories. *Perspectives on Psychological Science, 4*(6), 533-550.

Kiel Earth Institute. (2011). *Large-scale intentional interventions into the climate system? Assessing the climate engineering debate*. Retrieved from http://www.fona.de/mediathek/pdf/Climate_Engineering_engl.pdf

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. *BMJ: British medical journal, 311*(7000), 299.

Kraus, S. J. (1995). Attitudes and the prediction of behavior: A meta-analysis of the empirical literature. *Personality and Social Psychology Bulletin, 21*(1), 58-75.

Kreuter, J. (2015). *Technofix, Plan B or Ultima Ratio? A review of the social science literature on climate engineering technologies.* Oxford University, Institute of Science, Innovation and Society (Occasional Paper Series 2).

Krishnan, H. S. (1996). Characteristics of memory associations: A consumer-based brand equity perspective. *International Journal of Research in Marketing, 13*(4), 389-405.

Kruglanski, A. W., & Gigerenzer, G. (2011). Intuitive and deliberate judgments are based on common principles. *Psychological Review, 118*(1), 97-109. doi:10.1037/a0020762

Kurath, M., & Gisler, P. (2009). Informing, involving or engaging? Science communication, in the ages of atom-, bio-and nanotechnology. *Public Understanding of Science*. *18* (5), 559-573.

Lachman, R., Lachman, J. L., & Butterfield, E. C. (2015). *Cognitive psychology and information processing: An introduction*: Psychology Press.

Latham, J., Bower, K., Choularton, T., Coe, H., Connolly, P., Cooper, G., Craft.T., Foster, J., Gadian, A., Galbraith, L. Iacovides, H., Johnston, D., Launder, B., Leslie, B., Meyer, J., Neukermans, A., Ormond, B., Parkes, B., Rasch, P., Rush, J., Salter, S., Stevenson, T., Wang, H., Wang, Q., Wood, R. (2012). Marine cloud brightening. *Phil. Trans. R. Soc. A, 370*(1974), 4217-4262.

Lees, G., & Wright, M. (2004). The effect of concept formulation on concept test scores. *Journal of Product Innovation Management, 21*(6), 389-400

Lieberman, M. D. (2007). Social cognitive neuroscience: a review of core processes. *Annu. Rev. Psychol., 58*, 259-289.

Lindeman, M. (2002). Opinion quality and policy preferences in deliberative research. *Political decision making, deliberation and participation, 6*, 195-224.

Linnér, B.-O., & Wibeck, V. (2015). Dual high-stake emerging technologies: a review of the climate engineering research literature. *Wiley Interdisciplinary Reviews: Climate Change, 6*(2), 255-268.

Low, G. S., & Lamb Jr, C. W. (2000). The measurement and dimensionality of brand associations. *Journal of Product & Brand Management*, *9*(6), 350-370.

Low, S., Paker, A., Moore, N., Maas, A., Lawrence, M. G., Schäfer, S. (2015): Climate Engineering Conference 2014: Critical Global Discussions. Conference Report, Potsdam : Institute for Advanced Sustainability Studies (IASS). DOI: http://doi.org/10.2312/iass.2015.008

Lynch Jr, J. G., & Srull, T. K. (1982). Memory and attentional factors in consumer choice: Concepts and research methods. *Journal of Consumer Research*, 18-37.

Macnaghten, P., & Szerszynski, B. (2013). Living the global social experiment: an analysis of public discourse on solar radiation management and its implications for governance. *Global Environmental Change, 23*(2), 465-474.

Mandler, G. (1975). *Mind and emotion*: Krieger Publishing Company.

Marková, I. (1996). Towards an epistemology of social representations. *Journal for the Theory of Social behaviour, 26*(2), 177-196.

Mata, A., Ferreira, M. B., & Sherman, S. J. (2013). The metacognitive advantage of deliberative thinkers: A dual-process perspective on overconfidence. *Journal of personality and social psychology*, *105*(3), 353-373.

McNulty, J. K., Olson, M. A., Meltzer, A. L., & Shaffer, M. J. (2013). Though they may be unaware, newlyweds implicitly know whether their marriage will be satisfying. *Science, 342*(6162), 1119-1120.

Mercer, A., Keith, D., & Sharp, J. (2011). Public understanding of solar radiation management. *Environmental Research Letters, 6*(4), 044006-044015.

Merk, C., Pönitzsch, G., & Rehdanz, K. (2015). *Knowledge about aerosol injection does not reduce individual mitigation efforts*. (No: 2006) Kiel working paper.

Merk, C., Pönitzsch, G., Kniebes, C., Rehdanz, K., & Schmidt, U. (2014). *Exploring public perception of solar radiation management*. (No: 1892) Kiel working paper.

Meyers-Levy, J. (1989). The influence of a brand name's association set size and word frequency on brand memory. *Journal of Consumer Research*, 197-207.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 63*(2), 81.

Moxley, J. H., Anders Ericsson, K., Charness, N., & Krampe, R. T. (2012). The role of intuition and deliberative thinking in experts' superior tactical decision-making. *Cognition, 124*(1), 72-78.

Nakanishi, M. (1974). Decision net models and human information processing. In G. Hughes & M. Ray (Eds.), *Buyer/consumer information processing* (pp. 75-88). Chapel Hill, NC: University of North Carolina Press.

NASA Jet Propulsion Laboratory, & California Institute of Technology (Producer). (2013, 15 February). Geoengineering and climate intervention. *Von Karman lecture series*. [(video webcast)] Retrieved from http://www.ustream.tv/recorded/29293171

NASA scientists react to 400 ppm carbon milestone (2014). Retrieved from http://climate.nasa.gov/400ppmquotes/

Nenycz-Thiel, M., & Romaniuk, J. (2009). Perceptual categorization of private labels and national brands. *Journal of Product & Brand Management, 18*(4), 251-261. doi:10.1108/10610420910972774

Nenycz-Thiel, M., Sharp, B., Dawes, J., & Romaniuk, J. (2010). Competition for memory retrieval between private label and national brands. *Journal of Business Research, 63*(11), 1142-1147.

Nielsen. (2011). *Sustainable efforts & environmental concerns around the world*. Retrieved from http://hk.nielsen.com/documents/NielsenSustainabilityReportAug2011FINAL.pdf

Nisbet, M. C., & Scheufele, D. A. (2009). What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany, 96*(10), 1767-1778.

Osman, M. (2004). An evaluation of dual-process theories of reasoning. *Psychonomic Bulletin & Review, 11*(6), 988-1010.

Parkhill, K., & Pidgeon, N. (2011). *Public engagement on geoengineering research: Preliminary report on the SPICE deliberative workshops*. Retrieved from

Payne, C. R., Rachael, S., & Samantha, H. (2015). Public particpation and norm formation for risky technology: adaptive governence of solar-radiation management. *Climate Law*, *5*(2-4), 201-251.

Pennycook, G., Fugelsang, J. A., & Koehler, D. J. (2015). What makes us think? A three-stage dual-process model of analytic engagement. *Cognitive Psychology, 80*, 34-72.

Peters, G. P., Marland, G., Le Quéré, C., Boden, T., Canadell, J. G., & Raupach, M. R. (2011). Rapid growth in CO2 emissions after the 2008-2009 global financial crisis. *Nature Climate Change, 2*(1), 2-4.

Petty, R., & Cacioppo, J. (1991). Attitudes and Persuasion: classic and contempory approaches. Colorado: Westview Press.

Piggott, J. R., & Watson, M. P. (1992). A comparison of free-choice profiling and the repertory grid method in the flavor profiling of cider. *Journal of Sensory Studies, 7*(2), 133-145.

Podsakoff, P. M., MacKenzie, S. B., Lee, J., & Podsakoff, N. P. (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. *Journal of Applied Psychology, 88*(5), 879.

Podsakoff, P. M., MacKenzie, S. B., & Podsakoff, N. P. (2012). Sources of method bias in social science research and recommendations on how to control it. *Annual Review of Psychology, 63*, 539-569.

Preston, C. J. (2013). Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and carbon dioxide removal. *Wiley Interdisciplinary Reviews: Climate Change, 4*(1), 23-37.

Rayner, S. (2003). Democracy in the age of assessment: reflections on the roles of expertise and democracy in public-sector decision making. *Science and public policy, 30*(3), 163-170.

Reder, L. M. (1987). Strategy selection in question answering. *Cognitive Psychology, 19*(1), 90-138.

Reder, L. M., Park, H., & Kieffaber, P. D. (2009). Memory systems do not divide on consciousness: Reinterpreting memory in terms of activation and binding. *Psychological Bulletin, 135*(1), 23-49.

Reese, S. D. (2007). The framing project: A bridging model for media research revisited. *Journal of communication, 57*(1), 148-154.

Rodgers-Hayden, T., & Pidgeon, N. (2007). Moving engagement upstream? Nanotechnologies and the Royal Society and Royal Academy of Engineering inquiry. *Public Understand Science, 16*, 346-364.

Rogers, B., & Ryals, L. (2007). Using Repertory Grid to access the underlying realities in key account relationships. *International Journal of Market Research*, *49*(5), 595-612.

Romaniuk, J. (2003). Brand attributes–'distribution outlets' in the mind. *Journal of Marketing Communications*, *9*(2), 73-92. Retrieved from http://dx.doi.org/10.1080/1352726032000088896

Romaniuk, J. (2013). Modeling mental market share. *Journal of Business Research*, *66*(2), 188-195.

Romaniuk, J., Bogomolova, S., & Riley, F. D. O. (2012). Brand Image and Brand Usage. *Journal of Advertising Research*, *52*(2), 243-251.

Romaniuk, J., & Nenycz-Thiel, M. (2013). Behavioral brand loyalty and consumer brand associations. *Journal of Business Research*, *66*(1), 67-72.

Romaniuk, J., & Sharp, B. (2000). Using known patterns in image data to determine brand positioning. *International Journal of Market Research*, *42*(2), 219-230.

Romaniuk, J., & Sharp, B. (2004). Conceptualizing and measuring brand salience. *Marketing Theory, 4*(4), 327-342.

Romaniuk, J., & Sharp, B. (2016). *How brands grow Part 2*: Oxford University Press Melbourne

Scheer, D., & Renn, O. (2014). Public Perception of geoengineering and its consequences for public debate. *Climatic Change, 125*(3-4), 305-318.

Scholte, S., Vasileiadou, E., & Petersen, A. C. (2013). Opening up the societal debate on climate engineering: how newspaper frames are changing. *Journal of Integrative Environmental Sciences*, *10*(1), 1-16.

Selin, C., Rawlings, K. C., de Ridder-Vignone, K., Sadowski, J., Allende, C. A., Gano, G., Davies, S.R& Guston, D. H. (2016). Experiments in engagement: Designing public engagement with science and technology for capacity building. *Public Understanding of Science*, *25*(1), 1-16.

Sillmann, J., Lenton, T. M., Levermann, A., Ott, K., Hulme, M., Benduhn, F., & Horton, J. B. (2015). Climate emergencies do not justify engineering the climate. *Nature Climate Change*, *5*(4), 290-292.

Simon, H. A. (1974). How big is a chunk? *Science, 183*(4124), 482-488.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*(1), 3.

Smith, E. R., & DeCoster, J. (1999). Associative and rule based processing. *Dual-process theories in social psychology*, 323-336.

Smith, E. R., De Coster. J. (2000). Dual-Process Models in Social and Cognitive Psychology: Conceptual Integration and Links to. *Personality & Social Psychology Review (Lawrence Erlbaum Associates)*, *4*(2), 108.

Stanovich, K. E., & Toplak, M. E. (2012). Defining features versus incidental correlates of Type 1 and Type 2 processing. *Mind and society*, *11*(1), 3-13.

Stanovich, K.E., & West, R. F. (1998a). Cognitive ability and variation in selection task performance. *Thinking & Reasoning*, *4*(3), 193-230.

Stanovich, K. E., & West, R. F. (1998b). Individual Differences in Framing and Conjunction Effects. *Thinking & reasoning*, *4*(4), 289-317.

Stanovich, K. E., & West, R. F. (1998c). Individual differences in rational thought. *Journal of Experimental Psychology: General*, *127*(2), 161.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences*, *23*(5), 645.

Steenkamp, J-B., & Van Trijp, H. (1997). Attribute elicitation in marketing research: A comparison of three procedures. *Marketing Letters*, *8*(2), 153-165.

Stein, A. (2013). Are people probabilistically challenged? *Mich. L. Rev.*, *111*, 855.

Stirling, A. (2008). “Opening up” and “closing down” power, participation, and pluralism in the social appraisal of technology. *Science, Technology & Human Values*, *33*(2), 262-294.

Stocchi, L. (2011). *Exploring the link between consumer behaviour and brand associations* (Unpublished doctoral dissertation). Ehrenberg-Bass Institute for Marketing Science, University of South Australia, Adelaide, Australia.

Stocchi, L., Wright, M., Driesener, C., Lee, N., & Dawes, J. (2016). Why familiar brands are sometimes harder to remember. *European Journal of Marketing*, *50*(3/4).

Sturgis, P., & Allum, N. (2004). Science in society: re-evaluating the deficit model of public attitudes. *Public Understanding of Science*, *13*(1), 55-74.

Sundqvist, G. (2014). ‘Heating up’or ‘cooling down’? Analysing and performing broadened participation in technoscientific conflicts. *Environment and Planning A*, *46*(9), 2065-2079.

Supphellen, M. (2000). Understanding core brand equity: guidelines for in-depth elicitation of brand associations. *International Journal of Market Research*, *42*(3), 319-338.

The Copenhagen Diagnosis. (2009). *Updating the world on the latest climate science*. Retrieved from Sydney: http://www.copenhagendiagnosis.com/download/default.html

The Royal Society. (2009). *Geoengineering the climate science, goverance and uncertainty*. Retrieved from London United Kingdom: http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/8693.pdf

Thompson, V. A. (2013). Why It Matters The Implications of Autonomous Processes for Dual Process Theories—Commentary on Evans & Stanovich (2013). *Perspectives on Psychological Science, 8*(3), 253-256.

Thompson, V. A., Prowse Turner, J. A., & Pennycook, G. (2011). Intuition, reason, and metacognition. *Cognitive Psychology, 63*(3), 107-140.

Tsujii, T., & Watanabe, S. (2010). Neural correlates of belief-bias reasoning under time pressure: a near-infrared spectroscopy study. *Neuroimage, 50*(3), 1320-1326.

Tulving, E., & Psotka, J. (1971). Retroactive inhibition in free recall: Inaccessibility of information available in the memory store. *Journal of experimental Psychology, 87*(1), 1.

United Nations Framework Convention on Climate Change. (2012). Kyoto Protocol Retrieved from http://unfccc.int/kyoto_protocol/items/2830.php. http://unfccc.int/kyoto_protocol/items/2830.php

Van Osselaer, S. M. J., & Janiszewski, C. (2001). Two Ways of Learning Brand Associations. *Journal of Consumer Research, 28*(2), 202-223.

Van Ryzin, G. (2008). Validity of an on-line panel approach to citizen surveys. *Public Performance & Management Review, 32*(2), 236-262.

Vaughan, N., & Lenton, T. (2011). A review of climate engineering proposals. *Climatic Change, 109*(3-4), 745-790.

Wibeck, V., Hansson, A., & Anshélm, J. (2015). Questioning the technological fix to climate change – Lay sense-making of geoengineering in Sweden. *Energy Research & Social Science, 7*(0), 23-30.

Wigley, T. (2006). A combined mitigation/geoengineering approach to climate stabilisation. *Science, 314*, 452-454.

Wilkinson, C. (2014). Engaging With Strangers and Brief Encounters Social Scientists and Emergent Public Engagement With Science and Technology. *Bulletin of Science, Technology & Society, 34*(3-4), 63-76.

Wilsdon, J., & Willis, R. (2004). *See-through science: Why public engagement needs to move upstream*: Demos.

Williams, C. J. (1986). Attitude accessibility as a moderator of the attitude-perception and attitude-behavior relations: An investigation of the 1984 presidential election. *Journal of personality and social psychology, 51*(3), 505-514.

Wright, M., Gendall, P., & Lewis, T. (1999). Making survey-based price experiments more accurate. *International Journal of Market Research, 41*(2), 245.

Wright, M., & Klÿn, B. (1998). Environmental attitude–behaviour correlations in 21 countries. *Journal of Empirical Generalisations in Marketing Science*, *3*(3).

Wright, M. J., Teagle, D. A. H., & Feetham, P. M. (2014a). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change*, *4*(2), 106-110. doi:10.1038/nclimate2087

Wright, M. J., Teagle, D. A. H., & Feetham, P. M. (2014b). A quantitative evaluation of the public response to climate engineering: Reply to Gardner – Guest Post. Retrieved from: http://dcgeoconsortium.org/2014/08/13/a-quantitative-evaluation-of-the-public-response-to-climate-engineering-reply-to-gardner-guest-post-malcolm-j-wright-damon-a-h-teagle-and-pamela-m-feetham/htm

Wynne, B. (2005). Risk as globalizing 'democratic'discourse? Framing subjects and citizens. *Science and citizens: Globalization and the challenge of engagement*, 66-82.

Wynne, B. (2006). Public engagement as a means of restoring public trust in science-hitting the notes, but missing the music. *Community Genetics*, *9*, 211-220.

Zürn, M., & Schäfer, S. (2013). The Paradox of Climate Engineering. *Global Policy*, *4*(3), 266-277.

Appendices

Appendix A: Stage 1 – Concept Boards

Biochar

- Vegetation removes the carbon from the atmosphere during photosynthesis
- After the vegetation dies the decomposing vegetation releases carbon back into the atmosphere
- In the Biochar process the vegetation is heated and starved of oxygen to lock th carbon into Biochar(charcoal)
- The Biochar is then buried and it can store away carbon for thousands of years

Adapted from Vaughan & Lenton (2011).
Image source: Okimori Biochar

Pros

Waste materials such as wood, leaves, food leftovers, straw or manure make Biochar. Adding Biochar to soil can improve agricultural productivity.
When making Biochar, bio-fuels and bio-oils are produced that can be used as renewable fuel source.
Farmers could make profits selling their Biochar which is feasible in many places.

Cons

Small scale potential, and timescale for effectiveness (100 years+).
Requires additional energy consumption for transport, purchase and processing.
May disrupt growth, nutrient cycling and viability of the ecosystems involved.
Potential conflicts overland use for agriculture and crops for boi-fuels.

Air Capture

- Structures ‘scrub’ the air clean of carbon dioxide (CO_2)
- Air passes through a filter that absorbs and collects CO_2
- The trapped carbon molecules are then removed, transported and stored
- The carbon cold be stored in old oil and gas wells or in certain underground rock formations
- Need to pay for the electricity to run structures plus the cost of transporting and storing the carbon.

Adapted from Vaughan & Lenton (2011).
Image source: Carbon engineering Ltd.

Pros

Very efficient as can remove more times carbon dioxide than a tree.

Placed anywhere.

Capture is very safe and shouldn’t have any bad side effects.

Would operate 24 hour a day but could be switched off if something went wrong.

Easy to measure the amount of carbon captured.

Cons

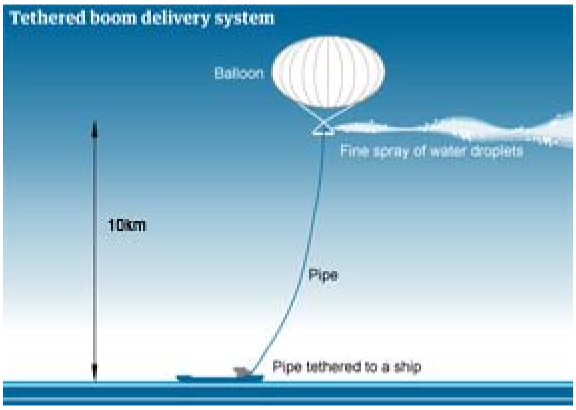
Would be slow to reduce global temperatures.

The capture devices may be an eyesore and would take up land space.

There will be a limit on places to store CO_2 underground.

Stratospheric Aerosols

- Some particulates are shiny so they scatter the sun's rays back into space preventing them from reaching, and in doing so, cooling the Earth (e.g. sulphates, clay)
- One idea is to use very large balloons connected to a pipe to disperse aerosols (or aircrafts, missiles, platforms)
- Computer modelling has been carried out
- If using sulphates, the amount involved is quite modest and so would not significantly add to acid rain



Adapted from Vaughan & Lenton (2011).
Image source: Vidal, J. 2011

Pros

Works fast, so could start lowering temperatures within a year.

Would reduce the global average temperature in a fairly uniform way.

Cons

If suddenly stopped the world would get warmer more quickly.

Effects would only last about 1 – 3 years so have to be repeated.

Difficult to get the aerosol up that high and to release it.

Very uncertain side effects. May affect the climate/rainfall and lead to droughts.

Could damage the ozone layer and high altitude clouds.

Other impacts of rising carbon emissions still remain e.g. increasing ocean acidification

Appendix B: Stage 1 – List of 30 Pre-determined Attributes Biochar Concept

A.	Biochar

Here is a list of attributes relative to the Biochar technique. Please tick the box(es) of any attributes that you personally think are associated with Biochar.

Beneficial	☐	Constructive	☐
Necessary	☐	Controversial	☐
Proven	☐	Risky	☐
Interfering	☐	Harmless	☐
Unbalanced	☐	Flawed technology	☐
Reversible	☐	Effective	☐
Band-aid	☐	Ingenious	☐
Impossible	☐	Engineered	☐
Controllable	☐	Good for the planet	☐
Too expensive	☐	Crazy	☐
Artificial	☐	Quick fix	☐
Understandable	☐	Visually cumbersome	☐
Dangerous	☐	Unpredictable	☐
Feasible	☐	Not easily regulated	☐
Good value for money	☐	Unrealistic	☐

Appendix C: Qualitative Interviews Sample Demographics

Attribute Elicitation Method	Age years	Gender	Qualification	Occupation
Kelly's Repertory Grid				
	24	Male	School proficiency	Student
	29	Male	Certificate/diploma	Business owner
	20	Female	School proficiency	Student
	21	Male	School proficiency	Student
	54	Female	Certificate/diploma	Management
	36	Female	School proficiency	Cafe owner
	20	Male	School proficiency	Student
	49	Male	Post graduate	IT technician
	61	Female	Certificate/diploma	Business owner
	73	Male	Post graduate	Retired principal
	52	Male	Post graduate	Principal
	51	Male	Post graduate	Hospital orderly
	48	Female	No formal	Retail
	62	Female	School proficiency	Swim Instructor
	22	Female	School proficiency	Student
Pre-determined List				
	72	Female	School proficiency	Weight leader
	20	Male	Certificate/diploma	Chef
	71	Female	Bachelor's degree	Retired teacher
	70	Female	Certificate/diploma	Social worker
	40	Male	School proficiency	Librarian
	70	Male	Post graduate	Retired journalist
	37	Male	Trade qualification	Council engineer
	75	Male	No formal	Retired army
	65	Male	Trade qualification	Council engineer
	42	Female	Certificate/diploma	Retail
	29	Female	School proficiency	Student nurse
	40	Female	No formal	Teacher aide
	40	Female	Bachelor's degree	Teacher
	77	Female	No formal	Retiree
	18	Female	School proficiency	UCOL student

Appendix D: On-line Survey Sample Demographics & Census Comparison

New Zealand (*n* = 1006) Australia (*n* = 1022)

	Australia	AU Census	**New Zealand**	NZ Census
Age (years)	%	%	%	%
16-24	14.5	12.3	11.6	13.0
25-34	20.2	14.4	14.2	13.2
35-44	21.8	14.0	13.9	13.0
45-54	22.6	13.5	13.7	13.9
55-64	14.5	11.5	21.0	11.4
>65	6.5	11.6	25.5	11.0
Gender				
Male	46.4	49.7	50.7	49.2
Female	53.6	50.3	49.3	50.8
Education				
P & High School	38.3		30.3	
Trade/Technical	23.5		23.9	
Some University	14.1		17.5	
Completed Undergraduate	13.8		16.9	
Completed Postgraduate	10.3		11.4	
Household Yearly Income				
<$10,000	6.6		4.1	
$10,001-20,000	8.3		8.3	
$20,001-40,000	17.2		24.9	
$40,001-60,000	19.5		17.8	
$60,001-80,000	14.9		15.4	
$80,001-100,000	12.8		11.7	
$100,001-120,000	7.4		7.7	
$120,001-140,000	4.9		4.3	
>$140,000	8.5		5.8	
Location				
Rural area	11.1		10.5	
Small town(less than 1,500)	7.1		7.9	
Large town(1,500-60,000)	18.3		22.1	
Small city(60,001-300,000)	15.3		21.8	
Medium city(300,001-1million)	12.8		17.4	
Large city(more than 1 million)	35.4		20.3	

Appendix E: Stage Two – Copy of the Quantitative Survey Questionnaire

MASSEY UNIVERSITY
COLLEGE OF BUSINESS
KAUPAPA WHAI PAKIHI

Default Question Block

Dear ResearchNow Panelist

Thank you for clicking through to our survey. It should take you 10-15 minutes to complete.

The survey is being conducted by researchers from Massey University New Zealand, and the University of Southampton, United Kingdom, to help better understand public reaction to important scientific issues.

Your participation is voluntary. No identifying information will be collected. The survey findings only report summarized results and will not identify specific individuals.

This project has had ethical peer review and has been judged to be low risk. Consequently, it has not been formally reviewed by Massey University's Human Ethics Committee. If you have any further concerns or queries you are welcome to contact either Pam Feetham or Malcolm Wright, who are responsible for the conduct of this research (email p.m.feetham@massey.ac.nz or m.j.wright@massey.ac.nz.)

To proceed to the survey please click on the 'Next >>' button at the bottom right of the page.

Once you click the 'Next >>' button you cannot go back and change your answers. If you lose your connection to the Internet at any point, please go back to the original email to click the link again. It will restart the survey at the point you left off.

For a number of years, global warming has been in the news. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, that it may increase more in the future, and that the world's climate is changing as a result. This increase is attributed to increased emissions of greenhouse gases such as carbon dioxide.

Please read the statements below and then indicate whether you agree or disagree by clicking **ONE** button beside each statement

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	Don't know
Global warming is not causing climate changes.	○	○	○	○	○	○
Humans are not primarily responsible for global warming.	○	○	○	○	○	○
The International community should not try to reduce global warming.	○	○	○	○	○	○

Scientific research shows that over the past 100 years the Earth's temperature has increased by 0.74 degrees Celsius. If this warming continues it will have a profound effect on ecosystems and human social systems. Some scientists believe it is too late to stop global warming through control of carbon emissions. They think that, to avoid the effects of global warming, we may have to directly engineer the climate to reduce the Earth's temperature.

There are two broad approaches to doing this. One is to remove carbon dioxide from the atmosphere. The other involves reflecting sunlight back into space. There are many different techniques suggested for each of these approaches.

We would like to know what you think about some of these climate engineering techniques. In the following pages we will present four of these techniques and ask some questions about each one. There are no right or wrong answers in this survey. Rather we are interested in your opinion.

Block 2

Biochar

Copyright: UK Biochar Research Centre

Biochar is the process of making charcoal from decomposing vegetation. Carbon dioxide is locked into the charcoal, which would be buried for thousands of years to reduce atmospheric carbon dioxide. When Biochar is made, bio-fuels are produced and can be sold. Biochar, used as a soil additive, might also increase agricultural productivity. Biochar can be implemented locally, in small increments. Processing would need to continue for a long time, and it could take decades to noticeably lower global temperatures. Making, transporting and burying Biochar will use additional energy. The long-term effect on eco-systems is not well understood. There could be controversy if land is farmed for Biochar and its beneficial side products, instead of being used for crops.

Which of the descriptions in the list below do you think applies to Biochar?
Please select as many as apply.

- ☐ Eyesore
- ☐ Unpredictable
- ☐ Controllable
- ☐ Quick-fix
- ☐ Understandable
- ☐ Environmentally friendly
- ☐ Artificial
- ☐ Cost effective
- ☐ Long-term sustainability
- ☐ Beneficial
- ☐ Risky
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
I think **Biochar** would help reduce global warming.	○	○	○	○	○
I think **Biochar** is practical with modern technology.	○	○	○	○	○
I think **Biochar** is a technique most people would support.	○	○	○	○	○
I think **Biochar** might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain **Biochar** to somebody else.	○	○	○	○	○

Block 3

Air capture

Copyright: Carbon Engineering Ltd

Air capture involves building structures that filter carbon dioxide from the air. The captured molecules would be transported and stored in old oil wells or underground rock formations, reducing atmospheric carbon dioxide. The captured molecules are harmless. Air capture structures could be concentrated in large-scale sites, like factories, or placed locally as part of the community, like utilites. Air capture can be implemented in small increments. The operation could run continuously, but is easily stopped at any time. To lower global temperatures quickly, many air capture structures would have to be built. Costs would be incurred for electricity, transport and storage. The structures might be unattractive.

Which of the descriptions in the list below do you think applies to Air capture?
Please select as many as apply.

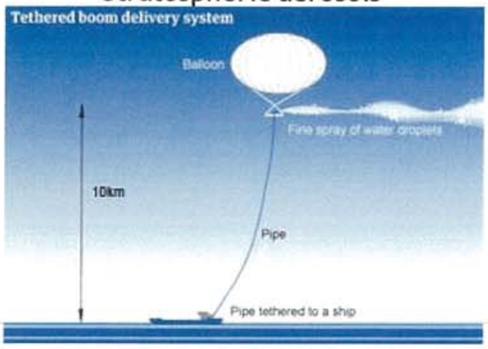
- ☐ Unpredictable
- ☐ Understandable
- ☐ Controllable
- ☐ Risky
- ☐ Eyesore
- ☐ Artificial
- ☐ Cost effective
- ☐ Beneficial
- ☐ Quick-fix
- ☐ Long-term sustainability
- ☐ Environmentally friendly
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Air capture** would help reduce global warming.	○	○	○	○	○
I think **Air capture** is practical with modern technology.	○	○	○	○	○
I think **Air capture** is a technique most people would support.	○	○	○	○	○
I think **Air capture** might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain **Air capture** to somebody else.	○	○	○	○	○

Block 4

Stratospheric aerosols



Stratospheric aerosols could be used to spread very small, shiny particles in the upper atmosphere. This would reflect some sunlight back into space, reducing the Earth's temperature. Stratospheric aerosols would be delivered using large balloons connected to ultra-long but lightweight pipes. Sulfates could be used in quantities that would not to add to acid rain. Use of stratospheric areosols requires international agreement and large-scale investment. The areosols would spread widely and start to lower temperatures within a year. The effect would be temporary, so the procedure would need to be continuously applied. The effect on the ozone layer, high altitude clouds and rainfall are not well understood.

Which of the descriptions in the list below do you think applies to Stratospheric aerosols? Please select as many as apply.

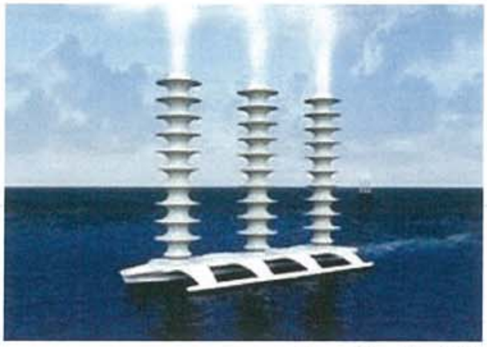
- ☐ Environmentally friendly
- ☐ Artificial
- ☐ Eyesore
- ☐ Cost effective
- ☐ Understandable
- ☐ Controllable
- ☐ Beneficial
- ☐ Unpredictable
- ☐ Quick-fix
- ☐ Long-term sustainability
- ☐ Risky
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Stratospheric aerosols** would help reduce global warming.	○	○	○	○	○
I think **Stratospheric aerosols** is practical with modern technology.	○	○	○	○	○
I think **Stratospheric aerosols** is a technique most people would support.	○	○	○	○	○
I think **Stratospheric aerosols** might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain **Stratospheric aerosols** to somebody else.	○	○	○	○	○

Block 5

Cloud brightening



Copyright: J MacNeill 2006

Cloud brightening involves automated ships spraying small seawater droplets over the ocean. These droplets would increase the number of bright clouds, which in turn would reflect more sunlight and lower global temperatures. Spraying would need to be widespread to have an effect and purpose built ships would be required. Cloud brightening may require international agreements, and could be expensive. It would only work for a short time unless spraying is continuously repeated. It may cause significant cooling in localized areas. The effects on sea life and weather are not well understood.

Which of the descriptions in the list below do you think applies to Cloud brightening? Please select as many as apply.

- ☐ Understandable
- ☐ Risky
- ☐ Controllable
- ☐ Long-term sustainability
- ☐ Quick-fix
- ☐ Eyesore
- ☐ Environmentally friendly
- ☐ Unpredictable
- ☐ Artificial
- ☐ Cost effective
- ☐ Beneficial
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Cloud brightening** would help reduce global warming.	○	○	○	○	○
I think **Cloud brightening** is practical with modern technology.	○	○	○	○	○
I think **Cloud brightening** is a technique most people would support.	○	○	○	○	○
I think **Cloud brightening** might have bad side effects.	○	○	○	○	○
After reading the description I think I could explain **Cloud brightening** to somebody else.	○	○	○	○	○

Block 6

Enhanced weathering

Copyright: Dave Craw

Enhanced weathering involves increasing the rate that carbon dioxide dissolves minerals to form limestone. This could be achieved through greater exposure to the atmosphere, fine grinding or heating of the minerals, and could be applied to volcanic ash, sand or mine tailings. The resulting limestone traps the carbon dioxide for thousands of years. Enhanced weathering can be implemented locally, increased gradually, and stopped at any time. It could take decades to noticeably lower global temperatures. It will produce large amounts of limestone and could use a lot of water. It has similar environmental impacts to mining.

Which of the descriptions in the list below do you think applies to Enhanced weathering?
Please select as many as apply.

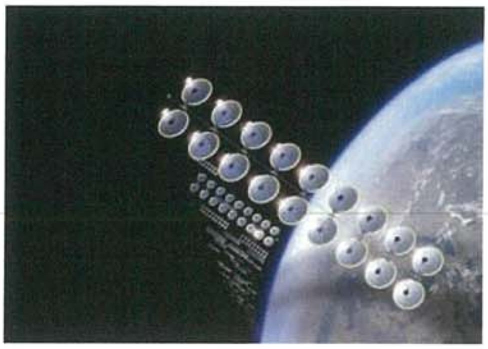
- ☐ Controllable
- ☐ Long-term sustainability
- ☐ Artificial
- ☐ Beneficial
- ☐ Understandable
- ☐ Environmentally friendly
- ☐ Unpredictable
- ☐ Eyesore
- ☐ Risky
- ☐ Quick-fix
- ☐ Cost effective
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Enhanced weathering** could help reduce global warming.	○	○	○	○	○
I think **Enhanced weathering** is practical with modern technology.	○	○	○	○	○
I think **Enhanced weathering** is a technique most people would support.	○	○	○	○	○
I think **Enhanced weathering** might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain **Enhanced weathering** to somebody else.	○	○	○	○	○

Block 7

Mirrors in space



Copyright: Transmissions media

Large mirrors or sunshade structures could be placed to orbit the Earth. They would block or reflect some sunlight before it reached the atmosphere and lower global temeratures. Mirrors in space, or sunshade structures, would stimulate growth of the space industry. They would require international agreement and large scale investment. They may have an uneven cooling effect, and could be difficult to remove without creating hazards to space navigation. The effects on weather and ecosystems are not well understood. It is not clear how quickly mirrors or sunshades could be developed and deployed.

Which of the descriptions in the list below do you think applies to Mirrors in space? Please tick as many as apply.

- ☐ Quick-fix
- ☐ Beneficial
- ☐ Unpredictable
- ☐ Eyesore
- ☐ Artificial
- ☐ Risky
- ☐ Understandable
- ☐ Environmentally friendly
- ☐ Controllable
- ☐ Long-term sustainability
- ☐ Cost effective
- ☐ Unknown effects

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Mirrors in space** would help reduce global warming.	○	○	○	○	○
I think **Mirrors in space** is practical with modern technology.	○	○	○	○	○
I think **Mirrors in space** is a technique most people would support.	○	○	○	○	○
I think **Mirrors in space** might have bad side effects.	○	○	○	○	○
After reading the description I think that I could explain **Mirrors in space** to somebody else.	○	○	○	○	○

Block 8

Did you know about climate engineering techniques before you began this survey?

- ◯ Yes
- ◯ No

Which of the following climate engineering techniques had you heard of before participating in this survey? Please select as many as apply.

- ◯ Cloud brightening
- ◯ Afforestation
- ◯ Biochar
- ◯ Liming the ocean
- ◯ Enhanced weathering
- ◯ Mirrors in space
- ◯ Roof whitening
- ◯ Stratospheric aerosols
- ◯ Iron fertilization
- ◯ Air capture
- ◯ Other (write in the text box below)

Now we would like to ask a few questions about your views on the environment. Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
I am not willing to pay more for eco-friendly products.	◯	◯	◯	◯	◯
I do not think it is important for companies to have environmental programs.	◯	◯	◯	◯	◯
I do not think mining for minerals is more important for the economy than the need for conservation.	◯	◯	◯	◯	◯
My personal actions will have little impact on the environment.	◯	◯	◯	◯	◯

On a scale of 0 - 10, what is the liklihood that you will search for more information on climate engineering techniques in the next **three** months.

	Not very likely					Likely				Very likely	
	0	1	2	3	4	5	6	7	8	9	10
Please move the cursor along to the number that applies.											

Finally, some questions about you.

Are you?

- ○ Male
- ○ Female

Which of these best describes the place that you live?

- ○ Rural area
- ○ Small town (less than 1,500 people)
- ○ Large town (1,501 to 60,000 people)
- ○ Small city (60,001 to 300,000 people)
- ○ Medium city (300,001 to 1 million people)
- ○ Large city (more than 1 million people)

Which of these best describes your highest formal qualification?

- ○ Primary School
- ○ High School
- ○ Trade/Technical
- ○ Some university
- ○ Completed undergraduate
- ○ Completed Postgraduate

Which of the following categories best describes your household's yearly income, from all sources, before tax?

- ○ < $10.000
- ○ $10,001 - $20,000
- ○ $20,001 - $40,000
- ○ $40,001 - $60,000

○ $60,001 - $80,000

○ $80,001 - $100,000

○ $100,001 - $120,000

○ $120,001 - $140,000

○ > $140,000

Which year were you born?

If you have any comments about climate change or climate engineering, please write them here.

Appendix F: Matrix of Average Kendall Tau-b Nonparametric Correlation (Australia)

Supplementary Table 5: Matrix of Average Kendall Tau-b Nonparametric Correlation (Australian Data)

	Unknown effects	Unpredict-able	Risky	Artificial	Quick-fix	Eyesore	Under-standable	Beneficial	Controll-able	Env. friendly	Long-term s.	Cost effective
Unknown effects		0.27	0.23	0.14	0.05	0.06	-0.13	-0.24	-0.18	-0.23	-0.18	-0.15
Unpredictable	0.27		**0.39**	0.25	0.13	0.13	-0.05	-0.16	-0.15	-0.17	-0.13	-0.06
Risky	0.23	**0.39**		0.24	0.14	0.13	-0.07	-0.18	-0.16	-0.17	-0.13	-0.01
Artificial	0.14	0.25	0.24		0.18	0.21	0.04	-0.02	-0.01	-0.04	0.00	-0.01
Quick-fix	0.05	0.13	0.14	0.18		0.15	0.07	-0.02	0.01	0.00	-0.05	0.05
Eyesore	0.06	0.13	0.13	0.21	0.15		0.05	-0.02	0.01	-0.02	-0.02	-0.01
Understandable	-0.13	-0.05	-0.07	0.04	0.07	0.05		0.31	0.32	0.29	0.24	0.17
Beneficial	-0.24	-0.16	-0.18	-0.02	-0.02	-0.02	0.31		**0.37**	**0.39**	0.33	0.21
Controllable	-0.18	-0.15	-0.16	-0.01	0.01	0.01	0.32	**0.37**		0.32	0.31	0.19
Env. friendly	-0.23	-0.17	-0.17	-0.04	0.00	-0.02	0.29	**0.39**	0.32		0.33	0.23
Long-term sustain.	-0.18	-0.13	-0.13	0.00	-0.05	-0.02	0.24	0.33	0.31	0.33		0.24
Cost effective	-0.15	-0.06	-0.01	-0.01	0.05	-0.01	0.17	0.21	0.19	0.23	0.24	

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change, 4*(2), Supplementary material.

Supplementary Table 6: Attributes Counts After Elimination of Overlapping Attributes (Australian Data)

	Biochar	Air Capture	Enhanced Weathering	Could Brightening	Stratospheric Aerosols	Mirrors in Space	TOTAL	%
Unknown effects	371	254	352	448	448	460	2333	24%
Risky	193	136	263	273	310	376	1551	16%
Artificial	120	194	144	226	235	240	1159	12%
Quick-fix	81	136	81	174	233	96	801	8%
Eyesore	48	323	118	113	104	68	774	8%
Understandable	143	169	120	107	106	81	726	7%
Controllable	131	204	135	99	90	52	711	7%
Environmentally friendly	189	171	87	103	74	63	687	7%
Long-term sustainability	163	160	136	59	55	54	627	6%
Cost effective	117	92	88	57	69	65	488	5%
TOTAL	1556	1839	1524	1659	1724	1555	9857	
%	16%	19%	15%	17%	17%	16%		

Note: The Chi-Square values for the test of independence are $X^2 = 1312$ for the Australian data in Supplementary Table 6, and $X^2 = 2631$ for the equivalent New Zealand data. These exceed the critical value for statistical significance at p=.001, $X^2_{(.999,\ 45)} = 80$.

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change*, *4*(2), Supplementary material.

Supplementary Table 7: Percentage Point Deviations from Expected Attribute Counts (Australian Data)

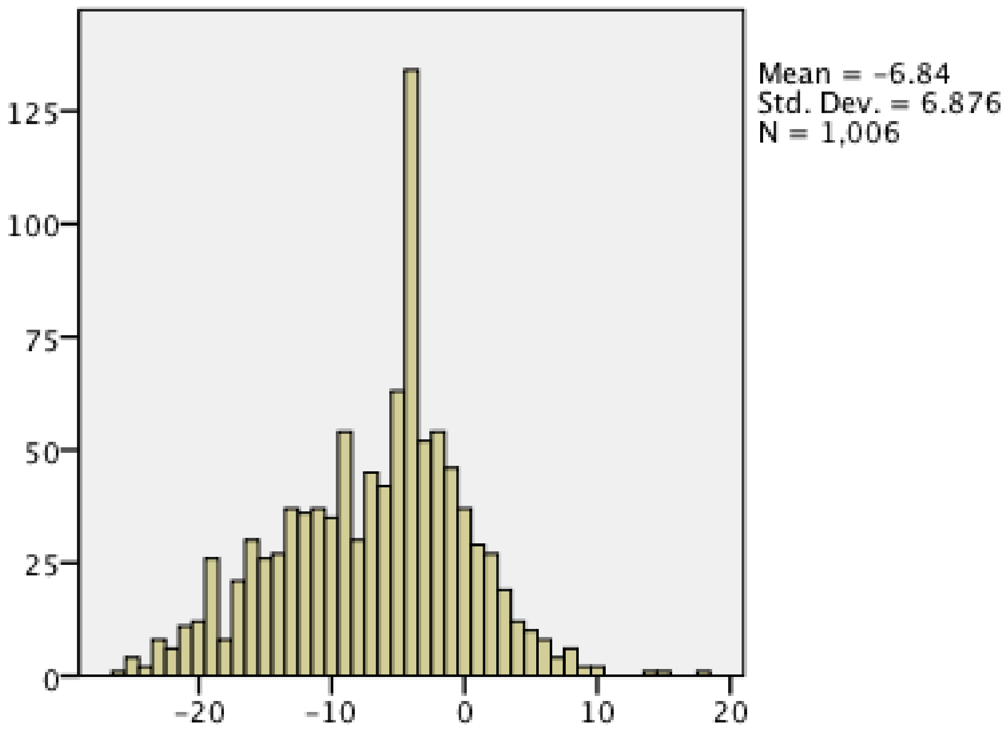
	Biochar	Air Capture	Enhanced Weathering	Could Brightening	Stratospheric Aerosols	Mirrors in Space
Unknown effects	0%	-10%	-1%	3%	2%	6%
Risky	-3%	-8%	2%	1%	2%	8%
Artificial	-4%	-1%	-2%	2%	2%	4%
Quick-fix	-3%	-1%	-3%	2%	5%	-2%
Eyesore	-5%	10%	0%	-1%	-2%	-3%
Understandable	2%	2%	1%	-1%	-1%	-2%
Controllable	1%	4%	2%	-1%	-2%	-4%
Environmentally friendly	5%	2%	-1%	-1%	-3%	-3%
Long-term sustainability	4%	2%	3%	-3%	-3%	-3%
Cost effective	3%	0%	1%	-2%	-1%	-1%

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change*, *4*(2), Supplementary material.

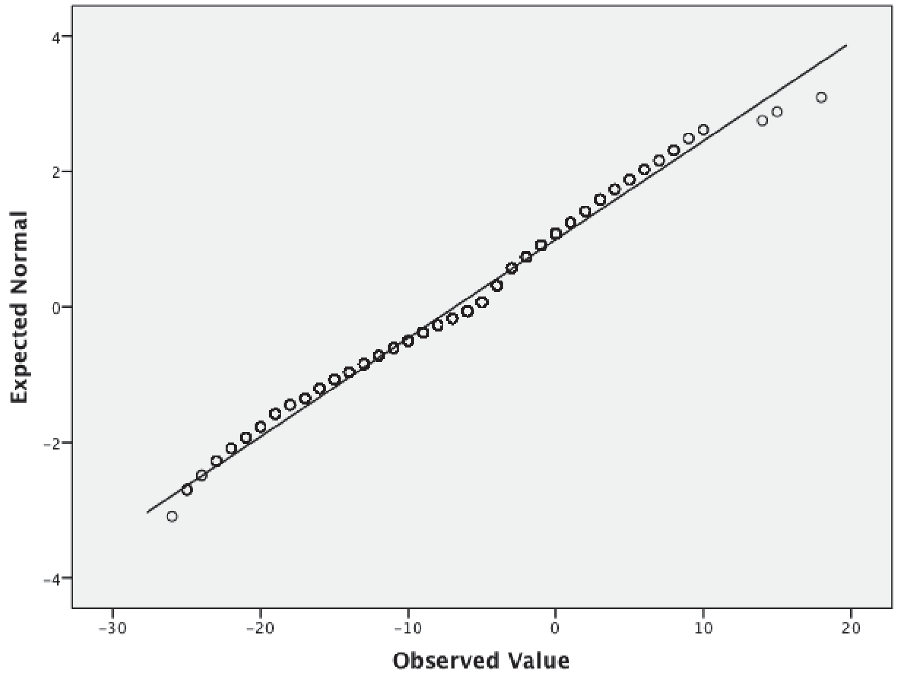
Appendix G: Histograms and Q-Q plots

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change*, *4*(2), Supplementary material.

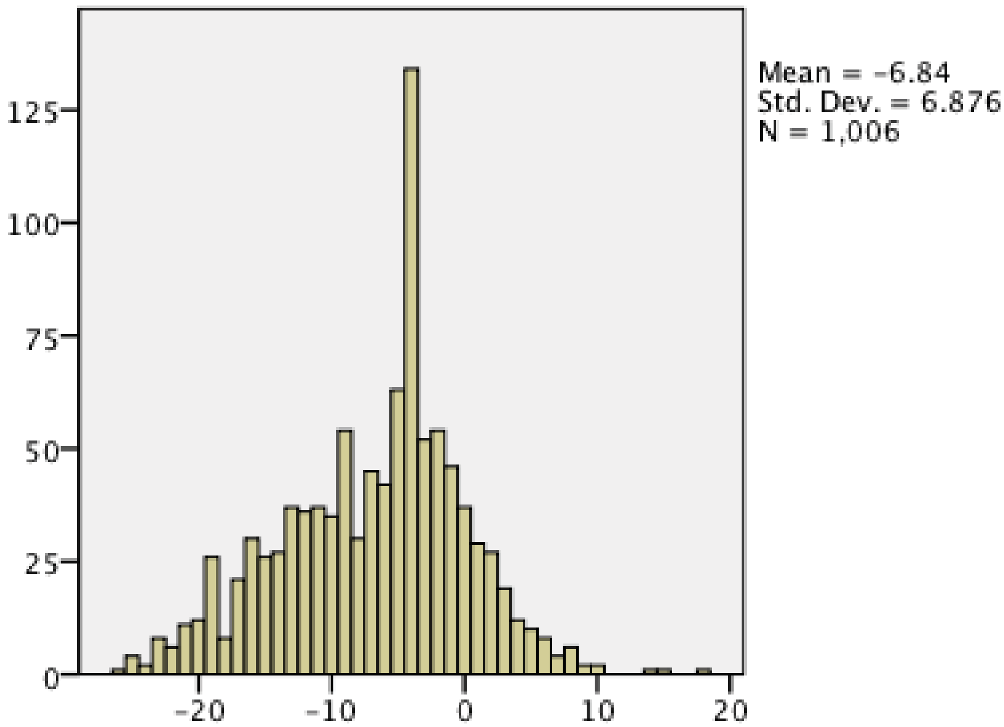
Supplementary Figure 1: Histogram of Net Positive Measure (Australia, n=1006)



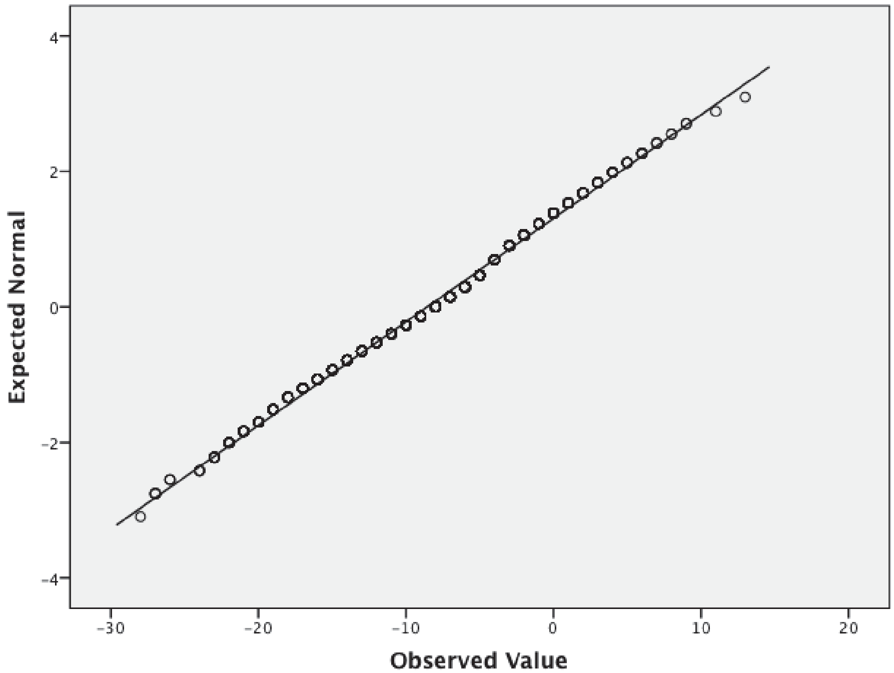
Supplementary Figure 2: Normal Q-Q Plot of Net Positive Measure (Australia)



Supplementary Figure 3: Histogram of Net Positive Measure (New Zealand)



Supplementary Figure 4: Normal Q-Q Plot of Net Positive Measure (New Zealand)



Supplementary Figures 1, 2, 3 and 4 examine the properties of the Net Positive variable for each country. In both cases a Kolmogorov-Smirnov test rejects the null hypothesis of no difference from a normal distribution. However, the histograms in Figures 1 and 3 do show an approximately normal distribution, as do the normal probability plots in Figures 2 and 4. While there is an obvious peak in each distribution, Kurtosis is low at -.074 for Australia (std. error = .154) and -.146 for New Zealand (std. error = .153). Skewness is also low at -.257 for Australia (std. error .077) and -.136 for New Zealand (std. error .077). Therefore, the Net Positive variable approximates a normal distribution in both countries and is acceptable for further analysis for the purposes of this research (Wright, Teagle & Feetham, 2014a Supplementary material).

Appendix H: Focus Group Demographics

Focus Groups	Gender	Age	Qualification	Occupation
Young Professionals				
	Female	24	Batchelor's degree	Personal assistant
	Female	23	Batchelor's degree	PR practitioner
	Female	23	School qualifications	University student
	Male	25	Batchelor's degree	Accountant
	Male	23	Batchelor's degree	Retail assistant
	Male	24	School qualifications	Sales representative
	Male	27	Batchelor's degree	University student
Creative Professionals				
	Female	57	Certificate or Diploma	Media sales consultant
	Male	27	School qualifications	Account director/video prod
	Male	57	Certificate or Diploma	Photographer/gallery owner
	Male	44	Certificate or Diploma	Sales (IT)
	Male	21	School qualifications	Designer & Web developer
	Male	28	Batchelor's degree	Graphic designer
Young Parents				
	Female	29	School qualifications	Stay at home Mum
	Female	33	Certificate or Diploma	Stay at home Mum
	Female	43	Post-grad or higher	Stay at home Mum
	Female	40	Batchelor's degree	Stay at home Mum
	Female	36	Batchelor's degree	Part-time chef
	Female	39	Batchelor's degree	Financial officer
	Male	38	No formal qualification	House Dad
Retirees				
	Female	65+		
	Female	65+		
	Male	65+		
	Male	65+		
	Male	65+		
	Male	65+		
Indigenous Descent				
	Female	33	Batchelor's degree	Administrator
	Female	53	Post-grad or higher	Social worker/manager
	Female	30	School qualifications	Stay at home Mum
	Female	46	Batchelor's degree	Chairman of Maori Trust
	Male	29	Certificate or Diploma	Food processor/qual control
	Male	43	School qualifications	Case Leader/youth Ministry
	Male	19	Certificate or Diploma	Student relations consultant

Appendix I: Focus Group Topic Guide

1. What are the first things that come to your mind when you hear the words “global environmental problems”?
2. Open-ended questions about climate change (CC), e.g. what are the first things you think about when you hear the words “climate change”? Is it seen as a problem or not? How should CC be addressed? What actors/institutions do you trust in to handle CC-related issues? Who should take responsibility for CC mitigation and adaptation?
3. Transitory question to climate engineering (CE): scientists and politicians have started to discuss different technologies for carbon dioxide removal from the atmosphere or sunlight reflection from Earth back into space. Is this something that you have heard of?
4. Brief information about CE (no images; try to avoid value judgement or pre-given framings): E.g. information on a general level about two main approaches to CE: CDR (Carbon Dioxide Removal) and SRM (Solar Radiation Management)
5. What are your thoughts about CE? (The following aspects should be brought up, among others: ethical aspects, politics/governance, technological aspects, risks, comparisons between options (both CE options, but also other options for mitigation and adaptation)
6. If needed, provide some more information about CE, e.g. as regards the policy context, arguments frequently voiced in the scientific and policy debate concerning e.g. risks and possibilities.
7. If CE technologies would be considered as real alternatives in the future, would that affect you in any way? If so, how? Would it influence you to change anything in the way you live or the choices you make? (= assessment of the moral hazard argument)
8. What types of actions (mitigation, adaptation, CE) do you see as most important to tackle climate change?

Source: Topic Guide – focus groups on climate engineering, Wibeck, Anshelm, Hansson, Linnér, 2015.

Appendix J: *Nature Climate Change* Publication

Appendix K: Supplementary Material *Nature Climate Change* Publication

Supplementary Table 3: Univariate Tests for Differences on the Net Positive Variable

		Test statistic	Test statistic value	P value	Bonferroni-corrected critical P value
AU data					
Treatment	Oneway Anova	$F_{(.05, 2, 1003)}$	0.25	.778	.008
Gender	Oneway Anova	$F_{(.05, 1, 1004)}$	0.11	.739	.008
Location	Oneway Anova	$F_{(.05, 5, 1000)}$	1.81	.109	.008
Education	Oneway Anova	$F_{(.05, 5, 1000}$	1.67	.134	.008
Household Income	Oneway Anova	$F_{(.05, 8, 997)}$	1.87	.061	.008
Age	Correlation	r	-0.290	<.001	.008
NZ Data					
Treatment	Oneway Anova	$F_{(.05, 2, 1019)}$	2.81	.061	.008
Gender	Oneway Anova	$F_{(.05, 1, 1020)}$	1.03	.391	.008
Location	Oneway Anova	$F_{(.05, 5, 1016)}$	0.88	.492	.008
Education	Oneway Anova	$F_{(.05, 5, 1016)}$	1.59	.161	.008
Household Income	Oneway Anova	$F_{(.05, 8, 1013)}$	2.04	.039	.008
Age	Correlation	r	-0.202	<.001	.008

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change, 4*(2), Supplementary material.

Supplementary Table 3 shows univariate tests for associations between the net positive variable and both survey treatment and the demographic variables. No differences are expected for survey treatment, as participants were randomly assigned and the treatments were balanced between CDR and SRM. We use ANOVA for all demographic tests except Age, where bivariate correlation is appropriate. Due to the large number of tests we employ the Bonferroni correction to critical p-values. On this basis, the only statistically significant relationship is for Age in New Zealand. Age is a negatively coded ratio variable (Yearborn), indicating that in New Zealand older people tend to be more positive about climate engineering than younger people; however, the effect is small and visual inspection of the scatterplot shows very little structure (Wright, Teagle & Feetham, 2014a)..

We test the robustness of this univariate analysis using a multifactor random effects General Linear Model, with treatment as a fixed effect, demographics as random effects, and Age as a covariate. We test for interactions as well as main effects. Again we employ the Bonferroni correction to critical p-values. As the Bonferroni correction depends on the number of tests conducted we also report the Bonferroni critical p-value for main effects alone. *Supplementary Table 4* presents these results: the only effects that are statistically significant after the Bonferroni correction are in New Zealand, for the intercept term and for Age (Wright, Teagle & Feetham, 2014a).

Supplementary Table 4: Multivariate Tests for Differences on the Net Positive Variable

		F value	P value	Bonferroni-corrected critical P value*
AU Data	1. Intercept	9.62	0.006	.002
	2. Treatment	2.04	0.134	.002
	3. Gender	2.22	0.151	.002
	4. Location	2.50	0.032	.002
	5. Education	1.89	0.113	.002
	6. Household Income	1.04	0.409	.002
	7. Age	2.24	0.135	.002
	3x4 Interaction	0.46	0.808	.002
	3x5 Interaction	1.16	0.328	.002
	3x6 Interaction	0.98	0.450	.002
	3x7 Interaction	1.05	0.306	.002
	3x2 Interaction	1.05	0.351	.002
	4x5 Interaction	0.67	0.874	.002
	4x6 Interaction	0.99	0.490	.002
	4x7 Interaction	1.11	0.356	.002
	4x2 Interaction	0.86	0.574	.002
	5x6 Interaction	0.81	0.779	.002
	5x7 Interaction	1.39	0.225	.002
	5x2 Interaction	2.07	0.025	.002
	6x7 Interaction	0.82	0.586	.002
	6x2 Interaction	0.79	0.704	.002
	7x2 Interaction	0.82	0.443	.002
NZ Data	1. Intercept	43.45	<0.001	.002
	2. Treatment	1.87	0.166	.002
	3. Gender	0.04	0.852	.002
	4. Location	0.56	0.731	.002
	5. Education	1.04	0.400	.002
	6. Household Income	1.16	0.330	.002
	7. Age	15.20	<0.001	.002
	3x4 Interaction	2.86	0.014	.002
	3x5 Interaction	2.04	0.087	.002
	3x6 Interaction	0.94	0.484	.002
	3x7 Interaction	0.72	0.395	.002
	3x2 Interaction	0.72	0.486	.002
	4x5 Interaction	1.55	0.056	.002
	4x6 Interaction	1.16	0.228	.002
	4x7 Interaction	1.22	0.297	.002
	4x2 Interaction	0.92	0.510	.002
	5x6 Interaction	1.31	0.122	.002
	5x7 Interaction	2.09	0.080	.002
	5x2 Interaction	1.75	0.084	.002
	6x7 Interaction	0.70	0.692	.002
	6x2 Interaction	1.16	0.297	.002
	7x2 Interaction	5.33	0.005	.002

Source: Wright, M. J., Teagle, D. A. H., & **Feetham, P. M.** (2014). A quantitative evaluation of the public response to climate engineering. *Nature Climate Change*, *4*(2), Supplementary material.