Opening up the societal debate on climate engineering: How newspaper frames are changing

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Abstract: The use of climate engineering or geo-engineering technologies to combat climate change has been a controversial topic, even in the scientific debate. In recent studies it has been claimed that the debate on climate engineering technologies may be closing down prematurely, with detrimental effects on the possibility of social and

ethical reflection of the discussion and development of policy guidelines around these controversial technologies. We examined the extent to which the debate on climate engineering is opening up or closing down, analyzing English-speaking newspaper frames in the period 2006-2011. The results provide strong support for an opening of the debate, especially since 2009, given the decline of overly deterministic frames, the emergence of frames related to socio-political issues, and an overall more even distribution of the various frames. This provides evidence that different perspectives are voiced in the public debate, which enable societies to critically reflect on these emerging technologies.

Keywords: climate engineering, geoengineering, newspaper frames, environmental technology

1. Introduction

Geoengineering, or climate engineering, refers to techniques that either remove carbon dioxide from the atmosphere, also known as Carbon Dioxide Removal (CDR), or deflect incoming solar radiation, commonly referred to as Solar Radiation Management (SRM). Many uncertainties exist with respect to potential risks, costs, feasibility and effectiveness of the technologies, many of which can have regional or global side effects. Field tests are necessary to reduce these uncertainties, but these may already be full of risk, as some technologies cannot be properly tested without full-scale implementation (Robock et al. 2010). This has led to public debate and

criticism: for example, the SPICE (Stratospheric Particle Injection for Climate Engineering) experiment in Norfolk (U.K.), was postponed due to protest from environmental groups; in the end the project cancelled because of lack of rules, and an intellectual property rights dispute (Cressey 2012).

Until recently most of the discussion on climate engineering has taken place between scientists and knowledgeable policymakers, addressing mainly technological and environmental aspects. During 2006 and 2007 climate engineering became a more prominent topic in media coverage (Nerlich and Jaspal 2012) and it is now slowly emerging in the public sphere. The debate about climate engineering seems to be expanding, not only by attracting more social actors, policymakers, citizens and NGOs, but also by raising questions about ethical and social implications, following a broader trend towards requests for public deliberation on controversial environmental topics (Krütli et al. 2010).

Media exert considerable power on the public and political agenda, as they constitute the principal arena where policy relevant issues come to the attention of these groups (Nisbet and Lewenstein 2002). In previous studies it has been emphasized how the increase in attention to climate change coverage is linked to science- politics interaction (Boykoff and Boykoff 2007). Moreover the media may shape public understanding of topics, especially with respect to scientific issues as "knowledge about science comes largely through mass media, not through scientific publications or direct involvement in science" (Corbett and Durfee 2004). Public attitude towards climate engineering is important in relation to its further development, as the very concept provokes strong and often divided positions (Corner et al. 2012).

Similarly, the media may influence the political agenda, because political actors are to some extent comparably influenced by the media as the public

(Lyytimäki 2007). More importantly, politicians often take the media as a mirror of public opinion, whether this is truly the case or not (Linsky 1986).

Only two attempts so far have been made to study media attention on climate engineering (Nerlich and Jaspal 2012, Buck forthcoming). While the former investigated the frames and the voices around geoengineering, using both print and broadcast media, the latter focused on the metaphors in the news stories on geongineering. The disadvantage of both articles is that the time dimension is not taken into account in the analysis. On a topic so new and changing as climate engineering, the way media present it is expected to change over time. More precisely, it is suggested that the debate over geoengineering may be closing down, instead of opening up (Nerlich and Jaspal 2012), even though no systematic time analysis has been conducted. We wish to contest this notion, using empirical material on how media frames on climate engineering have emerged and especially how they have evolved over time. English-language newspaper articles between 2002 and 2011 are analyzed for the presence of frames, using both qualitative and quantitative analysis.

The paper is thus addressing the following questions: *What are the common newspaper frames related to climate engineering? How have these newspaper frames evolved over time?*

2. Theoretical background

2.1. Communicating environmental science and technology

The traditional science communication model, whereby science produces "true knowledge" and the media translate this information into understandable language,

has been challenged, as we have come to understand that science and journalism construct truth or knowledge according to different principles (Weingart 1998, Peters et al. 2008). Journalists may use frames to package information so that they can quickly identify and classify it, especially when reporting on issues they are not familiar with (Nisbet and Lewenstein 2002). Once a topic has already been framed by the media, it can become difficult for external influences to bring about a shift in perspectives (ibid.). As a previous study suggested, scientists strategies for attracting media attention can be successful, in terms of media coverage, but the content of media will also be shaped by media logic, as well as the national context. (Höijer et al. 2006)

Climate engineering is a complex scientific issue, involving technologies that do not make part of our daily lives. Citizens (and journalists) often have little or no direct experience with climate engineering: it is something novel, mostly unknown, and, as such, difficult to grasp. As such, climate engineering can be conceptualized as an emerging technology; such technologies have been studied extensively in technology studies. People get in touch with emerging technologies through mass media, which is why media coverage provides a key heuristic to the public (ibid.), as well as to policymakers.

Much contemporary framing research of emerging technologies is inspired by an older study on the media discourse and public opinion on nuclear power between 1945 and 1989, which identified three frames to be most prevalent: (a) *progress*, which describes nuclear power in terms of "society's commitment to technological development and economic growth" (p. 4), (b) *public accountability*, which puts emphasis on the misleading of the public by the nuclear industry, and (c) *runaway*,

which portrays a fatalistic position on nuclear power, i.e. something that will spin out of control after it is unleashed (Gamson and Modigliani 1989).

The progress frame was dominant in the early stages of media communication of nuclear technology, confirmed by scholars studying other types of emerging technologies (Nisbet and Lewenstein 2002, Scheufele and Lewenstein 2005). This is understandable as new discoveries are brought to light by their proponents, who emphasize the benefits of the technology and believe that the use of technology will lead to societal progress.

Following these early stages, the media discourse can become more controversial, stressing doubts about the safety of the emerging technology (Gamson and Modigliani 1989). Media coverage refers at this later stage to the technology in terms of industry secrecy, exclusion of the public, caught in the *public accountability* frame, or in terms of the *runaway* nature of the technology (Nisbet 2009). Looking into the frames of nanotechnologies, Scheufele & Lewenstein (2005) suggested that as soon as media coverage of the issue expands, "we will see more and more a war of words" and coverage becomes more focused on controversy (p. 665). This is not to say that media coverage consequently became more negative; a struggle of interests trying to frame the debate may lead to the inclusion of both risks and benefits of the technology, which Gamson & Modigliani (1989) described as the *devil's bargain* frame.

Building further on this work, Nisbet (2009) developed a general set of frames concerning scientific issues: *social progress, economic development, morality/ethics, scientific/technical uncertainty, Pandora's box/runaway science, public accountability/governance, middle way/alternative path* and *conflict/strategy*. These serve as an important framework for the analysis conducted in this paper.

2.2. Framing climate engineering

As a new scientific topic, we expect that frames in scientific literature may influence frames in newspapers, since in new issues external influences coming from political actors, scientists or other elite groups are of large importance as a source of frames (Scheufele 1999).

It is suggested that "the heart of the resistance to geoengineering … is fear of the unknown" (Davies 2011). Anticipated side-effects of climate engineering could be quantified now, but the "unknown unknowns" may only become apparent once climate engineering has already been implemented (Boyd 2008). These unanticipated side effects are worrisome, especially since they could be irreversible (Robock, Bunzl, Kravitz and Stenchikov 2010).

On the other hand, the risks of climate change may be larger than those of climate engineering. Those who favor climate engineering, often talk of it as "the lesser of two evils" or an emergency measure in a bad situation (Preston 2011). Climate engineering could serve as a "plan B", when emission reductions "achieve too little too late" (Shepherd et al. 2009). Further research into climate engineering is thus advocated so that if we ever need to deploy it, we can do so wisely. For others, this argument unravels another concern; as research on climate engineering continues, implementation will become more likely (Bunzl 2009). We may never have a sound basis for deploying climate engineering, since there is no "practice planet" on which these technologies can be tested (ibid.).

In addition, the fear exists that it will divert attention from current mitigation and adaptation efforts, also known as the *moral hazard dilemma* (Davies 2011, Virgoe 2009), particularly the SRM methods, which do not address the root of climate change, that is, greenhouse gases. Moreover, it is suggested that global warming is not

a technical problem but a political problem, in which case climate engineering is not a proper solution (Robock 2008). Some scholars question the capacity of technology as a solution to global warming: "we would be taking on the ultimate state of hubris to believe we can control Earth" (Kiehl 2006). This argument is part of a much larger debate about the relationship between man and nature, which questions human ability to manipulate, control, modify or manage natural systems (Preston 2011).

With respect to policy, fears have been expressed that when climate engineering remains unregulated, "rogue states" could act unilaterally, posing risks for others (Barrett 2008). Joint action is not a requirement for the deployment of climate engineering. Moreover side effects may be unevenly distributed, creating "winners" and "losers". This may generate questions about liability (Virgoe 2009) and increase the potential for conflict between nations (Boyd 2009). Existing international law does not address climate engineering directly, which is why scientists urge governments to start thinking about regulation (ibid.).

Given the aforementioned arguments we may expect the following themes to be present in newspapers: risks and uncertainty, climate engineering as plan B, relationship between man and nature, climate engineering versus mitigation, and governance of climate engineering. The two previous studies on geoengineering also find similar themes.

Buck (2012), who performed a study on the media attention on climate engineering, analyzed 93 articles from "major world newspapers" between 1990 and mid-2010 and found five key narrative frames: the *catastrophic*, the most common, described climate change as a catastrophe, which is linked to the need to "save" the planet; the *cautionary*, doubting climate engineering; the *spatiotemporal struggle*; the *managerial*, which frames geoengineering as cheap solution and reward, and the

bildungsroman, linked to the metaphor of a patient planet which we need to cure. Even though this distinction is certainly useful, the work does not make any differentiation between earlier and later frames, while literature suggests that such a difference can be expected. Furthermore, no links were made with previous media studies on emerging technologies, which is needed in order to make comparisons of trends of media frames over time.

Nerlich and Jaspal (2012) performed a metaphor analysis on 91 newspaper articles between 1988 and 2010. They demonstrated that "metaphors, analogies and arguments were mainly used to frame geoengineering as a last resort technology that has to be adopted in a context of impending catastrophe" (p. 143). Because of the trend to frame climate change as a catastrophe and climate engineering as the only way to avert it, they suggest that the debate about climate engineering might be closing down instead of opening up (Nerlich and Jaspal 2012). Emphasis on climate change as catastrophe can lead to demoralization and fatalism among society and policy makers (Hulme 2009) and limit social and ethical reflection on the issues by posing boundaries on the "legitimate" debate (ibid.). They suggest a change in metaphors over time, as dissenting metaphors and arguments (portraying geoengineering more negatively) were used towards the end of the sample period (ibid.). Further, they also claim that, as NGOs have started campaigning against geoengineering, the debate may be shifting. It is precisely these changes that we aim to capture empirically in a systematic way.

We wish to confront the notion that the debate on geoengineering may be closing down over time: indeed in scientific literature one can see more publications about the socio-political implications, as well as ethical dimensions, which were

lacking before (Bellamy et al. 2012). These developments suggest that over time the debate may be opening up to more voices.

3. Methodology

The corpus for this analysis was derived by searching through the newspaper database LexisNexis[1] using "geoengineering", "geo-engineering" and "climate engineering" as keywords. A time span of ten years (2002 – 2011) was chosen (Nerlich and Jaspal 2012). We selected the more elite English-speaking newspapers and those with high circulation rates, as these often tend to influence more regional or local news outlets (Nisbet et al. 2003). Only articles in which climate engineering was a major theme were selected. This narrowed down the corpus to 181 articles. All but three articles were written between 2006 and 2011.

To code the newspaper articles we combined a *deductive,* i.e. *top-down* with an *inductive*, i.e. *bottom-up* approach (de Vreese 2005). We used the framework developed by Nisbet (2009) as a coding manual, to which we added the themes from the scientific discussion on climate engineering. As observed before, the coding of smaller frame elements may be more straightforward than the coding of whole frames (Matthes and Kohring 2008). We therefore adapted the framework provided by Nisbet, by specifying the frames he proposed to this particular study. We considered these smaller units to be *frame elements,* which could be part of a larger pattern, i.e. frame. Some paragraphs contained several frame elements in which case they were all coded.

[1] For the frame analysis the following search term was used: ((geoengineering OR geo-engineering OR climate engineering) AND date(geq(1/1/2002) AND leq(31/12/2011)) AND pub(The Australian OR The Canberra Times OR Sunday Telegraph London OR The Guardian OR The Herald OR The Independent OR International Herald Tribune OR The Irish Times OR Los Angeles Times OR The Mirror OR The New York Times OR The Observer OR Sunday Herald OR The Sydney Morning Herald Abstracts OR (Times and London) OR The Toronto Star OR USA Today OR Wall Street Journal Abstracts OR The Washington Post))

Next to this, we added elements, using a *bottom-up* approach, identifying recurrent elements not provided by the framework.

Table 1 demonstrates the 21 frame elements that were attained. To cluster these variables, we performed a factor analysis to see whether these elements were part of larger hidden patterns that constitute frames.

Frame elements	***Sentences or phrases referring to...***
Risks and uncertainty	anticipated risks but also to the "unknown unknowns", doubts about the effectiveness of the technology
Scientific discoveries	creator of wonderful things, cool ideas, benefits of the technology, it is cheap and easy
Catastrophe	catastrophe, disaster, we are running out of time, dangerous climate change, runaway climate, points of no return
Ambivalence	a pro and con argument, trying to form a balanced opinion on the matter, risks versus benefits
Mitigation	relationship between climate engineering and mitigation, moral hazard dilemma, climate engineering is not an alternative
Call for science	the need of sound science, the wish to treat the technology like any other science, we need to know more
Current approach is failure	how current strategies to tackle global warming are failing, mitigation will not be sufficient and is going too slow
Benefits for society	how the technology will solve the problem and help society, it can buy us time, offer us an escape route
Necessity	the need for the technology to save us, it is our only hope, there may be no other option
Ethical principles	questions about right or wrong, is it acceptable, relationship man and nature, belief in technology, hubris, (un)naturalness climate
No trust in science	how science is in over its head, it will never happen, it's just false hope, pie in the sky ideas, mad and wacky scientists
Governance/Public accountability	a call for (international) control, who gets to turn the knobs, who controls, how will the public be involved?
Afraid of science	concerns about science taking a wrong turn, science making things even worse, opening Pandora's box, runaway science

Out of proportion	"extreme", "radical" or "drastic" measures. This is like Dr. Strangelove, or pushing the panic button
Man can change nature	man's ability to control nature, technological fix, quick-fix, we've changed nature and we can do it again, we can play god
Conflict	conflict between different interests, groups within society, there is a debate, it's a battle, who is going to win?
Economic prospect	economic investments, both by markets and government, competitiveness, funding of climate engineering
Last resort	climate engineering only as a last ditch solution, last resort, if all else fails
Science fiction	science fiction, fantastical ideas (although often it is said that these technologies *used* to be science fiction)
Climate is complex	climate as a complex system, complex machine, we do not understand it enough
Political risk	political conflict, fears about unilateral action, "rogue states"
It's serious	the fact that climate engineering is gaining attention, it is serious people who are talking about it seriously

Table 1: Frame elements on geoengineering

4. Results

4.1. Newspaper frames

Principal Component Analysis PCA was conducted (Varimax Rotation) on the 21 elements listed in Table 1 (N=181). After seven iterations, nine factors were deducted, which explain 62 % of the variance (see Table 2). These factors can be interpreted as frames.

Frames	1	2	3	4	5	6	7	8	9
Ambivalence *(n=128)*									
Ambivalence	0.768								
Call for science	0.619								
Risk/Uncertainty	0.528								
Avoiding catastrophe *(n=96)*									
Necessity		0.681							
Last resort		0.658							
Catastrophe		0.639							
Pragmatism *(n=74)*									
Science fiction			0.686						
Current app. failure			0.593						
It's serious			0.520						
Norms and values *(n=108)*									
Afraid of Science				0.690					
Mitigation				0.621					
Ethical Principles				0.519					
Benefits for society *(n=76)*									
Economic Prospect					0.744				
Benefits for society					0.643				
Controversy *(n=36)*									
Climate is complex						0.842			
Conflict						0.667			
Techno-fix *(n=82)*									
Scientific discoveries							0.836		
We can change nature							0.580		
Governance *(n=51)*									
Political Risk								0.754	
Governance/Public accountability								0.731	
Out of proportion *(n=27)*									
Out of proportion									0.888
No trust in science									0.426
Eigenvalue	3,008	1,726	1,493	1,421	1,325	1,269	1,204	1,113	1,100
R^2	0,137	0,078	0,068	0,065	0,060	0,058	0,055	0,051	0,046

Table 2: Factor analysis of frame elements

Factor 1*: Ambivalence* (71% of the articles)

This frame is weighing risks and benefits. Climate engineering evokes mixed feelings, expressed in phrases such as or "Geoengineering: Climate Intervention Is a Dilemma for Scientists" (Guardian Unlimited, 10 November 2010). Risks were juxtaposed to benefits, much like the *devil's bargain* frame (Gamson and Modigliani 1989). Closer analysis showed that most phrases firstly referred to a negative argument and subsequently to a positive argument, e.g. risks were mentioned before benefits of climate engineering. Seven per cent of the articles labeled climate engineering as "the lesser of two evils", referring to the fact that it may be risky, but less risky than "doing nothing".

Thirty one per cent of the articles referred to *risk and uncertainty,* emphasizing negative side-effects or how the effect of climate engineering is not fully certain. Climate engineering was phrased as "risky action", "gambling" or even "the global equivalent of playing Russian roulette" (Washington Post, 13 June 2010).

The clustering of the frame elements *ambivalence, risk and uncertainty* and *call for science,* suggests the following argument: "climate engineering can be good but can also be risky; and thus more research is needed". The call for more research was based on the seriousness of the climate change problem. Taking this one step further, 6% of the articles mentioned that ignoring climate engineering is "potentially dangerous" or "irresponsible".

The second argument to conduct further research is "so that, if we ever do need to deploy them, we can do so in a sensible and effective way" (in 4% of the articles), an assertion that was quoted from John Shepherd, lead author of the Royal Society report (The Guardian, 2 September 2009). In that same article, Ken Caldeira strengthened this argument by applying the metaphor of the "untested parachute".

Factor 2*: Avoiding catastrophe* (53% of the articles). It tells the story of how the planet is in trouble and needs to be "saved" from climate change, because it is "catastrophic" or "disastrous". In some cases this was linked to the worry of potential tipping points; 10% of the articles mentioned the fear of climate going "runaway" or "speeding towards the point of no return". Nine per cent of the articles emphasized that we should act now before it is too late as "we don't have enough time left available to us" (Canberra Times, 21 November 2009).

Because the planet is in such grave danger, there is an urgent "need" for climate engineering, explaining the link between frame elements *catastrophe* and *necessity*. Climate engineering is described as our "only hope" or as something that we may "need" to do. "There may come a point when we have no alternative but to try geoengineering" (The Independent, 29 January 2009). Often this necessity was linked to the urge to have a "plan B" or an "insurance policy" in case mitigation does not go quick enough. Nine per cent of the articles however, brought some nuance to this notion and described climate engineering as a "last ditch " or a measure of "last resort".

Factor 3*: Pragmatism* (41% of the articles). Even though 5% of the articles referred to frame element *science fiction*, in most cases, it is made clear that climate engineering *used to* belong to the fringes of science, as they are "ideas that were once the realm of science fiction" (The Australian, 16 March 2009). Such phrases are often followed by the frame element *it's serious*: a statement that climate engineering is now gaining serious attention since "interest in projects with a twist of science fiction if anything, appear to be growing" (The International Herald Tribune, 10 May 2007). These

statements are not given any particular value; this growing interest in climate engineering is neither positive nor negative.

Twenty per cent of the articles refer to the *failure of current approaches* to tackle global warming; an assertion that serves to explain why interest in climate engineering is growing. Climate negotiations are going too slow and "it's pretty clear that no post-Kyoto treaty is in the making – certainly not in Cancun and maybe not ever" (Toronto Star, 2 August 2010).

Factor 4*: Norms and values* (60%) The frame element *ethical principles* was identified when reference was made to the "acceptability" of climate engineering or when the relationship between man and nature was discussed. In 13% of the articles climate was referred to as something natural, with which humans should not interfere, "tinker" or "fiddle". It would be unwise to "meddle" with the climate, because "if anything, global warming has taught us to expect the unexpected and learn some humility and not alter the way nature works" (The Irish Times, 3 February 2007). Technology already messed up climate, so technology should not try to fix it. Furthermore, it was often questioned whether humans even have the ability to control nature. Climate engineering exemplifies "hubris".

The link with the frame element *mitigation* means that climate engineering is compared to climate mitigation, as the SRM-type of climate engineering does not address rising atmospheric carbon dioxide concentrations. Therefore such climate engineering technologies "mask the core problem rather than permanently dealing with it" (The Guardian, 22 October 2009). Taking it one step further, 16% of the articles expressed the fear that climate engineering will even distract from mitigation, i.e. the moral hazard dilemma.

The *afraid of science* frame element adds to this frame the fear that science is making things worse than they already are. Science could open a Pandora's Box or might spin out of control. Climate engineering is something "scary", "dreadful" or even "outright dangerous".

Factor 5: *Benefits for society* (42% of the articles). This frame presents how climate engineering could solve the problem of climate change and thus save the planet and society, much like is the case for the *avoiding catastrophe* frame, but without assertions on whether we need this or not. Several arguments are used to promote the benefits of climate engineering: it could buy us time to get our emissions back on track[2] and in some cases it might even have additional benefits. Moreover, there is an economic prospect for climate engineering technologies as companies are starting to "eye up" opportunities. It could create jobs and make money.

This frame also refers to discussions about the funding of climate engineering. There are some opportunities for the private sector to invest in climate engineering but the major responsibility should be with the government. In some cases the argument is that we need to invest in climate engineering, because other countries are starting research as well and might gain the lead in research and development.

Factor 6: *Controversy* (20% of the articles) This frame explicitly mentions the controversy and debate around climate engineering. It refers to parties that make opposite claims or have competing interests, ranging from conflicts between industries or organizations to conflicts between countries, although mostly mentioned in the debate are the "greens". Most environmentalists do not want to consider

[2] This argument holds mostly for SRM-type of climate engineering.

climate engineering as a viable option for tackling climate change, because of its potential environmental risk(s). This position is criticized by others, who do not understand how environmental groups can be seriously concerned with climate change, while dismissing one of the options that has the potential to treat it.

The factor analysis demonstrates that the *conflict* element is related to the *climate is complex* element. The latter refers to climate as a "poorly understood"; a "complex" system, perhaps too complex for us to "toy with". The co-occurrence of these two assertions could mean that complex issues are susceptible to conflict, because they can be viewed from multiple perspectives. These various meanings with which the topic can be approached, may lead to potential conflict between proponents and opponents of climate engineering.

Factor 7: *Techno-fix* (46% of the articles). This frame describes climate engineering as a "techno-fix" or a "quick fix"[3] for climate change. The underlying assumption here is that man can change nature; climate change is a practical problem and we can grab our "toolkit" to "tweak" the climate. In the *techno-fix* frame, technology is considered the key solution to the problem of climate change, because it has helped us several times before.

Emphasis is also put on the ability of humans to control nature: "we are as gods, we just have to get good at it" (New York Times, 20 April 2010). Scientists are put in the spotlight as "bright minds" who have created a technology that is "simple", "cheap", "quick". In fact, if you think about it logically, climate engineering is the most sensible option: "the only rational scheme" (The Australian, 16 March 2009).

[3] Again this would hold for SRM-type of geoengineering.

Although the *techno-fix* frame advocates the use of technology to control nature, it does not necessarily mean that climate engineering has to go *against* nature. Six per cent of the articles refer to climate engineering as "just nature". This is especially the case for the stratospheric aerosol method, which aims to simulate the effect of volcanic eruption, by releasing sulphate particles that reflect sunlight. As suggested in an article written in the Washington Post, 16 June 2007: "… if a volcano can do it, why not us?"

Factor 8*: Governance* (28% of the articles). Here the role of governments is the main issue. If climate engineering is ever to be deployed, the question arises who decides how and when it will be implemented. In 7% of the articles, a call was made for an international regime that oversees research and implementation of climate engineering. Related to this story is the fear of *political risk*, which refers to the possibility that climate engineering will lead to political conflict, firstly because countries may disagree about the way climate engineering should be implemented. While some countries may gain from climate engineering, others may suffer and they are unlikely to come to an agreement if not rightfully compensated. Secondly, conflict may arise as some technologies do not require international cooperation and so may be implemented locally, while having global effects. The fear exists that "rogue states" might decide to go ahead with climate engineering without the consent of others. An international framework would be necessary "before some nutcase does it [climate engineering] prematurely" (The Washington Post, 4 October 2010).

A few stories also address *public accountability.* An article in the Guardian, 16 June 2011, spoke of climate engineering as a "public good" and therefore "there should be public participation in schemes".

Factor 9*: Out of proportion* (12% of the articles) In this frame climate engineering was described as "extreme", "wild", "drastic" or "radical". Some articles even referred to Dr. Strangelove or viewed the implementation of climate engineering as pushing "the panic button": an exaggerated reaction that may be more extreme than the threat of the situation itself.

The element *no trust in science* loads moderately on this frame, and can thus help us better understand it. Climate engineering is dismissed as an out of proportion reaction, related to low/no trust in science. Geoengineering is "weird", "bizarre" and something cooked up by "mad scientists".

In contrast to the *techno-fix* frame, scientists are referred to negatively. There is no trust in science; scientists will not be able to address the problem of climate change. Climate engineering is a "false hope", an "irresponsible dream"; it is all just make-believe and "we should all start to get seriously angry with our politicians for being carried away by all this claptrap" (The Sunday Telegraph, 5 December 2010).

4.2. Evolution of frames

The following figure (Figure 1) shows how the nine frames evolved over time. After the results of the factor analysis, we recoded all articles for the presence of the nine frames.

In 2006, newspaper attention for climate engineering started to emerge, mostly due to the call of Paul Crutzen, who proposed to use the injection of sulphate aerosols. Indeed, many articles put Crutzen in the spotlight as the "scientist who worked out the ozone problem", a "star of atmospheric science". Positive aspects of science

dominated this period, which is why *benefits for society* and *techno-fix* were two prevalent frames. No article makes reference to governance issues or political risk.

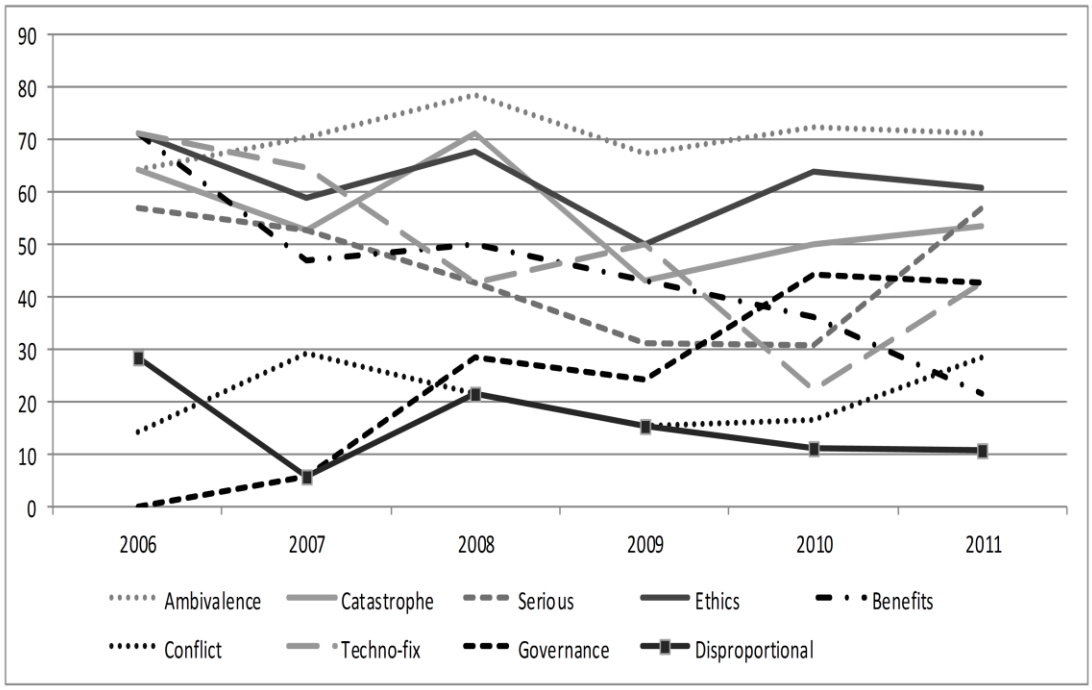

Figure 1: Percentage of frames over time (2006-2011)

Nevertheless it was already a controversial issue in newspaper coverage, as articles also referred to the *norms and values* frame. Some stories wrote about what climate engineering would mean for the relationship between man and nature, while others mentioned how climate engineering would distract from current mitigation efforts, arguments already present in the scientific literature (Kiehl 2006).

Most emphasis in 2006 was on the frames *ambivalence, norms and values, techno-fix, benefits for society* and *pragmatism*, while other frames, i.e. *governance, controversy* and *out of proportion*, were present far less often. This demonstrates how

media coverage was not yet diverse, mostly focusing on the arguments already been mentioned in the scientific debate. Especially, the high occurrence of the *techno-fix* frame highlights the technocratic attitude with which climate engineering was approached (Bellamy, Chilvers, Vaughan and Lenton 2012).

In 2007, the *governance* frame emerged, most likely because climate engineering itself became a topic of policymaking, as the UNFCCC was going to address it during its meeting in Bali. More stories started to include the risks of climate engineering, explaining the increase of the *ambivalence* frame. The discussion on climate engineering became more versatile and diverse; hence the *controversy* frame became more prevalent, referring to different voices.

In the run-up to the Royal Society report in 2009, many scientific articles were published in 2008 looking into the potential of various climate engineering proposals (Boyd 2008, Latham et al. 2008). This may explain the increase in the *avoiding the catastrophe* and *benefits for society* frame. The release of the IPCC Fourth Assessment Report in November 2007 may have also be linked to the increase in the *avoiding the catastrophe* frame. At the same time however, several scholars were publishing about the risks of climate engineering (Robock 2008), which may be linked to the increase of the *out of proportion* and *norms and values* frames. Moreover *governance* became a more common frame, as the fear of political risks had also been expressed (Barrett 2008).

In 2009, the *techno-fix* frame regained a new boost, most likely due to the publication of *Superfreakonomics*, a book in which climate engineering is portrayed as a simple and cheap solution (Levitt and Dubner 2009). In the same year, the Royal Society report took a fairly moderate view towards climate engineering, assessing the

risks and benefits of different techniques, probably supporting a continued prevalence of the *ambivalence* frame.

The moderate approach taken by The Royal Society may also explain why the division between the two groups of frames, which was still visible in 2008, disappeared in 2009. The frames became more equally spread than before. This trend continued in 2010, where another shift can be signified: a large increase in the *governance* frame, most likely due to the CBD meeting, held in Nagoya in 2010. At the same time, the *techno-fix* frame decreased, which could be linked indirectly to the *Climategate* incident in November 2009, which sparked an ethical debate around practices and usefulness of climate science (Vasileiadou et al. 2011, Leiserowitz et al. 2010).

In 2011 the *pragmatism* frame increased, which may be related to the failures of the COP 15 in Copenhagen (December 2009) and the subsequent COP16 in Cancun (December 2010), leading to the conclusion that international mitigation efforts were not making enough progress. The IPCC meeting about climate engineering in June 2011 sparked the attention of critical NGO's, partially explaining the rise of the *controversy* frame. Another factor that could have led to more stories about conflict is the SPICE experiment, which also flamed the attention of NGOs. At the same time, the experiment may explain the increase of the *techno-fix* frame as some articles referred to the good of the technology, portraying it as "an important step towards the ultimate techno-fix for climate change" (Guardian Unlimited, 6 October 2011).

Overall, the *ambivalence* and *norms and values* frame have been most prevalent across the whole period from 2006 to 2011, suggesting that climate engineering has been controversial since media attention on the topic emerged.

Nevertheless, climate engineering was framed more positively during earlier years as the *benefits for society* frame and *techno-fix* frame were much more common between 2006 and 2008 than they were between 2009 and 2011. As the presence of these two frames declined, media coverage about climate engineering became more diverse by increasingly including social concerns, and by providing a more balanced distribution of the different frames over time. This is confirmed by the emergence and rise of the *governance* frame, which was not yet discussed in 2006 articles but was present in 43% of the 2011 articles.

5. Discussion

Looking at the development of these larger themes between 2006 and 2011, it is clear that earlier media coverage referred to climate engineering more positively than later media coverage. Although the frame *norms and values* was also prevalent from the beginning on, there was also considerable focus on the benefits for climate engineering between 2006 and 2008. This is in line with previous studies that have demonstrated the salience of *progress* as a theme, at the onset of media attention for other emerging technologies.

So is the debate opening up or closing down? Previous work suggested the latter (Nerlich and Jaspal 2012, Buck forthcoming), whereas our empirical work shows that: (1) new frames have emerged over time; (2) overly deterministic frames such as the *techno-fix* and *benefits for society* are decreasing over time; (3) there is more balanced distribution of frames now, than in 2006. On the basis of this we would say that the debate is now more open than before.

This opening up could be explained by the suggestion that expanding media attention can lead to a "war of words" as different interests struggle to get their voices heard (Scheufele and Lewenstein 2005). The dominance of a particular group of frames may suggest that earlier media coverage of climate engineering reflected the scientific debate, which is probably because scientists themselves were a prominent news source, as confirmed elsewhere (Buck forthcoming).

The analysis performed in this study has demonstrated how the discussion on climate engineering is becoming increasingly complex. Climate engineering is an "uncertainty" or "ambiguity" issue (Bellamy, Chilvers, Vaughan and Lenton 2012), which would fit into what we have called the *controversy* frame, implying that climate engineering is complex and thus has multiple sides. The emergence of the *governance* frame and the *controversy* frame demonstrate how social aspects and political aspects are gaining momentum in the discussion on climate engineering. The emergence of these frames, together with the decline of the technocratic frame can also be understood in the broader context of a changing relationship between technology and society on controversial technologies, as noted already in discussions on nuclear waste facilities (Krütli, Flüeler, Stauffacher, Wiek and Scholz 2010) .

As questions about the governance of climate engineering are also gaining momentum, both policy makers and the public will have to start actively participating in the discussion. The time analysis showed how most of the media frames originated from scientists. It also showed that developments in geoengineering science and technology fuelled media attention. The time has come, however, for the issue to move out of the scientific arena, so that the public can be engaged upstream. A transparent and accessible public discussion, which does not only take place in the media, is vital, given the divergent frames on the topic. The participatory turn in

technology assessment and governance requires meaningful input from the citizens (Strauss 2010), which can only be facilitated with reflexivity. The prevalence of the ambivalence frame in the media gives rise to hope for reflexivity in the debate, as both positive as well as negative arguments are presented at the same time. However, it remains questionable how the public and policy makers perceive such a frame. As knowledge may not be the dominant determinant of public attitude (Scheufele and Lewenstein 2005), the *ambivalence* frame may prove to be less powerful than other frames that evoke strong positive or negative feelings. Nevertheless, understanding the frames used in media coverage of climate engineering is the first step towards participating in the broader public debate which is needed.

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