Advanced Review

Online communication on climate change and climate politics: a literature review

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The study of climate change communication has become an important research field. As stakeholders such as scientists, politicians, corporations, or NGOs increasingly turn to the Internet and social media for providing information and mobilizing support, and as an increasing number of people use these media, online communication on climate change and climate politics has become a relevant topic. This article reviews the available scholarly literature on the role of online and social media in climate communication. It analyzes how stakeholders use online communication strategically, showing, for example, that climate scientists and scientific institutions do not seem to be major players in online debates about climate change and climate politics. Furthermore, it highlights the characteristics of online climate communication, outlining, for example, that although (or because) many stakeholders participate online, this does not lead to robust scientific information or better debates. Eventually, the review assesses what is known about the uses and effects of online climate communication, showing that impacts on the broader public seem to be limited so far. Research desiderata are identified in the end, and directions for further studies are shown.

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INTRODUCTION

Climate change and the possible range of responses to it are challenging issues to communicate[1]: They are complex phenomena with causes and consequences that lie beyond the life-worlds and biographical horizons of most people, and on which few people have first-hand experience. Accordingly, the media are 'important agents in the production, reproduction, and transformation of the meaning' of climate change (Ref 2, p. 172).

Analyses of climate communication in the past have often focused on the role of mass media such as newspapers or television (for overviews see Refs 1–4). However, this communication has diversified nowadays, as 'communicators attempt to reach many more audiences, use more diverse forums, channels, a wider range of messengers, and a number of different framings' (Ref 1, p. 32, cf. Ref 5, p. 1f.). The article at hand focuses on one of these new channels that has gained importance in recent years: the World Wide Web (WWW).[a]

On the one hand, this encompasses 'traditional' WWW communication such as websites that are interlinked and accessed via Internet connections. Since the WWW sprung up in the early 1990s, the number of such pages has grown sharply to an estimated 550 billion websites, which are used by approximately two billion people worldwide.[6] Apart from this (quantitative) growth, on the other hand, the WWW has changed qualitatively. It is increasingly used for interactive, many-to-many communication in which user-generated content is exchanged and the distinction between senders and receivers is blurred—a development software producer Tim O'Reilly[7] has famously called 'Web 2.0', and which scholars label 'social media.' Kaplan and Haenlein (Ref 8, p. 62ff., for other typologies see Ref 9, p. 29ff., Ref 10, p. 25ff.) distinguish six types of social media: 'collaborative

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projects' such as Wikipedia, which 'enable the joint and simultaneous creation of content by many end-users'; blogs and microblogs like Twitter; 'content communities' such as YouTube or FlickR, in which users can share audio and/or visual content; social networks like Facebook; 'virtual game worlds' like World of Warcraft; and 'virtual social worlds' like Second Life. The use of these media has also expanded significantly in the past years.[11]

In scholarly circles, the emergence and rise of these online and social media has led to lengthy discussions about their impacts. 'Cyber-optimists'[12] have portrayed them, for example, as ideal tools in science communication to improve the communication of science to the broader public by publishing 'aspects of scientific research previously hidden from the general public' (Ref 13, p. 247, cf. Ref 14) and by using audiovisual and interactive features that might enhance user engagement and understanding.[15] They are also seen as potential means to improve the effectiveness of communication among scientists (e.g., Ref 16, p. 1350). Other theorists point out that online media might improve societal communication. Given that online content can be posted easily and without gatekeeping journalists, the WWW might 'empower'.[17] formerly underprivileged groups and make previously unheard arguments heard (for a summary of the literature see Ref 18). Although such hopeful voices dominate the scholarly debate, 'cyber-pessimist' voices have also pointed out the limitations and even dangers of online communication. They have emphasized that online media are rarely used as sources for political information, and that they do not trigger political engagement or participation (e.g., Refs 19–21, although some studies explicitly exempt the issue of climate change from this, e.g., Ref 22, p. 62). Furthermore, they have argued that online media might cause a fragmentation of public debates into small isolated communities of like-minded people,[23] that online media are being instrumentalized by those in power,[24] or that laypeople have difficulty distinguishing credible scientific information from faulty ones in online formats.[25]

In contrast to these far-reaching hopes and concerns regarding online media, however, most articles on climate communication mention these media only in passing or not at all (e.g., Ref 1, pp. 41ff., Refs 4, 26). The aim of this article is to change this. A significant amount of scholarly work on the role of online media in climate communication has been assembled in the past years, albeit scattered across disciplines such as political science, sociology, communications, anthropology, economics, and others. And although this body of literature still has substantial gaps and shortcomings, it warrants a first review. The article at hand will provide that.

It will identify the major themes of existing research, present their most robust findings, and outline what needs to be studied in the future. It is organized in three sections, which (roughly) follow the process of communication. The first section deals with different stakeholders' strategic use of online and social media in climate communication. The second section describes what is known about the structure and characteristics of online climate communication. The third section reviews studies on the uses and effects of this communication. The concluding section points out directions for future research.[b]

STRATEGIC CLIMATE COMMUNICATION: STAKEHOLDERS' USE OF ONLINE AND SOCIAL MEDIA

The public debate about climate change and the appropriate responses to it is 'a deeply contested area [with] considerable competition among (and between) scientists, industry, policymakers, and nongovernmental organisations (NGOs), each of whom is likely to be actively seeking to establish their particular perspectives on the issues' (Ref 26, p. 166, cf. Ref 5, p. 2, Ref 27, p. 264). Strategic communication, public relations and advocacy efforts of various stakeholders have therefore 'played a highly significant role in the climate change debate' (Ref 26, p. 171), trying to be successful in setting the public agenda and 'framing' the issue of climate change according to their particular perspectives. These efforts often involve online media nowadays, and a relatively large number of studies (mainly from political science, sociology, communications, and marketing) have analyzed them.

Ideally, these studies should teach us how and with what intensity different stakeholders from science, politics, the economy, etc. approach and use online media in climate communication. They should present their aims and strategies, and model the dynamics of online debates involving these stakeholders.

The studies that have been assembled so far cannot answer all of these questions sufficiently. They can, however, show that the public debate on climate change also extends to online, that many stakeholders try to position themselves and their arguments in these debates, and that the intensity and purpose of this online climate communication vary strongly from stakeholder to stakeholder.

Scientists and Scientific Institutions Play a Limited Role in Online Climate Communication

An initial, and quite striking, finding is that climate scientists and scientific institutions from the field do not seem to be the major players in online climate communication. Admittedly, the evidence is still relatively fragmentary in this regard. But it appears that (notwithstanding numerous diagnoses of scientists presumably engaging in public and media communication in order to 'sell' science[28,29]) engaging in online communication does not seem to be not a main occupation of climate scientists. Even though scientists have organized spectacular online events like 'virtual conferences' on climate change (Ref 30, p. 243), it seems that such events are rather rare.

Individual scientists' online activity seems to concentrate on the 'climate blogosphere',[31c] in which diverse positions and a heated debate can be found, but where climate science is far from dominant. Among the (estimated) 50 million existing weblogs, the Technorati[32] blog search engine labels approximately 1900 (or one in 25,000) as 'climate' blogs, 1400 as 'climate change' blogs, and only 323 as 'climate science' blogs. In addition, experienced bloggers argue that even most of the blogs with 'science' labels are actually 'pseudoscience' blogs, with the number of 'real' science blogs a fraction of that (Ref 33, p. 443). The number of blogs run by scientists actually doing research on climate change, therefore, can be assumed to be even smaller, perhaps in the vicinity of the estimated 100 blogs that Bentley[34] identifies for the Earth sciences in general.

Accordingly, science seems to be 'adrift in the blogosphere' (Ref 35, cf. Ref 36, p. 275f.) and the same appears to be true for scientists on Twitter (Ref 37, p. 453). Reasons might be that scientists do not have time for (micro)blogging (Ref 37, p. 453), are not (yet) used to the novel format (Ref 33, p. 444), or do not like it because it is not restricted to factual information and rational discussion (Ref 33, p. 444, Ref 35, p. 201, Ref 38, p. 78). At least, however, observers indicate that there is an increase in Earth science blogs.[34,39]

Regarding the strategic online communication of entire scientific institutions, evidence is scarce. Generally, it seems safe to say that many academic and nonacademic research institutions have expanded and professionalized their PR efforts offline and online in past years,[40] and that this also applies to climate science.[41] However, at least in 2003, the professionalism of these efforts was questionable. Lederbogen and Trebbe show how institutional websites from meteorological and other scientific facilities fail to clearly target audiences, strongly utilize scientific jargon, do not take advantage of the Web's interactive opportunities (Ref 41, p. 343ff.), etc.

Therefore, the online engagement of climate scientists and scientific institutions seems limited. Regarding the motivation of those scientists who do communicate online, a small number of surveys (with fewer than or approximately 100 responses each, mainly from the United States, and partially published online only) is available that show why scientists engage in online climate communication.[34,39,42–44] Their main goals seem to be:

- *To educate the public:* By far the most important aim seems to be to provide information to educate the broader public.[43] To make 'discussions of climate science open to potentially everyone through the use of blogs on the [WWW]' is considered a good idea by most climate scientists (Ref 38, p. 77), and '[d]isseminating scientific information is a driving mission for many [scientific] Twitter users' who consider it 'an effective way of telling people about your work' (Ref 37, p. 453). These objectives, of course, drive practically all efforts of science communication. They have an additional driving force, however, in the case of climate change. Given that climate 'skeptics' are perceived to be very present online (Ref 45, cf. Ref 5, p. 2) and particularly in the blogosphere (Ref 31, p. 82), scientists turn to communicating online to address such 'pseudoscience' (Ref 39, cf. Ref 33, p. 444, Ref 34). Their two main target groups in doing so are 'lay audiences' (Ref 33, p. 443, cf. Ref 5, p. 2) and 'opinion leaders, activists, and journalists' as a particularly relevant section of the public (Nisbet in Ref 33, p. 444, cf. Ref 31, p. 81).
- *To further scientific discussion*: Some scientists also use online media to initiate and improve the discussion with the (climate) scientific community, and to 'create weblogs for the discussion of new ideas and the dissemination of research findings. Such weblogs could act as platforms for brainstorming new concepts and generating ideas[,] provide an alternative mechanism for gaining feedback in the early stages of a research project [and] be used for publicizing and interpreting peer-reviewed literature' (Ref 35, p. 201, cf. Ref 34).
- *To allow for public participation in science*: Some science bloggers value that online communication enables the broader public to participate in science, although the understanding of what such

'participation' might mean differs strongly. Some bloggers like that online media give scientists an opportunity to discuss their findings with laypeople (Ref 15, p. 78, cf. Ref 38, p. 77), or to engage in 'discussions of scientific issues that do not typically take place in the scientific literature' (Ref 33, p. 444)—a kind of participation that might not have strong repercussions on the proceedings and working routines of science itself. Others, in contrast, value that online media enable the public to be included more extensively in science, for example, in an 'extended' or 'open' peer review of scientific publications via social media (Ref 46, cf. Ref 14, Ref 47, p. 3, Ref 36, p. 278).

NGOs Are the Champions of Online Climate Communication

Climate and environmental NGOs seem to be the champions of online climate communication. They communicate extensively online, and for good reason: Compared to other stakeholders in society with whom they compete for public attention,[48] they are 'weak' (Ref 49, p. 34) actors often lacking resources, networks, and influence, and accordingly rely more than others on mobilizing the public. Online communication is ideal to address these problems, because it is relatively cheap and reaches potentially large audiences.[50] Furthermore, it is considered to provide 'a more level playing field' (Ref 51, p. 461) compared to news media, where gatekeeping journalists are often seen to favor established stakeholders (Ref 2, p. 175), particularly in countries such as China, where access to news media is strongly regulated.[52]

Accordingly, online communication is part of the repertoire of practically every climate NGO. Surveys, strategy analyses and ethnographic research in the United States and Canada,[53] the UK,[50,54] the Netherlands,[55] Australia,[56] China,[57] several other countries[58] and among transnational NGOs[59] show that NGOs in the field cannot afford not to use online media.

It is also clear that NGOs use online media with different motivations and for different purposes. Drawing from Stein's (Ref 60, p. 752f., cf. Ref 54, p. 161ff.) typology, four functions of online media for NGOs can be distinguished:

- *Provide information:* Many NGOs use online communication mainly to provide information about their topics, aims, and actions, and to allow 'the real facts to be read without our message being distorted by the [news] media prism' (Ref 54, p. 161). Apart from internal communication such as 'informational e-mails' (Ref 50, p. 10ff., cf. Ref 54, Ref 61, p. 151), websites are the main channel used to establish 'direct contact with the public' (Ref 54, p. 161, cf. Refs 57,62,63). Website programming has been shown as usually being the first online step of British NGOs (Ref 54, p. 150ff.), 75 surveyed NGOs activists from various countries perceive websites as their main online tool (Ref 59, p. 124), and Chinese NGOs spend most of their time 'maintaining and expanding the Web site' (Ref 57, p. 89). In turn, this also often means that (maybe due to lacking 'commitment, time, money and expense', Ref 54, p. 161, cf. Ref 64), social media are rarely used to disseminate information. Jun's analysis of 60 websites from American, British, Canadian, Australian, Indian and other 'climate change organizations' shows that less than one-quarter of them link to social networks, Twitter, YouTube, etc. (Ref 65, p. 248). It seems that high-profile social media campaigns like *The Climate Campaign* (from 2006), the *We Campaign* (from 2008) and the ongoing *Climate Reality Project*, which were set up in the aftermath of *An Inconvenient Truth*,[66] remain rare.
- *Address news media*: Ample evidence exists that many NGOs use online communication mainly as a tool to get into news media.[60] Based on literature reviews and interviews with Australian activists, Lester and Hutchins conclude that '[r]ather than seeking to move around or bypass the news media', NGOs attempt to get 'into these communication channels through the use of websites and email' (Ref 67, p. 582, cf. Refs 68,69). Jun shows that most international 'climate change organizations' provide specific websites for journalists and media relations (Ref 65, p. 247). Castells describes that online media are 'crucial' for the *Stop Climate Chaos* NGO and its 'media strategy implementation' (Ref 70, p. 324). Some NGOs also seem to measure the success of their online communication mainly by the amount of news media attention they generate this way.[71,72]
- *Increase outside support*: Climate NGOs also use online media to strengthen support. Fund-raising is crucial in this respect (cf. Ref 73, p. 35ff.): NGO's PR people claim that it is one of the main goals of their online communication,[59] and a majority of climate NGOs' websites provide information for donors and volunteers (Ref 65, p. 247, cf. Ref 74, p. 654) or sell merchandise

(Ref 75, p. 175). In addition, online networking with outsiders and other NGOs serves to 'strengthen movement networks' (Ref 54, p. 153, Ref 51, p. 468). It may give individuals a sense of belonging to an organization and further its collective identity (Ref 70, p. 324), an important facet for social movements to be successful (Ref 76, p. 162f.). It is rather surprising, however, that the considerable potential of social media lies dormant in this respect. Many climate NGOs do not use social media,[65] and few activists seem to be aware of the opportunities they provide (cf. Ref 67, p. 591). Fanenbruck's case study on a protest march in London during COP 15 indicates that this may be due to a lack of resources and know-how, as only 'resource-strong' (Ref 77, p. 78ff.) organizations such as *Stop Climate Chaos* were able to employ social media (cf. Ref 70, p. 323f., for an overview over the importance of resource mobilization for social movements see Refs 78,79). A recently developed antidote to these difficulties—whose effectiveness has yet to be evaluated, however—are platforms on which various NGOs can coordinate their actions, such as the *Global Campaign for Climate Action*'s platform *tcktcktck.org*, which includes approximately 300 NGOs, or the British *stopclimatechaos.org*, which is used by more than 100 groups.

- *Change behavior and mobilize action*: Eventually, most of climate NGOs' online communication aims to change behavior and trigger action. On the one hand, they accomplish this via 'persuasive action' (Ref 55, p. 526), often directly coupling the promotion of 'a green cultural consciousness' with the description of 'a set of corresponding practices' (Ref 57, p. 91). Online communication offers unique opportunities to do so. The Facebook app(lication) 'Global Warming's Six Americas,' for example, surveyed users' attitudes toward climate change online, categorized them into an attitude type ('alarmed', 'concerned', 'cautious', 'disengaged', 'doubtful', 'dismissive'[80]) and subsequently informed them about actions they might take to fight climate change (for a UK initiative using Facebook see Ref 30, p. 244f.). On the other hand, NGOs engage in 'pressurizing action' (Ref 55, p. 526), encouraging supporters to petition online to decision-makers (for examples see Ref 81, Chapter 4) or to engage in real-world actions such as the violent protests during COP 15, which were fired up by the *Never Trust a COP* campaign's viral YouTube videos.[77,82] In addition, some NGOs turn to 'disruptive action'[51] or 'Hacktivism' (Ref 83, cf. Ref 54, p. 149, Ref 55, p. 526), for example, by replacing the *European Climate Exchange* webpage with a fake site stating 'Super Promo—Climate on Sale: Guaranteed Profit!'

Knowledge about Strategic Communication from Politicians, Corporations, and Others Is Limited

In comparison, only fragments are known about the online activities of other stakeholders. Regarding politicians and political institutions, far-reaching claims—such as 'the pervasiveness of Web 2.0 social media has changed the power dynamics between governments and citizens' (Ref 84, p. 7, cf. Ref 85, p. 24)—are much easier to find than actual data. Many scholars assume that 'the Internet is increasingly being used as a tool of governance' (Ref 86, p. 328), and as a means to improve the legitimacy of political action.[87] Furthermore, a very small number of studies from Australia,[86,88] India,[89] Japan,[90] the Netherlands,[91] Sweden[92] and the United States[93] have demonstrated how governments use offline and online media for information campaigns on climate change, to encourage public participation, and as tools in disaster management. However, the extent and intentions of these measures, as well as the full spectrum of politicians' online climate communication, is yet unknown.

Similar uncertainties persist regarding corporate actors. A lot is known about their strategic communication on climate change in general, and it has been shown that PR efforts are an important facet in corporations' stakeholder management.[53,94–96] But few studies mention or even specifically address their online communication. It has been pointed out that online communication has advantages for corporations, such as the high degree of control over what to disclose (e.g., Ref 97, Ref 98, p. 249). In addition, a number of studies indicate that large global,[99,100] American,[101,102] Spanish,[103] Indian[104] and Egyptian[105] companies indeed favor environmental and sustainability reporting online. However, not much is known about how the, often considerable, corporate resources are utilized in strategic, persuasive online communication in order to '"spin" claims about the science of climate change to suit their agendas' (Ref 106, p. 539). A recent report by the US' Union of Concerned Scientists shows that 'while some American companies have taken consistent and laudable actions in support of

climate science—and of consequent policy—others have worked aggressively to undermine the science and block science-based policy proposals' (Ref 107, p. 1), and that they do so using lobbying and direct access to decision-makers and contacts to journalists (Ref 107, p. 17f.) as well as websites (Ref 107, p. 24). Another study, analyzing BP's online communication, shows that once a company of that magnitude is committed to online campaigning, it is able to employ a large variety of tools 'such as online games, . . .downloadable ringtones, desktop backgrounds, and screen savers' (Ref 108, p. 153) as well as a professional selection of colorways, imagery and rhetoric.

In addition, only a small number of publications analyze thinks tanks, which seem to be very active online (cf. Ref 109, p. 219f.), both using websites,[110,111] the blogosphere[31,45] and advertisements.[107] Lockwood shows how skeptical think tanks 'have progressed to using blogs formats, for example, Cato-at-Liberty, of the Cato Institute' and that, for example, 'Climate denialist An Englishman's Castle is in *Total Politics* magazine's Top 20 libertarian blogs' (Ref 45, p. 3). However, more research is necessary here—as well as on the strategic climate communication of other stakeholders, ranging from churches and artists to sports associations (for examples, see Ref 30), about which practically nothing is known.

CHARACTERISTICS OF CLIMATE COMMUNICATION IN ONLINE AND SOCIAL MEDIA

In addition to studies analyzing different stakeholders' efforts to use the WWW for climate communication, a number of studies have described the characteristics of online climate communication. They have examined the amount of attention for climate change and climate politics in the WWW, as well as the characteristics of online debate in terms of structure (who links to whom, talks to whom, etc.) and content (what does the online debate look like, etc.). So far, the respective research centers around a small number of themes.

The Amount of Online Climate Content Is Significant and Increasing

A significant amount of online content and communication is concerned with climate change, even though this is difficult to measure accurately. A simple measure is to count the number of search engine results, which indicates that a considerable portion of online content deals with climate change. In April of 2012, an English-language Google search brought up 377 million hits for 'climate change', more than, for example, 'The Simpsons' (29.9 million), 'Barack Obama' (297 million), or 'Kim Kardashian' (348 million).

Furthermore, the 'New Media Index' provided by the Pew Research Center shows that, at times, 'climate change' and 'global warming' were among the five most common keywords used in all English-language blogs[112,113] and Twitter feeds[114,115] that were surveyed. Furthermore, it seems that '[i]n many countries, the volume of content on climate change that is put online has increased immensely in the last few years' (Ref 5, p. 1). This corresponds to the increased PR efforts of many stakeholders and the steep rise in news media attention to the issue worldwide.[116]

The Quality of Science Communication Online Is Considered Poor

Apart from the sheer amount of climate-related content, many studies focus on its characteristics. Quite a few of them analyze online climate communication as a case of science communication, investigating how the science of climate change is represented online. Implicitly or explicitly, most of these studies employ what has been called the 'public understanding of science' paradigm, which aims to impart science to the public, further the scientific literacy of the people, and improve the image of science.[114,118,119] In the past, proponents of the model have often compared public or media representations of science with peer-reviewed scientific publications or assessments made by scientists, and usually ended up diagnosing a 'deficit' of the public representation of science (the so-called 'deficit'[120]). Many studies on the online representation of climate change do essentially the same, with the same results: They show that, on average, the scientific mainstream is not adequately represented in online climate communication.

One of the most influential studies in this respect is Ladle's[121] analysis of news media and Internet representations of a '*Nature*' paper on species extinction due to climate change. Based on extensive content analysis, it shows that the paper's findings were strongly misrepresented and its consequences exaggerated and sensationalized. That was particularly the case in the news media. Online communication was shown to be more diverse; while it contained some correct representations of the science, it also included 'extreme and unorthodox viewpoints' (Ref 121, p. 235) that were 'overtly critical of the underlying science' (Ref 121, p. 231).

Several analyses by Gavin have produced similar results. In a 'discourse analysis' of skeptical arguments found on the top Google-ranked websites during COP 15, he demonstrates that 'not a great many' websites (7%) contain skeptical arguments in a narrow sense, but when different kinds of skepticism are totaled, the number of websites containing at least some skeptical content amount to 29% (Ref 110, p. 1039f.). He also shows that the quality of scientific content on weblogs deviates strongly from scientific standards, rendering the blogosphere a 'Rantosphere' (Ref 122, p. 137f.).

Other studies have added more evidence to these findings. Ashlin[35] shows that environmental issues are often misrepresented in weblogs, and Trench describes the climate blogosphere as 'notably diverse and diffuse' (Ref 36, p. 282, cf. Ref 31, pp. 83, 85). In addition, Barr reports the participation of a significant number of climate skeptics in a British online discussion forum.[123] Lockwood criticizes that in blog aggregation sites such as 'Wikio, four of the top 20 science blogs are skeptics. The most successful, WattsUpWiththat.com, the US-based blog of skeptic and former weatherman Anthony Watts, in July this year posted 646,024 page views (2.8 million since launch). It is in the top four of 3.4 million blogs using the free online blog authoring tool, Wordpress. Using the latest Nielsen Net Ratings data, even the most conservative estimate would give it over 300,000 monthly visits and a readership of over 31,000 users.' (Ref 45, p. 3). Malone concludes that although online media seem to be 'encouraging lots of people to express their opinions and share them widely, [they] are not very good at supporting evidence-based, logical deliberation' (Ref 85, p. 20). Holmes' online content analysis also shows a large 'PR footprint of Exxon Mobil' (Ref 124, p. 95), meaning that, for instance, many websites and weblogs mention scientists funded by the corporation without mentioning the link between both, which 'is likely to be highly misleading for readers' (Ref 124, p. 96).

In sum, it seems that even though scientifically correct presentations of climate change can be found online, on average, online media and blogs paint a picture of climate change that deviates significantly from the scientific view. What, if any, deviation from the scientific standpoint is deemed acceptable depends on the author's position. Gavin,[110,122] for example, considers the degree of deviation found in his studies to be highly problematic. The 375 international climate scientists surveyed by Bray and von Storch also assess the 'quality of scientific discussion [on blogs, in comparison to peer reviewed articles]' as rather poor (Ref 38, p. 77).

Online Debates on Climate Change Are Not 'Better' Than Offline Debates

Other scholars analyze online climate communication based on a different theoretical foundation. They are interested in the presumably more egalitarian nature of WWW debates. Given that online communication, in contrast to news media content, is not structured by gatekeeping journalists, actors with alternative viewpoints and fewer resources, such as small NGOs or individual citizens, may participate more easily. Some social theorists consider such 'popular inclusion' to be desirable, because including NGOs and other grass-roots actors who are not part of established power structures could lead to more 'deliberation', that is, a more rational and civil debate (for more detail see Ref 18). Some accounts on climate communication mirror this view. For example, Carvalho argues that mainstream media sometimes suppress critical voices (Ref 2, p. 175), whereas the Internet might allow 'a much wider set of individuals and organizations to express their views in a public forum with a potentially far reach' (Ref 5, p. 1). This 'may provide more frames as well as different kinds of information and knowledge' (Ref 125, p. 780).

The empirical evidence that has been assembled on these questions, however, indicates that these hopes are only partially fulfilled in online climate communication. It especially 'put[s] a question mark against the notion of the web as an egalitarian, democratised, alternative and separate avenue of communication' (Ref 51, p. 459).

- *Popular inclusion* is the hope that online debates enable previously marginalized actors to become visible—visibility being 'an extremely important indicator in [an online] environment because of the competition for a web user's attention' (Ref 109, p. 224, cf. Ref 126). There are indications that this may happen in online climate communication. '[T]he Web makes a positive influence as it allows civic groups that are developing new ways of dealing with climate change to gain some visibility. Currently there is a wide range of groups that address climate change in creative and potentially influential forms, such as the Transition movement and Carbon Rationing Action Groups' (Ref 5, p. 3). Large numbers of individuals are able to, and actually do contribute in discussions about YouTube videos on climate change (Ref 127, p. 60f.) or policy proposals—Zavestoski et al. (Ref 93, p. 5) show how environmental policy proposals by the US Department of Agriculture received more than 1.5 million online responses

from individual citizens. Such instances indicate a 'quantitative leap in 'green interactions'' (Ref 50, p. 17). But other studies also show a potential downside: While online communication can bring people together quite easily,[128] they might lead to a fragmentation of online debates in small, not interconnected sub-publics (Ref 30, p. 239). Several studies, using software tools such as Web or issue crawlers to identify online linking patterns, hint toward such developments. McNutt, for example, has analyzed some 80,000 websites in order to identify 'virtual policy networks' on several issues including climate change.[109,129] She found a strong dominance of governmental actors: 86% of all links in the policy networks went from one governmental actor to another, with only a small number going to NGOs (Ref 129, p. 6ff.). A similar study found that .com domains tend not to link to .gov domains; there are '.org-centric and .com-centric issue networks' (Marres quoted in Ref 130, p. 65f.) with 'distinctive .com, .gov and .org linking styles' (Ref 131, p. 141). And Sullivan, in an analysis of linking networks among Chinese NGOs, also finds that NGOs mostly link to other NGOs, although some of the Chinese ones are government-run 'GoNGOs' (Ref 132, p. 430).

- *Deliberation and Civility*: Apart from who participates, research has also strived to determine whether online debates are better than offline debates in that they contain more argumentative, civil discussions. Based on the evidence so far, the answer is no. Although online media seem to stimulate debates 'where diverse positions were aired and engaged,' they are often aired 'in a limited and unstructured manner' (Ref 93, p. 386). Holliman observed a 'polarized and sometimes ideologically driven nature of debates' around 'ClimateGate' (Ref 133, p. 834), and Malone describes online debates on climate change as 'strident and unproductive' (Ref 85, p. 15). This seems to be especially true for online debates among individual users, which 'have some fairly consistent features—they are often long[,] unstructured, angry or abusive, and filled with assertions that would be difficult to cross-check[. T]here are high numbers of controversial and uncheckable assertions, plus more than a few questions with no obvious answers, or answers with no obvious questions. Entries are often highly disjointed and difficult to follow—part polemic, part rant, part ramble, part squabble, and often involving people flatly contradicting or sniping at one another. The caliber and tone of content is often 'uninspiring', and can in places descend to playground level', describes Gavin (Ref 51, p. 469, cf. Ref 122, p. 137). He concludes that 'the web perhaps generates more heat than light, its contribution to informed debate being mixed at best, and very unedifying, or even distasteful, at worst' (Ref 51, p. 469).

USES AND EFFECTS OF ONLINE CLIMATE COMMUNICATION

'So there is volume, but what of its impact?' (Ref 45, p. 4). In other words, what do we know so far about how many people actually access climate-related content online, and what effects this has on diverse audiences? Many assume such effects on people's issue awareness, knowledge or behavior (cf. Ref 3, p. 535, Ref 4, p. 1471), and some even argue the effects of communication in online media may be particularly strong. After all, online and social media allow for more interactions, re-iterations of questions, recommendations from friends, and discussions in pre-existing communities, etc.-all features that mirror the characteristics of interpersonal communication which, on many issues, has proven to have stronger effects than news media.[134] However, research on this dimension is still rare, and has not yet shown consistently strong effects.

The Use of Online Media by the General Public and Its Effects

Most of the existing research on the uses and effects of online climate communication has focused on the general public, or 'ordinary' citizens. These studies indicate, first of all, that online media are (still) less important sources for information and orientation on climate change than news media such as television (e.g., Ref 135, p. 28, Ref 83, p. 69). However, recent survey studies also show that the Internet has already become a more common source for information about climate change than friends and family,[83,136] and that the relevance of online media has risen considerably compared to earlier studies.[137] This has to be qualified in three respects, however. First, online media are used primarily for non-political issues,[19] and, as analyses of Google's search entries indicate, information on climate change is much less likely to be searched and retrieved from online sources than issues such as sports, entertainment etc. (Ref 110, p. 1042). Second, the relevance of the Internet differs significantly from country to country,[135] and can still be very low in regions like rural India, where Internet access is not commonly available.[138] Third, even in developed

countries, the use of online media varies over time. For example, the number of English-language, climate-related Google searches peaked regularly during the annual 'Conferences of the Parties' (COP) and rose dramatically during COP15 in Copenhagen (Ref 110, p. 1040ff., cf. Ref 122, p. 133f.). It has also been show that Google searches were triggered by NGO action in the UK (Ref 51, p. 464ff.) and by governmental climate mitigation initiatives in Japan (Ref 139, p. 122f.).

Apart from being a fairly common source for climate information, online media also seem to be considered a rather credible source. A representative survey showed that 'if in doubt,' Germans would trust 'the Internet' more on climate change than any other source except television, i.e. more than radio, newspapers, talking to friends and family, etc. (Ref 83, p. 69). Similarly, a US survey indicated that websites, search engines and (to a lesser extent) social media are evaluated rather well as sources for climate information.[136] Again, however, these findings have to be qualified, not only because they are few, but also because not much is known about the embedding of such attributions of credibility and trust. The uses of online climate communication are still thoroughly under-researched. The social settings and dynamics in which users engage with climate-related online content, their motivations and the extent to which they are realized, as well as their interpretations of the online content have not yet been taken up in research. Theories ranging from uses-and-gratifications approaches[140] to opinion leadership[66] might be helpful to shed light on the black box that are the uses of online climate communication so far.

Regarding the effects of online media, research has mainly focused on individual-level effects on peoples' problem awareness, their level of information, and their willingness to act—in other words: on potential first and second level agenda-setting effects,[141] and on persuasion.[142] Although more research is necessary, the available results indicate a somewhat sobering picture.

- *Effects on problem awareness*: Stakeholders like *tcktcktck*, for example, often claim to have 'mobilised over 4790 bloggers on October 15th 2009, reaching over eleven million people in an effort to raise awareness around the issues to be discussed at Copenhagen' (Ref 84, p. 7). Some scholars also argue that online media 'continue to engage the attentive public in scientific topics' (Ref 33, p. 444), or even that they create a 'new environmental consciousness' and a 'universal awareness of the reality, causes and implications of climate change' (Ref 70, p. 303). Indeed, the agenda-setting effects of news media have repeatedly been shown for climate change.[125,143] However, the specific contribution of online communication has not yet been properly distinguished from the more general effects of entire media ensembles. Ryghaug et al.'s work is symptomatic in this respect, as it shows that websites of newspapers contribute to problem awareness, but that they do so in connection with other media.[125] Few studies distinguish between the effects of news media and online communication, and one of these does not find specific effects of online communication.[144] Therefore, more research is needed on this issue.
- *Effects on knowledge*: The effects of online climate communication have mostly been analyzed regarding potential improvements in the audience's knowledge, i.e. in terms of cognitive effects (conative and affective effects have not been analyzed extensively, although some studies include them, such as Ref 144). And it seems that online communication, as well as news media, indeed increases the audiences' knowledge about climate change. It is still unclear, however, whether this applies to Internet use in general, or only to people who search the Internet intentionally and specifically for climate change information. Zhao, for example, in a re-analysis of the US General Social Survey, found that newspaper reading and frequent Internet use generally had positive effects on the self-professed knowledge of respondents on climate change.[145] Similarly, a recent Eurobarometer survey of approximately 13,000 citizens in 12 EU countries found that extensive Internet use correlates with more (self-assessed) knowledge about 'the different causes' and 'the different consequences' of climate change, as well as the potential '[w]ays in which we can fight' it (Ref 135, pp. 19, 23, 27). Kahlor and Rosenthal, however, do not find such general effects.[146] And Taddicken and Neverla demonstrate that although a general 'unspecified' use of the Internet has no positive effects on knowledge about climate change, using the Internet to specifically find information on the topic indeed increases knowledge about it.[147]
- *Effects on (intentions for) behavior*: The effects of online climate communication on actual behavior are a third important dimension that has received scholarly attention. Such effects might be theorized using the Theory of Reasoned Action or the Theory of Planned Behavior.[148]

Notwithstanding such expectations, they appear to be weak or even non-existent empirically. A study by Zhao[145] found some effects of online use on people's information-seeking; those using online media and learning from them are more likely to search for more information about climate change in the future. Regarding climate-related behavior and action, however, the effects of online media that have been shown are weak, and in practically all cases, they refer to behavioral intentions instead of actual behavior. For example, Taddicken and Neverla[147] show that the intentional use of online (together with other) media to acquire information about climate change correlates with peoples' intention to change their behavior. Arlt et al. also demonstrate that 'informational online usage' has effects on the intention to engage in 'societal relevant activities' (Ref 144, p. 59), but no influence on investment decisions or changes in lifestyles. Qualitative research, however, indicates that during times of crises, 'active citizens' human agency' may be triggered via online media such as websites.[149] More research is needed here to clarify these seemingly contradictory findings.

Special Effects on Special Audiences: Journalists, Scientists, and Politicians

Apart from effects on the general public, a number of studies have concentrated on specific and (presumably) particularly relevant segments of the public. Three such segments have received scholarly attention:

- *(Climate) Scientists*: The use and effects of online media on scientists who are concerned with the climate, its developments and potential responses to it have received some attention. A survey of approximately 1100 German climate scientists shows that they use online and social media heavily, both for private as well as professional purposes.[150] There are also numerous examples of individual scientists who heavily use online media, social networks, weblogs, or Twitter.[33,37] Many effects of such a use of online media among scientists have been theorized so far. These range from improving the exchange of information between scientists[37] to the creation of a new 'Science 2.0'[151] or 'Cyberscience',[152,153] in which facets like peer review may have to be 'extended' or 'opened' to the online public (Ref 46, cf. 31, Ref 47, pp. 3, 16), to the potential need to monitor conference audiences so that no audience member tweets unpublished findings to the outside (Ref 37, p. 452). However, actual analyses of both micro-level uses and effects of online communication amongst scientists, as well as analyses on potential systemic effects, which might draw from 'laboratory studies'[154] and 'medialization' research,[155] are still lacking.
- *News Media Journalists*: The uses and effects of online communication on journalists from 'old' news media have also been analyzed. Part of the reason is that many stakeholders go online specifically to trigger 'spillover' effects into television, newspapers, etc. (Ref 33, p. 444, Ref 31, p. 81). The existence of such effects is often assumed or taken for granted; for example, when weblogs are described as 'important sources for opinion leaders, activists, and journalists,' or when it is mentioned that 'many discussions that grab the attention of bloggers have ended up in the pages of *The New York Times*' (Ref 33, p. 444, Ref 31, p. 85). The rationale behind this assumption is that of a 'lazy media' (Bolt in Ref 45, p. 3) in which '[e]conomic pressures and organizational pressures have led to [environmental] journalism that is increasingly desk-bound, which in turn has increased the scope for proactive news sources and news-providers to 'subsidize' the work of news organizations and their journalists with ready-packaged and advantageously framed 'information', while at the same time depriving journalists of some of their most traditional networking and source-checking strategies based around 'face-to-face' interviews or contacts with sources' (Ref 156, p. 12, cf. Ref 121, p. 239). Indeed, some (partly anecdotal) evidence exists for such effects. The most obvious example has been the case of 'ClimateGate', that is, the publication of a large number of climate scientists' e-mails, which seemed to indicate that these scientists had manipulated data in order to underline the diagnosis of anthropogenic climate change. 'ClimateGate' was an issue in social media first, and only subsequently taken up in news media.[157,158] Other examples are that bloggers have been news sources in Australia's ABC TV in the past, that British Channel 4 made the number of skeptical comments in its forum the issue of a newscast, or that American newspapers have written articles about blog discussions on climate change.[45]
- *Politicians*: Studies on the effects of online communication on politicians are also rare (cf.

Ref 159, p. 99). The initial results, however, indicate that although online communication receives some attention from politicians, effects such as policy influence are limited. This may partly be due to the considerable amount of online communications, petitions, etc. that politicians receive.[159] Nevertheless, in some cases, policy effects were found. Zavestoski et al. show that when an intense debate in an online discussion forum on US agricultural policy reached 'a symbolic consensus,' it 'led to a change in the proposed rule' because the online forum 'allowed the public to insist on this consensus against the proposed rule' (Ref 93, p. 403). Similarly, Howes[86] reports how he and others were able to monitor and influence the Commonwealth's 'Environment Protection and Biodiversity Conservation Act' via online submissions.

CONCLUSION

Online communication already is, and will increasingly be, an important facet of climate communication. Scientific analysis of online climate communication is therefore a relevant and, as this review has shown, quite lively field. More than 100 publications from various disciplines were identified that examine the role of online and social media in climate communication; some specifically focus this new mode of communication, some analyze the Internet among other (news) media, and some only superficially address online communication. Up to now, this literature has already yielded a number of robust and partially surprising findings: the limited role that climate scientists and scientific institutions seem to play in online debates about climate change, the extensive online efforts of many NGOs which nevertheless often use the WWW in rather conventional ways, the visibility of many different stakeholders in the Internet, which obviously does not lead to better online deliberation, or the (so far) limited effects of this communication on the broader public.

These findings are important contributions to our understanding of climate communication. However, they must not divert attention from the fact that on almost every aspect of online climate communication, substantial gaps exist in the respective literature(s). Regarding different stakeholders' strategic use of online communication, the obvious hesitancy of scientists is an issue worth exploring. Furthermore, we need to know much more about the efforts of political and economic actors and institutions, particularly as they might have significant impact on climate policy and regulation.[107] Concerning the characteristics of online debates, best (or better) practices of science communication need to be explored. It would also be worthwhile to start analyzing the debate in larger sections of the Internet and over time, and to contextualize the results with larger theories of social and cultural change as well as with questions about the legitimacy of climate change regulation on national and supranational levels. This is certainly possible, because after all, one of the advantages of online research is the wealth of data that is, sometimes literally, only one click away. Concerning the uses and effects of online communication, the shortcomings of the existing literature are probably the largest. Research on the uses of online media regarding climate change and climate policy is almost absent from the literature. Much more research is also needed on the effects of online communication on knowledge, emotions, attitudes and values as well as behavior. Furthermore, the broader implications of these effects need to be studied in detail. For example, is the acquisition of knowledge from the Internet only possible for some users, which may lead to a widening 'knowledge gap' between Internet users and non-users[160] or between scientifically literate segments of the population and the rest (Ref 45, p. 4)?

Future research should also aim for a better balance of research topics. So far, scholarly attention has focused strongly on some aspects of online climate communication—for example, its strategic use by NGOs—while neglecting other aspects. It also seems very important to add more comparative studies to the literature, as most of the existing analyses involve European or North American countries or regions. In addition, not all modes of online communication have received (similar) attention. In comparison to the 'regular' WWW, social media have only recently become objects of studies, and this trend should certainly continue.

All of these future endeavors will require an interdisciplinary exchange of research findings on online climate communication. As this review has shown, political science, sociology, communications, anthropology, economics, and other disciplines have already contributed to our understanding of the phenomenon. It is necessary to continue uniting these fields to learn more about the nature and the impacts of online climate communication.

NOTES

[a] 'Mobile communication' via cellphones, etc. (cf. Ref 161) will not be included here in its entirety, but

only to the extent in which it constitutes online communication.

[b]Some issues touching upon new media and climate change are not addressed in this article, e.g., the debate about the rise of IT technologies contributing to climate change and the response of developing a 'Green IT',[162] the share of modern communication technologies in global waste production,[163] or the potential of using new media when conducting social scientific[164] or linguistic research on climate change.[165]

[c]This and several other quotations have been translated by the author into English for this publication.

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