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Climate Change and Climate Technologies: Public Perceptions and Communication Challenges

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Numerous survey studies reveal insight into the public's attitudes about climate change. These indicate that the majority of people around the world, including in the United States, do not deny that climate change is happening, but a smaller majority believe human activity is either partially or mostly to blame. In the United States, peoples' attitudes about climate change are politically polarized, leading some science communicators to suggest appealing to identity-affirming cultural meanings when discussing climate change. Studying the public's attitudes about climate technologies, or geoengineering, is a growing field. Most people have never heard of geoengineering or know very little about it. The topic is not yet politically polarized, creating an opportunity to encourage responsible societal discussions about the risks and benefits of climate intervention technologies. Given the possibility that every tenth or hundredth of a degree of warming avoided can matter in terms of the magnitude of climate impacts, these discussions are vital.



Introduction

Whether through personal experience with weather extremes or through the barrage of world news reports drawing attention to the aftermath of these extremes, it seems that the impacts of climate change are becoming increasingly difficult to deny. How large a role does the denial of climate change play in hindering the necessary but difficult work of climate change mitigation? Does the promise of climate intervention technologies further endanger the likelihood of action? To begin to answer these questions, a review of what is known about the public perceptions of climate change and climate technologies and the challenges of communication on these topics provides a useful starting point. This article summarizes recent public survey research on these topics and insights from science communicators. The research reviewed includes a world public, however the focus of this article is on public understanding and attitudes in the United States.

Global Perceptions of Climate Change

In 2019, the Lloyd's Register Foundation and Gallup conducted a World Risk Poll to help understand how people view a range of risks that may impact them (Lloyd's Register Foundation 2019). The poll was unique in that much of the data was collected through in-person interviews in places where people have never before been surveyed. One of the risks the survey explored was climate change (Lloyd's Register Foundation 2019, chapter 6). The poll surveyed 150,000 people in 142 countries, asking them, "Do you think that climate change is a very serious threat, a somewhat serious threat, or not a threat at all to the people in this country in the next twenty years? If you don't know, please just say so" (Lloyd's Register Foundation 2019, 110). Nearly 70 percent of people surveyed agreed that climate change is a "very" or "somewhat" serious threat, however less than half of these, 41 percent, believed the threat was "very serious." Answers varied at the regional and country levels, but at least 60 percent of people in every region agreed that climate change is a threat (from a high of 93 percent of people in southern Europe to a low of 60 percent of people in Northern Africa) (Lloyd's Register Foundation 2019, 109).

Respondents from the world's three largest carbon emitters—China (28 percent of the world's CO₂), the United States (14 percent of the world's CO₂), and India (7 percent of the world's CO₂)—described the risk from climate change differently than the overall responses from the rest of the world. Worldwide, only 13 percent of the people surveyed indicated that climate change is "not a threat at all." The United States, however, had the highest percentage of individuals among high income countries who chose this response at 21 percent. Individuals from India had a response similar to the United States at 19 percent. Only 12 percent of Chinese survey respondents indicated that climate change is

“not a threat at all,” but 29 percent indicated they “don’t know,” a much higher percentage than the overall worldwide response, 18 percent (Lloyd’s Register Foundation 2019, 117).

The demographic factor that most impacted people’s risk perception was education level (Lloyd’s Register Foundation 2019, 109). People with higher education levels were most likely to see climate change as a serious threat to their country. Other influences were whether or not the individual had experienced a severe weather event, how they felt about their local air and water quality, and whether or not the issue was ideologically politicized in their country (Lloyd’s Register Foundation 2019, 120). Despite these variations, it can be concluded that worldwide, people are aware of the risk from climate change and that the majority of people in all regions surveyed in 2019 do not deny this risk is real. How do people’s concerns about climate change in 2019 compare with their concerns about climate change in previous years?

The Pew Research Center’s Global Attitudes Project surveys, conducted in 2013, 2017, 2018, and 2022, suggest that climate change topped the list of people’s perceived global threats over these years and that their concern has been increasing with time. In 2013, 2017, and 2018, Pew surveyed people from twenty-three countries to determine how their concerns about a range of global threats—namely, China’s power and influence, Russia’s power and influence, the United States’s power and influence, the global economy, North Korea’s nuclear program, cyberattacks, and global climate change—ranked. In all survey years, global climate change was seen as the greatest international threat, with the median across the twenty-three countries surveyed increasing from 56 percent in 2013 to 67 percent in 2018. The closest threat competitors in people’s view in 2018 were cyberattacks at 61 percent and ISIS at 62 percent. In thirteen of the countries surveyed, worries about climate change increased significantly over this time, with double digit rises (Poushter and Huang 2019). In 2022, Pew Research Center’s Global Attitudes Project survey reported on the concerns of citizens in advanced economies in nineteen countries in North America, Europe, and the Asia-Pacific region. Citizens were surveyed about concerns related to the spread of infectious diseases, the condition of the global economy, cyberattacks from other countries, the spread of false information online, and global climate change. Once again, concerns about global climate change topped the list with a median of 75 percent of respondents across these nineteen countries describing it as a major threat. The spread of false information ranked the next highest with 70 percent (Poushter et al. 2022).

The majority of people around the world, including those in the most advanced economies, do not deny that climate change is happening, and they are concerned about the threat it poses to their countries. The United States distinguishes itself among high income countries as having the greatest number of climate change skeptics, though they are still a minority voice.

American Perceptions of Climate Change

The Political Psychology Research group at Stanford University conducted a series of national surveys from 1997 through 2020, all of which included twenty-two questions designed to reveal the American public's fundamental beliefs about climate change, their engagement on the issue, and their policy preferences. The results were reported for each state (McDonald et al. 2020). As noted, while the United States has the greatest number of climate change skeptics among high income countries, these skeptics are in the minority, and the same is true for the percentage of skeptics in each state. In 2020, more than 70 percent of residents in all states, and more than 80 percent in the majority of states, believed that global warming has been happening. Massachusetts had the largest majority at 88 percent and Utah the lowest at 71 percent.

In another report, the Stanford University researchers focused on what the survey data reveals about the certainty of Americans' beliefs about climate change (Krosnick and MacInnis 2020). Overall, the percentage of Americans who believe global warming has been happening over the past 100 years rose from 77 percent in 1997 to 81 percent in 2020. Looking towards the future, the overall percentage of Americans who think Earth's temperature will "probably go up" over the next 100 years if nothing is done to stop it remained unchanged at 75 percent. However, of this 75 percent, the percentage who are "extremely sure" or "very sure" temperatures will continue to rise increased from 45 percent in 1997 to 68 percent in 2020.

While acceptance of climate change is the norm, does the United States public also accept that human activity is the driver of global warming? In 2020, the percentage of individuals in each state who believed that past warming was caused by humans was not below 70 percent of the residents in any state but, overall, there was more skepticism around this question than whether or not global warming has been happening. Rhode Island and New Hampshire had the largest majority of citizens who believed that past warming was caused by humans at 91 percent, and Utah the lowest majority of citizens who accepted this at 71 percent (McDonald et al. 2020). From 1998 to 2020, the overall percentage of Americans who believe "human activity has been at least partially causing global warming" changed very little, from 81 percent to 82 percent (Krosnick and MacInnis 2020). What has changed is that from 2006 to 2018 this opinion has become highly politically polarized in the United States. The percentage of Democrats who accept that human activity has played at least a partial role rose from 83 percent to 91 percent during this time frame, whereas the percentage of Republicans fell from 77 percent to 66 percent (MacInnis and Krosnick 2020). Much to the frustration of climate scientists, Americans' views on climate change and its causes are often determined by political party identification. Making progress on this issue in the United States will require moving beyond partisanship, but science communication researchers are not in

agreement about how best to address the problem. This article discusses two contrasting suggestions.

Navigating Climate Change Communication

There is no significant disagreement within the scientific community as to whether climate change is happening or whether human activity is the driver of global warming. Scientists overwhelmingly agree that global warming is happening and that the burning of fossil fuels by humans is the reason. John Cook et al. (2013) analyzed peer-reviewed published studies on climate change and determined that the consensus among scientists that humans are causing global warming is greater than 97 percent. Cook (2023) also collected public perception data in the United States with the survey question “how many climate experts agree that the global warming we are witnessing is a direct consequence of the burning of fossil fuels by humans?” He found that only 12 percent of Americans are aware that the scientific consensus on humans causing global warming is higher than 95 percent. The most common answer, given by 45 percent of respondents, was that only 30 to 50 percent of scientists agree with this statement (Cook 2023). Cook suggests that communication efforts with the public should focus on closing the gap between the public perception of the scientific consensus and the reality of the scientific consensus. He and others argue that understanding the consensus among scientists is a gateway to accepting climate change and its cause (Cook et al. 2017). However, another school of thought, led by Dan Kahan, suggests that focusing on correcting knowledge deficits can be a polarizing message.

Kahan (2010) argues that the public will fit any evidence into their group identities, so successful science communication hinges on communicating identity-affirming cultural meanings, not just facts. Science communicators are advised to be cognizant of “cultural cognition,” recognizing that when positions on facts become associated with opposing social groups, individuals are likely to selectively assess evidence in patterns that reflect their group identity (Kahan 2015). The significance of cultural cognition for peoples’ opinions about climate change and its causes is clearly illustrated by the results of a 2019 Pew Research Center survey.

In 2019, Pew Research Center designed a survey with eleven questions to measure an individual’s general understanding of scientific facts and processes. They reported their findings as a function of the individual’s political ideology (Kennedy and Hefferon 2019). The mean score for the number of questions answered correctly by all who completed the survey was 6.7. Overall, Republicans and Democrats had similar levels of science knowledge, with mean scores of 7.0 and 6.6, respectively. Those who scored the highest were both the most conservative Republicans, mean score 7.4, and the most liberal Democrats,

mean score 7.8. Based on this survey, neither Republicans nor Democrats can claim that their political party, in general, has a greater understanding of science than the other party.

Pew then compared this general measure of science understanding based on test score (high 9–11, medium 5–8, and low 0–4) to agreement with the statement “human activity contributes a great deal to global climate change,” and once again reported the results as a function of the respondent’s political ideology (Funk and Kennedy 2020). For Democrats, agreement with the statement correlates to their score on the general understanding of science test, with results ranging from a low score and 41 percent agreement with the statement to a high score and 89 percent agreement. Democrats who scored highest on the general understanding test have the highest percentage of individuals agreeing with the statement “human activity contributes a great deal to global climate change.” There is no such correlation for Republicans, and those who scored highest on the general understanding test actually had less agreement with the statement, 17 percent, than their Republican peers, 25 percent of whom agreed with the statement. This is an example of why science communication researchers like Kahan argue that focusing on fixing an information deficit or closing the consensus gap by communicating what scientists know may not be as effective as appealing to identity-affirming cultural meanings, for example, showing a connection between climate change and what a person values. In the United States, one way many individuals identify themselves is in reference to their religious beliefs. Does religious commitment impact Americans’ views on climate change and its causes?

Religious Commitment and Climate Change Attitudes

The Pew Research Center approached the preceding question with a 2022 survey that explored climate attitudes as a function of both different religious affiliations and varying levels of religious commitment (Alper 2022). Individuals were asked about the frequency with which they pray and attend religious services and the degree to which they consider religion very important in their lives. A “high religious commitment” was assigned to those who pray daily, regularly attend religious services, and consider religion very important in their lives. Those who seldom or never pray, seldom or never attend religious services, and report that they do not consider religion important in their lives were categorized as having a “low religious commitment.” The survey also asked respondents if they agreed with four statements: “Earth is sacred”; “completely/mostly agree that God gave humans a duty to protect and care for the Earth”; “climate change is an extremely/very serious problem”; and “Earth is getting warmer because of human activity.” The “highly religious” had the greatest percentage of individuals who agree that “Earth is sacred,”

68 percent, and “completely/mostly agree that God gave humans a duty to protect and care for the Earth,” 92 percent, compared to those with a “low religious commitment,” 64 percent and 24 percent, respectively. However, the “highly religious” were least likely to agree that “climate change is an extremely/very serious problem,” 42 percent, compared to those with a “low religious commitment,” 72 percent. They were also least likely to agree that “Earth is getting warmer because of human activity,” 39 percent, compared to those with a “low religious commitment,” 70 percent.

The survey also asked individuals to identify themselves within a range of religious affiliations. There is a variation among religious affiliations as to whether individuals believe “climate change is an extremely/very serious problem” and the “Earth is getting warmer because of human activity.” For example, evangelicals are least likely to report that “climate change is an extremely/very serious problem,” 34 percent, or that “Earth is getting warmer because of human activity,” 32 percent. Catholics had the highest percentage of individuals who agreed with both these statements, 57 percent and 54 percent, respectively. However, those who described themselves as religiously unaffiliated had greater agreement with the statements, 70 percent and 66 percent, respectively, than those who identified with any religious affiliation.

At first glance, these results might suggest that religious affiliation is a key predictor of climate change attitude. However, the survey also reported responses to the aforementioned questions by members of each religious affiliation as a function of their political ideology. Within all religious affiliations, Republicans were more likely than Democrats to disagree with the two questions; this held for those who identified as religiously unaffiliated as well. For example, in response to the statement “climate change is an extremely/very serious problem,” only 17 percent of Republican evangelicals agreed, whereas 78 percent of Democratic evangelicals agreed. Likewise, for those who identified as religiously unaffiliated Republicans, 34 percent agreed with the statement versus 88 percent of religiously unaffiliated Democrats. Political party identification is the crucial factor in determining views toward climate change.

Finally, the survey asked all individuals who answered that “climate change is not/not too serious problem,” 20 percent of overall respondents, to choose among five options as to why they believed that to be the case: “there are much bigger problems in the world today”; “God is in control of the environment”; “climate change will not have a big impact on most people”; “I don’t believe it’s happening”; and “new technologies will fix problems created by climate change.” There was variation among religious affiliations as to the popularity of those options; for example, 29 percent of evangelicals said their reason was because “God is in control of the climate,” whereas only 8 percent of Catholics chose that option. However, the most common answer chosen by all affiliations, including those who identified as religiously unaffiliated, was that

“there are much bigger problems in the world today.” This option was chosen by 17 percent of all respondents followed by “God is in control of the climate,” chosen by 11 percent. The remaining options each accounted for less than 10 percent of the overall responses. Even among those who do not believe climate change is a serious problem, it seems the greatest barrier is not climate denial but a failure to see how climate change impacts their life. An important way to reach these individuals then would be to show a linkage between climate change and their values or the issues they worry about. This approach supports the work of Kahan (2010, 2015), who suggested appealing to identity-affirming cultural meanings when discussing climate change.

Public Perceptions of Climate Technologies

The studies reviewed indicate that the majority of people around the world, including in the United States, do not deny that climate change is happening, but a smaller majority believe human activity is either partially or mostly to blame. In the United States, people’s attitudes towards climate change are very politically polarized. Regardless of these varying attitudes, temperatures continue to rise, and many experts are concerned that given the current adoption rates of mitigation efforts, these efforts will not be enough to avoid disastrous climate impacts. Therefore, climate intervention technologies, or “geoengineering,” as a companion to mitigation are increasingly being considered as a way to manipulate the Earth’s climate and lessen the impact of climate change (e.g., Smith 2022). Geoengineering here refers to both solar radiation modification (SRM), technologies proposed to reflect sunlight back into space to prevent the atmosphere from absorbing the sun’s heat, and carbon dioxide removal (CDR), technologies aimed at the capture and storage of CO₂ from the atmosphere to slow further warming.

What is known about the public’s attitudes regarding the use of geoengineering to impact the climate? In 2021, the journal *Current Opinion in Psychology* published a themed issue on the psychology of climate change. This special issue included a review paper by Kaitlin Raimi (2021) that summarized the growing literature from the social sciences on public understandings of, and initial reactions to, geoengineering. Several points from this literature review are noteworthy and summarized here. First, most people have never heard of geoengineering or know very little about it. As noted, the survey that examined climate change attitudes as a function of religious affiliation asked the 20 percent of respondents who did not believe climate change was a problem to choose among five options as to why they felt that way. The response chosen the least, by only 4 percent of the respondents, was “new technologies will fix problems created by climate change” (Alper 2022). This result might reflect the reality

that the general public is not familiar with geoengineering techniques or the role they might play in impacting climate.

When people are introduced to CDR and SRM technologies, their initial reactions range from neutral to negative. Generally, more people are wary of SRM than of CDR. In regards to SRM, people are more supportive of laboratory research than deployment. This wariness extends beyond laypeople to experts, who perceive the risks to be even larger than laypeople do, especially regarding SRM. The CDR techniques people are most supportive of are afforestation or reforestation, in large part because these are seen as “natural” approaches. Finally, the lack of public awareness about geoengineering can be viewed through a lens of opportunity for early engagement. For a social scientist with a research goal, there is an opportunity to design their study in a way that avoids setting a particular agenda. The way the technologies are initially presented can have a large framing effect. For example, SRM portrayed as a way to address a climate emergency increases support for rather than opposition of the technology because the alternative is seen as a worse choice. Of course, the lens of opportunity is also there for those who are interested in marketing geoengineering techniques rather than collecting data on peoples’ attitudes toward these techniques once they are familiarized with them. That said, from a science communication point of view, the lack of public awareness about geoengineering can be advantageous because it is currently uncorrelated to any large degree with political ideologies. This keeps the possibility alive for the careful and inclusive dialogues that need to take place in regards to both the research and potential deployment of these technologies.

As the public learns more about geoengineering, a growing concern is the potential threat of moral hazard, namely, that learning about geoengineering and believing it could solve climate change will result in decreased support for reducing emissions. Alternatively, learning about the need for geoengineering might also result in an increase in the perceived threat of climate change and lead to an increase in support for reducing emissions. To explore these possibilities, one United States study looked at the influence of learning about CDR on support for mitigation policies (Campbell-Arvai et al. 2017). This study used a detailed online survey that began by introducing all participants to climate change then continued with five subsets of participants. One subset received no additional information, one subset read text that described the idea of CDR broadly, and the other three subsets read a description of just one type of CDR (reforestation, bioenergy plus carbon capture and sequestration, or direct air carbon capture). The participants then answered questions to determine if they perceived climate change as a threat, if they supported climate change mitigation, and what their political leanings were. The researchers discovered that learning about CDR did reduce the participants perceived risk of climate

change and that this was the case for all CDR messages except reforestation. This reduction in perceived risk correlated with a reduction in support for climate mitigation policies. While this was true for all political ideologies, it was most pronounced for conservatives. This study suggests that moral hazard will be a problem as the United States public learns more about CDR technologies.

However, things may be different for SRM: a study conducted with German citizens who were introduced to SRM resulted in a very different outcome. All participants in the online survey conducted in Germany received information about the effects of greenhouse gases on the climate, currently observed climate change, and mitigation and adaptation as two ways of dealing with climate change. One group also received information about a specific SRM technique, the injection of aerosols into the stratosphere (SAI), as a third way of dealing with climate change alongside mitigation and adaptation (Merk et al. 2016). In this unique study, all participants were also told about the possibility of supporting climate mitigation projects by purchasing voluntary carbon offsets and given funds that they could either keep for themselves or use to purchase offsets at a reduced rate. The researchers found that of those who learned about SAI, 42 percent reported being more alarmed about climate change and 3 percent less alarmed, and 55 percent stated no change in their perceptions. Those who were more alarmed used their funds to purchase more offsets than those in the control group who did not learn about SAI, but even those whose level of alarm did not increase after learning about SAI bought more carbon offsets than the control group. Participants were also asked whether they thought research about SAI in the lab or with computer models should take place. Those who disagreed that this research should go forward, or who were not sure, bought the most carbon offsets, but even those who were in favor of lab research bought more carbon offsets than the control group who received no information about SAI. Researchers concluded there was no evidence of moral hazard as a reaction to information on SAI. Even participants who perceived SAI to be an effective response to climate change did not reduce their support for mitigation efforts. Being informed about SAI technology led participants to choose mitigation. It seems the question of moral hazard remains an open one that can depend on the specific technology being considered (CDR or SRM), how the technology is framed, and who the audience is. For all the technologies being considered, policymakers or interest groups may react differently than individual citizens.

Public Engagement on Climate Technologies

The necessity for society to make difficult decisions concerning the regulation of research on, or the deployment of, geoengineering technologies is only going to increase in the future. At the same time, the window of opportunity for responsibly engaging the public on this topic, one with which they are largely

unfamiliar and opinions about which are not strongly associated with a political ideology, will close sooner rather than later. Colvin et al. (2020) urge science communicators to take advantage of this time frame to encourage “functional discourse” about geoengineering, where the goal of discussions is movement toward resolutions rather than defeating opponents.

With the public debate that has taken place around the topic of climate change in hindsight, Colvin et al. (2020) offer suggestions for moving forward with public engagement on climate technologies. First and foremost, they suggest that ideological bundling, that is, the technologies becoming associated with one political party over another, must be avoided. To do this, they advise that communication frames are chosen carefully. Most importantly, technologies should be presented as a complement to mitigation actions not a substitute for them. The possibility of co-benefits for both the environment and the economy should be noted. These benefits can appeal to a range of ideologies. Positive impacts are possible for both human and non-human wellbeing now and into the future. Old industries can be revitalized and new industries developed. To help convey these messages, Colvin et al. (2020) advise involving non-partisan trusted messengers and developing strategic alliances with individuals and organizations with diverse ideological leanings. Beyond avoiding ideological bundling, responsible functional discourse will also require differentiating among the numerous geoengineering technologies that exist under the umbrella of both CDR and SRM technologies. The risks and benefits of each will need to be considered in context. In addition to these guidelines, I suggest that science communicators also need to be cognizant of the psychological toll that the general topic of climate change is taking on many people.

The surveys reviewed show that the majority of both a worldwide and a United States public view climate change as a threat. In fact, there are a growing number of people, dubbed climate doomers, who believe that the climate problem cannot be solved in time to stop societal collapse. For many climate scientists and activists, this defeatist attitude, one that can undermine efforts to take action, is just as dangerous as the attitude of climate denialists (Osaka 2023). Recent research suggests that these scientists and activists have reason to be concerned.

Marlon et al. (2019) conducted an online study with Americans who accepted that global warming is happening. They first asked an open-ended question: “what if anything makes you hopeful/doubtful that global warming can be reduced?” They categorized the answers from that study and used those categories in a second study to see how the hopes and doubts identified impacted the respondents’ potential political engagement on the topic and their support of policies to address climate change. Marlon et al. (2019) discovered that those most likely to take action were those who possessed both a “constructive hope” and a “constructive doubt.” Those with constructive hope recognized that both

awareness of the problem and efforts to address it were on the rise, whereas those with “false hope” believed the problem would be solved without human action. Those with constructive doubt understood that humanity was not doing enough to address climate change, whereas those with “fatalistic doubt” believed humanity could never address the problem. Those who reported they would address climate change with both political engagement and policy support expressed both constructive hope and constructive doubt. Both of these are key to climate change action. When inviting the public to be part of a functional discourse about climate technologies, the importance of both constructive hope and constructive doubt to the success of those discussions should also be recognized. While climate technologies promise benefits, they also come with risks, and both need to be acknowledged.

In 2018, the Intergovernmental Panel on Climate Change published *Global Warming of 1.5°C*. The report outlines the potential impacts of global warming 1.5°C above preindustrial levels on natural and human systems and compares those to the impacts of global warming 2°C above preindustrial levels. One striking conclusion from the modeling is that every tenth or hundredth of a degree of warming avoided can matter in terms of the magnitude of the impact on natural and human systems. For example, model-based projections of mean sea-level rise by 2100 at 1.5°C of global warming are 0.1 meter less than those projected for 2°C global warming. That 0.1 meter could translate into ten million less people being impacted by the related risks of sea-level rise (IPCC 2018, B.2.1.) Efforts towards decreasing global warming must be focused on increasing mitigation. However, if climate technologies can also contribute to avoiding even a tenth or hundredth of a degree of warming, then working to encourage functional discourse around the research and potential application of these technologies, especially in the context of climate justice considerations, seems a prudent choice.

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