Energy Research & Social Science 116 (2024) 103694

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

The role of framing in public support for direct air capture: A moral hazard survey experiment in the United States

Daniel Sloot [a,b,*], Ann Bostrom [b]

[a] Karlsruhe Institute of Technology, Karlsruhe, Germany
[b] University of Washington, Seattle, United States

ARTICLE INFO

Keywords:
Direct air capture
Carbon dioxide removal
Public support
Negative emissions technologies
Moral hazard
Framing

ABSTRACT

Limiting global warming will likely require removing carbon dioxide from the atmosphere and keeping it out of the atmosphere by sequestering it. Public support is crucial for a rapid upscaling of carbon removal and sequestration. One central concern is that public support for these negative emissions technologies (NETs) could be hampered by a moral hazard: that NETs could undermine mitigation efforts and should thus be avoided. Building on previous research, we investigate four novel ways of framing the use of a form of carbon removal from the atmosphere that is currently of broad interest, direct air capture (DAC). We frame DAC use in terms of either necessity (DAC for limiting climate change being either *essential* or *dependent* on future mitigation) or temporality (DAC of either *past* or *future* emissions from the atmosphere). In a survey experiment with a nationally representative U.S. sample ($N = 2891$) we examined how these frames affect public support and risk perceptions in the U.S. for DAC, and the roles of prior awareness of DAC, climate change worry, and their interactions with the different frames. Frames differentially influenced support depending on prior awareness and climate change worry, higher levels of which were associated with more support for DAC (but also greater anticipated moral hazard) independent of the frames. Overall, framing only weakly affected public support, which was on average modest. These insights extend previous findings regarding the limited usefulness of moral hazard frames, but highlight the potential value of tailoring DAC messaging to different target audiences.

1. Introduction

As greenhouse gas emission levels continue to rise, recognition that approaches to remove carbon dioxide from the atmosphere will be necessary to meet even modest climate risk management goals has increased [e.g., [1,2]]. Negative emissions technologies (NETs) now exist that can remove previously emitted greenhouse gases from the atmosphere, for example through direct air capture (DAC), and store them in a stable form. This has sparked concerns that such approaches to achieving negative emissions could create a moral hazard by (inadvertently) decreasing commitment to reducing emissions [3–5], similar to the moral hazard posed by risk management technologies in other domains [e.g., [6]]. To better understand the merits of such concerns, recent research has investigated the question of moral hazard related to the use of NETs (see for example [7]). However, the majority of these studies have focused on moral hazard in terms of its implications for climate change mitigation support when NETs become available [4,8,9]. Conversely, little research has examined a second aspect of this moral hazard, namely if the perception of a moral hazard in terms of mitigation deterrence could hamper support for and risk perceptions of DAC and NETs themselves, as policy makers may be unwilling to support these technologies. In light of recent climate change assessment conclusions that current climate targets will likely require the use of NETs [1], the policy focus should increasingly shift to this second aspect of how the possible existence of a moral hazard relates to the public acceptance of NETs [10], and even DAC as an element of NETs. Hence, research is needed to investigate if public support is determined by the role DAC can play in the broader policy mix that includes both emissions avoidance (e.g., renewable energies) and paths toward negative emissions.

In this paper, we adopt the perspective that DAC—a carbon removal technology that when paired with storage/sequestration can enable negative emissions—will likely be necessary to reach current climate change targets. Consequently, we examine how different frames of the role of DAC influence DAC support and avoid public expectations of a moral hazard associated with the use of the technology. More specifically, we use an experimental design to analyze the extent to which the

* Corresponding author at: Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT), Hertzstraße 16, 76187 Karlsruhe, Germany.
E-mail address: daniel.sloot@kit.edu (D. Sloot).

https://doi.org/10.1016/j.erss.2024.103694
Received 10 October 2023; Received in revised form 10 July 2024; Accepted 22 July 2024
Available online 29 July 2024

public support for DAC and risk perceptions differ according to two aspects of DAC framing that may or may not contribute to moral hazard: the necessity and the temporality of DAC. Necessity refers to the question of whether the use of DAC is essential for limiting climate change (despite maximum mitigation efforts), or instead is dependent on the scope of mitigation efforts over the coming years [cf. [2]]. Framing DAC in terms of temporality refers to whether DAC would remove past emissions from the atmosphere, or would instead be available to remove future emissions from the atmosphere as they are released from burning fossil fuels. Both describing DAC as dependent on mitigation efforts and drawing attention to future carbon emissions present a potential moral hazard. In contrast, neither describing DAC as essential nor describing DAC as removing past emissions highlights moral hazard. By framing DAC along these two dimensions, we extend previous research on the risk of moral hazard with regard to the further upscaling of the technology [e.g., [11,12]]. Additionally, we explore if the effects of these frames, and public support and risk perceptions in general, differ depending on people's prior awareness of DAC or their worry about climate change. Specifically, we investigate the following three research questions:

1) What is the level of public support for DAC, and how do support and risk perceptions relate to individual characteristics such as prior awareness, climate change worry, or pro-environmental behavior?
2) How does framing DAC in terms of the necessity or temporality (and the interaction between the two) affect DAC support and risk perceptions?
3) Do the effects of framing differ across levels of awareness or across levels of climate change worry?

2. Theoretical background

Current climate targets, such as the Paris Agreement, aim to limit global warming to 1.5 °C above pre-industrial levels. However, recent assessments project that this target is unlikely to be achievable without removing carbon dioxide from the atmosphere (i.e., NETs) [1,13]. The urgency of climate change requires radical emissions cuts over the next decade, but emissions in some sectors are difficult to avoid in the short-term, including aviation and agriculture [e.g., [14]]. Technologies such as DAC may thus be essential even if mitigation efforts intensify [15]. Moreover, current mitigation commitments and policies by many governments do not meet the 1.5 °C target, for which reason DAC and similar technologies may be necessary to compensate for mitigation shortfalls in future [16]. Hence, the amount of carbon that will need to be removed and stored—and hence the level of DAC and NETs required—will depend on mitigation efforts over the next years.

The IPCC projects that a removal of about 100–1000 $GtCO_2$ will be needed over the 21st century [1]. Different options exist to potentially achieve such a removal target. The most prominent of these are afforestation or reforestation, which are relatively low-cost solutions, but with severe limitations and risks attached [17]. These risks include, among others, the susceptibility of forests to hazards such as forest fires or droughts, which can undermine long-term negative emissions from afforestation [17]. Other options include bioenergy with carbon capture and storage (BECCS) and DAC. DAC in particular is a relatively more costly option compared to other solutions, but does not require the vast changes in land use required by afforestation or BECCS [17]. Instead, DAC uses a chemical process to capture carbon dioxide from the ambient air through large filters. The captured carbon can then be released from the sorbent and permanently stored in underground sites to create negative emissions [16]. Recent techno-economic assessments indicate that both BECCS and DAC have relatively large potentials to remove carbon dioxide, of up to 5 $GtCO_2$ per year each [17,18]. DAC has the added advantage of not having substantial space requirements (unlike afforestation or BECCS), and instead relies on the availability of renewable energy as its main input.

Previous studies have shown that public acceptance differs between these options [19]. In this study, we focus exclusively on public perceptions related to DAC, which have been less studied, and which if paired with long-term carbon sequestration can be an element of NETs. Attitudes toward carbon dioxide sequestration once emissions are removed from the atmosphere is left for future research and remains outside the scope of this study. Concerns about long-term storage have been identified as an important, particular aspect of (lack of) public support for NETs [20]. Further, recent research points to opportunities for carbon utilization without long-term storage [21], suggesting that studying DAC decoupled from storage may provide useful insights into preferences and attitudes that would otherwise be confounded.

The availability of DAC (and more widely, NETs) gives rise to concerns that they might distract from focusing on reducing emissions as the primary approach to limit climate change; this is referred to as a moral hazard. Recent research has examined the possibility that the availability of NETs poses a moral hazard in several different ways [11,12,20]. Akin to the risk of moral hazard in other domains (e.g., insurance, or the wearing of seatbelts), some studies have investigated the possibility that NETs may undermine public support for existing climate change mitigation policies. The main concern is that the widespread use of NETs could be seen as an easy fix to the burning of carbon and thus legitimize current unsustainable lifestyles [7,11,12]. However, evidence for this concern is mixed; previous studies have not established consistently that NETs create a moral hazard with regard to climate mitigation behaviors [4,8,9,22]. Notably, the focus of this research has been less on public support for NETs per se than on their possible consequences for mitigation.

Other researchers have suggested that the sheer possibility of such a moral hazard may lead to a secondary risk, namely that policy makers or publics might reject NETs altogether on the grounds that they may impede a clear focus on climate change mitigation [9–11]. Less research has focused on this second aspect, which is directly concerned with public perceptions and support for NETs. However, this risk poses another type of moral hazard, as a rejection of NETs on these grounds might actually hinder overall efforts to limit global warming to 1.5 °C, for which the use of NETs is assumed to be necessary [1,23]. Thus, it is important to examine how the role of NETs might be communicated and under what conditions public support for these technologies might increase or decrease. We examine two novel framing approaches—necessity and temporality— that may or may not contribute to the perception of a moral hazard and the public's support for DAC. These two framing approaches are outlined in more detail below.

First, recent climate change assessments have shifted attention to the potential necessity of using technologies such as DAC [1], concluding that current targets to limit global warming are unlikely to be reached without the use of NETs. However, they point out that the degree to which the use of NETs will be necessary depends on complimentary efforts to avoid emissions in the first place. We propose that describing the need for DAC (i.e., *necessity*) as dependent on future mitigation efforts could be perceived by the public as a form of moral hazard that alludes to the potential undermining of mitigation strategies. Consequently, we reason that framing (i.e., highlighting) DAC as dependent on other mitigation efforts is likely to increase anticipated moral hazard and decrease public support for the technology. Conversely, framing DAC as essential should alleviate moral hazard concerns and increase public support for the technology. Framing DAC as essential should deemphasize potential conflict between the use of DAC and other emissions avoidance strategies.

Second, public support could further depend on whether DAC targets legacy or future emissions. Targeting legacy (i.e., past) emissions could lower the moral hazard risk, as these emissions have already been released and thus cannot be avoided (i.e., mitigated). In contrast, future emissions could in theory either be avoided in the first place (i.e., mitigated) or removed after they have been released, which creates a potential conflict between mitigation and removal. In other words, using

DAC to remove future emissions released in the event of insufficient mitigation efforts could reify the choice between removal and mitigation, thus highlighting the tradeoff and the risk of moral hazard. Lower support for DAC could therefore be expected when the technology is framed as targeting future emissions. This question of *temporality* of emissions removal has both theoretical and practical relevance. Regarding the first, people might keep mental accounts for different kinds of emissions and technology support might thus differ depending on which mental account is activated. Related to the second, widespread use of carbon removal (and storage) in the future might be embedded into wider emission offsetting schemes, and funders or donors of a particular removal technology may thus have to decide which emissions to remove or offset [see for example [24,25]]. Therefore, it is crucial to understand how the temporality of emission removal influences public support.

Moreover, certain frames may not be universally (in) effective in influencing DAC support and risk perceptions. Instead, their effectiveness could depend on characteristics of the framing information recipients. Framing studies in other domains of pro-environmental behavior have pointed to the importance of tailoring frames to pre-existing knowledge, motivations, or beliefs [e.g., [26–28]], but little is known about which underlying factors might interact with moral hazard framing. Corner et al. [11] investigated the influence of personal values and skepticism about climate change as antecedents of attitudes toward geoengineering, but they did not study whether these factors interacted with the moral hazard framing they employed in their study. To address this omission, and in keeping with other studies that find effects of worry and topical attitudes on policy support for climate change mitigation [e.g., [29]], we examine if people's level of worry about climate change moderates the influence of different frames on DAC support and risk perceptions. The reasoning for such a moderating influence is that people with greater climate change worry could respond more strongly to any measures that are framed as essential in fighting climate change. Specifically, they should be more likely to support DAC (and anticipate a lower moral hazard) if it is deemed essential next to other mitigation efforts. In contrast, they might oppose DAC more strongly (compared to those low in climate change worry) if it is framed as conflicting with conventional mitigation efforts.

Additionally, we study people's prior awareness as a second characteristic that is likely to influence DAC support in relation to moral hazard. Research has suggested that framing effects might be relatively more influential if people do not already have pre-formed attitudes on a specific issue [12,30], but this proposition has not been tested explicitly in the case of DAC. It is likely that a similar effect exists whereby differences between frames are generally more pronounced among people who lack prior awareness of the technology and whose attitudes are thus more malleable to new information. It is, however, unclear if prior awareness has a positive or negative influence on DAC support and risk perceptions in general, although Wenger et al. (2021) provide initial evidence indicating that the general evaluation of different NETs (including DAC with subsequent carbon storage) became more positive among Swiss participants after information exposure [12]. Contrary to this, other studies have provided some evidence that providing information about NETs or related technologies decreased public support [31–33].

Based on these prior studies, we expected that DAC support would increase (and anticipated moral hazard would decrease) when the use of the technology was framed as essential for curbing climate change (H1a) and when targeting past emissions already released into the atmosphere (H2a), since describing the technology in these ways decreases the risk of negative consequences on mitigation efforts (i.e., lowers the risk of moral hazard). Conversely, we expected that DAC support would decrease (and anticipated moral hazard increase) when framed as dependent on mitigation efforts (H1b) or framed as targeting future emissions (H2b). However, describing DAC as targeting past emissions could diminish any differences in the necessity frames, as the issue of a moral hazard due to interference with mitigation efforts might be less relevant in this case (H3). We also hypothesized that prior awareness of DAC would increase support (and decrease anticipated moral hazard), especially when the technology is framed as being essential for limiting climate change or removing past emissions (H4). Moreover, we explored if the strength of these relationships depends on participants' level of climate change worry.[1] Greater worry about climate change should increase support for DAC (and lower anticipated moral hazard), particularly when the technology is framed as essential for limiting climate change or removing past emissions (H5), as this type of removal does not compete with ongoing mitigation efforts.

3. Methods

3.1. Study design and dependent variables

In the current study, we used a 3 × 3 factorial between-subjects design to examine the impact of four frames along two framing dimensions—namely the *necessity* (essential, dependent, no frame control) and the *temporality* (past, future, no frame control) of carbon removal—on public support for and risk perceptions of DAC. Two of these frames, the dependent frame and the future emissions frame, present a potential moral hazard, while the other two (the essential frame and the past emissions frame) do not. In addition to analyzing the overall impact of these different frames, we investigated if these effects differed based on individual characteristics of the information recipients. In particular, we compared effects on those with versus without prior awareness of DAC and examined how climate change worry moderated the effects of the necessity and temporality frames.

To capture the potential effects of the necessity and temporality frames more widely and examine different facets of moral hazard effects, we assessed beliefs and attitudes related to DAC in three distinct ways. First, we measured *overall (absolute) support for DAC* use on a large scale in the U.S., as an indirect outcome of the existence of a moral hazard. Second, since using DAC entails a commitment of financial resources that could otherwise be used to mitigate emissions, we included a second outcome variable, *relative financial support*. This measures the tradeoff between spending financial resources on DAC versus on mitigation efforts, such as investments in renewable energies and energy efficiency. *Relative financial support* for DAC can therefore be seen as a more direct test of the existence of a moral hazard. Third, we captured the *anticipation of a moral hazard* by directly assessing people's belief that the use of DAC would encourage the prolonged use of fossil fuels.

3.2. Procedure

Prior to data collection, the study was reviewed by the University of Washington's Human Subjects Division under IRB ID STUDY00016659. We used Google Survey to collect a representative sample of the U.S. internet-using population via their paywall intercept method [35–37]. Using Google Survey had the advantage of reaching a highly diverse group of millions of internet users through a variety of online sites, incentivized to answer survey questions because doing so gave them access to the paywall-protected content of interest to them, such as sports and news websites. This method thus also reduced the self-selection bias common to other methods of data collection. On the other hand, Google Survey required studies to be very short, allowing a maximum of 10 questions.

[1] Other studies have examined participants' political orientation as a moderator of moral hazard effects instead (e.g., [4,9]). Including political orientation as a moderator was not possible in this study, due to the regulations of the Google Survey platform. However, other studies have shown that (left-leaning) political orientation and greater worry about climate change are often related [34].

The survey first briefly introduced the general idea of DAC, using one of two introductions (see Fig. 1 for an overview of the introduction and framing versions; Appendix A for an example display) and, to increase engagement with the information and assess awareness, asked participants in the context of this information if they had heard of DAC before. This was directly followed by a short text displaying the experimental framing (Fig. 1). For the first factor (*necessity*), the text described DAC use as being *essential* to halt global warming vs. *dependent* on future mitigation outcomes (in the control condition, no text was shown).

After each short framing text, as in Fig. 2, participants were immediately asked to rate their agreement with the text they had read (in the control conditions no text was displayed, so this agreement question did not appear in the control conditions).

Next, participants answered two questions about their absolute and relative support for DAC, followed by two questions about their assessment of the riskiness and moral hazard of DAC use. Lastly, participants were asked to indicate which of a range of pro-environmental behaviors they engaged in, how worried they were about climate change, and how costly they believed DAC use to be relative to other climate change measures (see Appendix A1 for an overview of the entire survey).

3.3. Sample

A total of 3819 participants completed the brief survey (out of 8065 people who started but did not provide a complete response). Out of these, 202 participants were excluded because they were not part of the factorial design[2] for this study and another 726 participants were excluded due to missing demographic variables including their sample weight. The final sample used in the main analysis therefore consisted of 2891 participants with complete data,[3] comprising 1189 women and 1702 men. Age was assessed in discrete categories and the median age group was 45–54 years. Responses were weighted based on age, gender, and region, using Google's inferred sample weight. Via this method, we give greater weight to underrepresented groups in the statistical analysis to more accurately reflect the U.S. population as a whole.

3.4. Measures

3.4.1. DAC awareness

As noted above, a binary item presented with the introductory text measured whether people had been aware of the possibility of direct air capture: 'Have you heard that carbon emissions (CO_2) can be removed directly from the air?' (No, I have not heard this before; yes, I have heard this before). This item was based on Corner et al. [11].

3.4.2. DAC support

The following item assessed participants' support of DAC: 'Should direct air capture be used in the U.S. on a large scale to remove CO_2 and other greenhouse gases from the atmosphere?' This item was adapted from Whitmarsh et al. [30] and was also a 7-point star scale, with endpoints labeled Definitely not and Definitely yes.

3.4.3. Relative financial support

Financial support for DAC relative to the avoidance of new emissions was assessed with the following item: 'If there were a single budget to fund "removing CO_2 directly from the air" and "improving renewable energy & energy efficiency", how would you split the budget between them? Participants could split the budget in any of seven discrete ways: All on removing CO_2 / Most on removing CO_2 / More on removing CO_2 / Split equally between the two / More on renewable energy & energy efficiency / Most on renewable energy & energy efficiency / All on renewable energy & energy efficiency. To align the interpretation with the item on DAC support, we recoded this item for the analysis so that higher values indicated more relative spending on DAC (1 = All on renewable energy & energy efficiency, 7 = All on removing CO_2).

3.4.4. Anticipated moral hazard

Participants indicated to what extent they agreed that 'Removing CO2 directly from the air will encourage the prolonged use of fossil fuels.' This item was adapted from Corner et al. [11] and was also a 7-point star scale, with endpoints labeled Totally disagree and Totally agree.[4]

3.4.5. Pro-environmental behavior (PEB) index

Participants were asked to indicate whether they engaged in six common pro-environmental/climate behaviors. We subsequently computed a sum score for each participant to form a pro-environmental behavior index that could range from 0 to 6 (see Supplementary Materials for more detailed information).

3.4.6. Climate change worry

'How worried are you about climate change?' was adapted from Jobin & Siegrist [19] and was measured on a scale with the scale points: Not at all worried / A little worried / Somewhat worried / Very worried / Extremely worried. We subsequently coded these as a five-point Likert scale (1 = not at all worried, 5 = extremely worried).

3.5. Data analysis

We present our results in three parts. First, in Section 4.1, to address RQ1 we provide descriptive statistics as well as bivariate correlations between all variables. Since we are interested in differences in the outcome variables across DAC awareness, we also split the data on this binary variable. Next, in Section 4.2, we present the main results for the three outcomes DAC support, relative financial support, and anticipated moral hazard. To estimate the effects of the four experimental frames on each outcome, we ran weighted linear regressions, with the four experimental framing conditions and their interactions coded as dummy variables (with the control group as the reference level). In these regression models, we included a weighting variable provided by the Google Survey data such that our sample data matched the U.S. population regarding gender, age, and geographic location. In Section 4.3, we report the results for DAC awareness as a moderator of the experimental framing conditions. We ran these models in the same way as the weighted least squares regressions introduced above, additionally including the moderator and all of the two-way interaction terms between DAC awareness and the framing conditions (dummy-coded).[5] We subsequently examined statistically significant interactions via comparing the respective simple means. In Section 4.4, we present the results for our other proposed moderating variable, climate change worry. As this variable was measured after the experimental manipulation, we checked if the means of this variable differed between the experimental conditions, which could indicate that it was affected by the

[2] These participants were part of an overall control group that contained none of the frames and also did not contain the short introduction text on carbon removal that all other participants saw. This group was not part of the full factorial design and was excluded from the main analysis.

[3] An a priori power analysis indicated that a sample size of roughly 2000 participants would be necessary to detect a small (f = 0.10) effect given an alpha error of 0.05 and a power of 0.90.

[4] We additionally assessed participants'risk perception of DAC. Since this item was strongly related to moral hazard perception, we excluded it from the main analysis and report on it in Appendix B.

[5] We did not have any specific hypotheses on three-way interaction effects and thus only include two-way interaction terms here. In Supplementary Materials we also provide the regression models with the three-way interactions for all three outcomes.

Brief Introduction	
Version 1	Version 2
The burning of fossil fuels releases carbon emissions (CO2) into the air, raising earth's temperature. To reduce this global warming and its negative impacts, we need to stop burning fossil fuels and putting CO2 in the air. We can do this by switching to renewable energy or conserving energy. Recently, scientists have shown that CO2 can also be removed directly from the air using large machines to filter it out.	*Earth changes sunlight's visible light energy into infrared light energy, which leaves Earth very slowly because it is absorbed by CO2 and other greenhouse gases in the air. When people add CO2 to the air by burning fossil fuels, energy leaves Earth even more slowly—raising Earth's temperature. Recently, scientists have shown how to remove CO2 directly from the air by using large machines to filter it out.*

Dimension 1: Necessity of DAC		
Carbon removal **essential** to halt global warming	Carbon removal **dependent** on future mitigation **	Control Group (no frame)
To halt global warming in time to prevent worse climate catastrophes than we are seeing now will require removing CO2 directly from the air, scientists around the world agree.	*The need to remove CO2 directly from the air depends on what the world does in the next 10 years. Rapid cuts in burning fossil fuels now will mean we won't have to rely as much on removing CO2 directly from the air.*	

Dimension 2: Temporality of carbon removal		
Removal of **past** emissions	Removal of **future** emissions **	Control group (no frame)
Removing some of the CO2 directly from the air that has already been released from burning fossil fuels is the only way to reduce CO2 put in the air by humans in the past.	*Removing CO2 directly from the air is a way of making sure that burning fossil fuels in the future doesn't add to the amount of CO2 already in the air.*	

Fig. 1. Overview of the introduction text and experimental groups. ** denotes a potential moral hazard. Introduction Version 2 is adapted from [37].

Fig. 2. Example of a Google Survey display framing DAC as essential (one of the two *necessity* frames; see Factor 1 in Fig. 1).

manipulation. An ANOVA showed that this was not the case (*Fs* < 1; see Appendix C for detailed results). Then we tested if climate change worry had a moderating effect on how the frames affected *DAC support*, *relative financial support for DAC*, or *anticipated moral hazard*. In the case of statistically significant interaction effects, we subsequently plotted the slopes of climate change worry separately for each frame of the relevant factor and computed the differences in the mean levels of the respective outcome variables for those low (−1 *SD*) and high (+1 *SD*) in climate change worry, using the R packages *interactions* and *emmeans*.

4. Results

4.1. Descriptive statistics and bivariate correlations

Participants on average neither supported nor opposed the use of DAC in the U.S. on a large scale, with the mean close to but significantly above the midpoint of this Likert scale (difference from 4.0: $t(2890) = 5.509$, $p < .001$; see Table 1 for descriptive statistics and bivariate correlations). When asked to make a tradeoff by splitting a single budget between DAC vs. renewable energy and energy efficiency, participants were less favorable, on average allocating slightly less money to DAC than to more conventional approaches to slowing or stopping climate change (difference from midpoint $t(2890) = -12.36$, $p < .001$). Anticipated moral hazard was generally moderate, but significantly lower than the scale midpoint (difference from midpoint $t(2890) = -4.92$, $p < .001$). Absolute support for DAC was only weakly positively (though significantly) correlated with relative financial support for DAC, suggesting that these two items tap into two distinct decision-making processes (Table 1). Higher support for DAC was moderately positively correlated with a higher belief that using this technology will prolong the use of fossil fuels (i.e., anticipated moral hazard). Conversely, the bivariate correlation between this belief and relative financial support for DAC was in the expected direction (though substantially smaller in magnitude), indicating that participants would allocate less money to DAC if they perceived the technology to be riskier and believed it prolonged the use of fossil fuels. Moreover, participants who were more worried about climate change were generally more supportive of DAC but allocated slightly less money to it than to renewable energy and energy efficiency investments. The same pattern of correlations was found for the pro-environmental behavior index, which was positively related to DAC support (and anticipated moral hazard) but negatively related to relative financial support for DAC (Table 1).

As only 43 % of participants indicated that they were aware of DAC, we split the sample based on prior DAC awareness and computed the bivariate correlations for these two subsamples (Tables 2a and 2b). Strong differences between these two subsamples appeared for some of the variables in the dataset. Most notably, independent-samples *t*-tests

Table 1
Means, standard deviations, and correlations with confidence intervals for the total sample.

Variable	*M*	*SD*	1	2	3	4	5
1. DAC support	4.19	1.86					
2. Relative financial support	3.61	1.70	0.07** [0.03, 0.10]				
3. Anticipated moral hazard	3.84	1.74 [0.36, 0.42]	0.39**	−0.06** [−0.10, −0.02]			
4. DAC awareness	0.43	0.50	0.19** [0.15, 0.22]	−0.06** [−0.10, −0.02]	0.09** [0.05, 0.12]		
5. Climate change worry	3.14	1.39	0.44** [0.41, 0.47]	−0.06** [−0.09, −0.02]	0.30** [0.26, 0.33]	0.13** [0.09, 0.17]	
6. PEB index	1.87	1.43	0.26** [0.22, 0.29]	−0.14** [−0.18, −0.11]	0.22** [0.18, 0.25]	0.16** [0.12, 0.19]	0.41** [0.38, 0.44]

Note. Values in square brackets indicate the 95 % confidence interval for each correlation. All correlations are based on Pearson's correlation coefficient. * indicates $p < .05$. ** indicates $p < .01$.

Table 2a
Means, standard deviations, and correlations for participants unaware of DAC (N = 1649).

Variable	*M*	*SD*	1	2	3	4
1. DAC support	3.89	1.83				
2. Relative financial support	3.70	1.74	0.04 [−0.01, 0.08]			
3. Anticipated moral hazard	3.71	1.73	0.50** [0.46, 0.53]	−0.07** [−0.12, −0.03]		
4. Climate change worry	2.98	1.41	0.40** [0.36, 0.44]	−0.03 [−0.08, 0.02]	0.30** [0.26, 0.34]	
5. PEB index	1.67	1.32	0.29** [0.24, 0.33]	−0.11** [−0.15, −0.06]	0.24** [0.20, 0.29]	0.38** [0.33, 0.42]

Table 2b
Means, standard deviations, and correlations for participants aware of DAC (N = 1242).

Variable	*M*	*SD*	1	2	3	4
1. DAC support	4.59	1.83				
2. Relative financial support	3.49	1.66	0.14** [0.09, 0.20]			
3. Anticipated moral hazard	4.01	1.74	0.23** [0.18, 0.29]	−0.03* [−0.09, 0.02]		
4. Climate change worry	3.35	1.35	0.45** [0.41, 0.49]	−0.08** [−0.13, −0.02]	0.27** [0.22, 0.32]	
5. PEB index	2.13	1.53	0.18** [0.12, 0.23]	−0.17** [−0.22, −0.11]	0.17** [0.11, 0.22]	0.42** [0.37, 0.46]

Note. Values in square brackets indicate the 95 % confidence interval for each correlation. All correlations are based on Pearson's correlation coefficient. * indicates $p < .05$. ** indicates $p < .01$.

indicated that absolute support for DAC was substantially higher among those who indicated they were aware of DAC ($\Delta M = -0.70$, $t(2{,}669) = -10.15$, $p < .001$), but the opposite was the case for relative financial support in that those aware allocated slightly less money to DAC ($\Delta M = 0.21$, $t(2{,}735) = 3.25$, $p = .001$). Moreover, those aware of DAC anticipated a moral hazard more strongly than those unaware ($\Delta M = -0.30$, $t(2{,}667) = -4.63$, $p < .001$). There was no relationship between absolute support for DAC and relative financial support among those unaware of DAC, whereas this correlation was positive for those with prior DAC awareness. Moreover, the relationship between anticipated moral hazard and DAC support (both absolute and relative) was much more pronounced among those unaware of DAC compared to those aware. In contrast, correlations between PEBs, climate change worry, and absolute and relative support were relatively similar across the two subsamples. This suggests that people with prior knowledge not only differ in the level of support for DAC, but they might also use a different decision-making process in terms of how they associate different risks (including moral hazard) with their support.

4.2. Effects of the experimental conditions and covariates

Table 3 displays the mean values of DAC support, relative financial support, and anticipated moral hazard across the experimental conditions. As Table 4 (left column) shows, DAC support was significantly lower when the technology was framed as targeting future emissions (as compared to the control group; H2b), but framing DAC as targeting past emissions did not influence support (no significant difference from the control group; H2a). Additionally, the regression results show a significant negative effect of framing DAC as essential for limiting climate change on DAC support (opposite to H1a), and no interaction emerged between the frames (H3). The regression results further indicate that after controlling for other factors, people with prior awareness of the technology supported DAC more than those lacking prior awareness, while men and older participants (over 55 years of age) supported DAC less.

Weighted least-squares regression did not reveal any significant effects of the frames on relative financial support for DAC (H1-H3; Table 4, middle column). Interestingly, the analysis showed a significant negative association of DAC awareness with relative financial support, opposite what was found for absolute DAC support. In other words, people with prior awareness of the technology allocated *less* money to DAC than to energy efficiency and renewable energy measures, as compared to those who lacked prior awareness. These results also indicate that the two outcomes of absolute and relative support were perceived and assessed in substantially different ways by the participants. While the different frames had a small influence on absolute DAC support, this was not the case for relative support.[6]

A third weighted least squares regression analysis showed no significant effects of framing on anticipated moral hazard (H1−H3). Taken together, we found some support that framing DAC use in terms of necessity or temporality influences DAC support, but framing did not appear to influence relative financial support, nor perceptions of moral hazard associated with the use of this technology.

[6] In the Supplementary Materials, we include perceived costs of DAC as a covariate. As expected, we find higher perceived costs of DAC associated with lower relative financial support for DAC, and with higher perceptions of moral hazard, climate change worry, and PEBs, but no correlation with absolute DAC support.

Table 3
Mean levels of the dependent variables across experimental conditions.

		DAC support				Relative financial support				Anticipated moral hazard			
		No Frame	Essential	Depen-dent	Total	No Frame	Essential	Depen-dent	Total	No Frame	Essential	Depen-dent	Total
No Frame	*M*	4.50	4.18	4.26	4.32	3.66	3.61	3.68	3.65	3.87	3.64	3.81	3.78
	SD	1.97	1.91	1.90	1.93	1.69	1.83	1.75	1.75	1.76	1.78	1.81	1.79
	n	*322*	*298*	*311*	*931*	*322*	*298*	*311*	*931*	*322*	*298*	*311*	*931*
Past	*M*	4.25	4.17	3.98	4.14	3.55	3.48	3.62	3.55	3.99	3.87	3.78	3.88
	SD	1.79	1.79	1.81	1.8	1.61	1.63	1.66	1.63	1.59	1.71	1.74	1.68
	n	*327*	*328*	*324*	*979*	*327*	*328*	*324*	*979*	*327*	*328*	*324*	*979*
Future	*M*	4.05	4.17	4.15	4.13	3.66	3.70	3.51	3.62	3.93	3.76	3.89	3.86
	SD	1.80	1.91	1.87	1.86	1.75	1.77	1.66	1.73	1.77	1.72	1.76	1.75
	n	*329*	*332*	*320*	*981*	*329*	*332*	*320*	*981*	*329*	*332*	*320*	*981*
Total	*M*	4.27	4.18	4.13	4.19	3.63	3.60	3.60	3.61	3.93	3.76	3.83	3.84
	SD	1.86	1.87	1.86	1.86	1.69	1.74	1.69	1.70	1.71	1.74	1.77	1.74
	n	*978*	*958*	*955*	*2891*	*978*	*958*	*955*	*2891*	*978*	*958*	*955*	*2891*

Table 4
Weighted least squares regression results for DAC support, relative financial support, and anticipated moral hazard.

		Dependent variable:		
		DAC support	Relative financial support	Anticipated moral hazard
		(1)	(2)	(3)
Framing condition (experimental treatment)	Essential (vs. control)	−0.326* (0.146)	−0.113 (0.137)	−0.190 (0.138)
	Dependent (vs. control)	−0.133 (0.145)	−0.089 (0.136)	−0.074 (0.137)
	Past (vs. control)	−0.100 (0.142)	−0.139 (0.133)	0.215 (0.134)
	Future (vs. control)	−0.348* (0.142)	−0.061 (0.133)	0.055 (0.134)
	Essential x Past (vs. control)	0.217 (0.204)	0.036 (0.191)	0.018 (0.193)
	Dependent x Past (vs. control)	−0.230 (0.204)	0.158 (0.190)	−0.212 (0.193)
	Essential x Future (vs. control)	0.390 (0.203)	−0.012 (0.190)	0.036 (0.192)
	Dependent x Future (vs. control)	0.114 (0.203)	−0.012 (0.190)	−0.051 (0.192)
Gender: male (vs. female)		−0.166* (0.069)	0.013 (0.064)	−0.067 (0.065)
Age: 35–54 (vs. 18–34)		−0.142 (0.083)	0.190* (0.078)	−0.115 (0.079)
Age: 55+ (vs. 18–34)		−0.232** (0.084)	0.052 (0.079)	−0.214** (0.080)
DAC awareness: yes (vs. no)		0.671** (0.070)	−0.217** (0.065)	0.342** (0.066)
Constant		4.372** (0.119)	3.700** (0.112)	3.873** (0.113)
Observations		2891	2891	2891
R^2		0.039	0.008	0.016
Adjusted R^2		0.035	0.003	0.011
Residual Std. error (df = 2879)		1.813	1.696	1.716
F statistic (df = 11; 2879)		9.823**	1.828*	3.788**

Note: *p < .05; **p < .01; coefficients are unstandardized OLS regression coefficients and weighted by gender, age, and geographic location in the U.S.

4.3. Exploring moderating effects of DAC awareness on framing effects

Since people's prior awareness was positively related to DAC support and anticipated moral hazard, and negatively related to relative financial support, we explored if DAC awareness moderated the effects of the frames. For the outcome of DAC support, the analysis showed two significant interaction effects, indicating that the effects of the four frames differentially affected support for those aware and unaware (H4; see

Table 5
Moderation analysis by DAC awareness for different outcomes.

		Dependent variable:		
		DAC support	Relative financial support	Anticipated moral hazard
		(1)	(2)	(3)
Framing condition (experimental treatment)	Essential (vs. control)	−0.162 (0.164)	−0.157 (0.154)	−0.147 (0.155)
	Dependent (vs. control)	−0.047 (0.160)	−0.093 (0.150)	−0.058 (0.152)
	Past (vs. control)	−0.087 (0.158)	−0.226 (0.148)	0.216 (0.150)
	Future (vs. control)	−0.500** (0.158)	−0.068 (0.148)	−0.124 (0.150)
	Essential x Past	0.191 (0.204)	0.044 (0.191)	0.004 (0.193)
	Dependent x Past	−0.222 (0.203)	0.089 (0.191)	−0.200 (0.193)
	Essential x Future	0.371 (0.203)	0.161 (0.190)	0.026 (0.192)
	Dependent x Future	0.110 (0.203)	−0.004 (0.190)	−0.052 (0.192)
	Essential x DAC awareness	−0.358* (0.168)	0.104 (0.157)	−0.085 (0.159)
	Dependent x DAC awareness	−0.217 (0.168)	−0.005 (0.158)	−0.053 (0.159)
	Past x DAC awareness	−0.029 (0.170)	0.208 (0.159)	−0.008 (0.161)
	Future x DAC awareness	0.380* (0.169)	0.010 (0.159)	0.435** (0.160)
DAC awareness: yes (vs. no)		0.740** (0.153)	−0.324* (0.144)	0.241 (0.145)
Gender: male (vs. female)		−0.163* (0.069)	0.016 (0.064)	−0.066 (0.065)
Age: 35–54 (vs. 18–34)		−0.156 (0.083)	0.190* (0.078)	−0.129 (0.079)
Age: 55 and older (vs. 18–34)		−0.238** (0.084)	0.051 (0.079)	−0.223** (0.080)
Constant		4.348** (0.133)	3.744** (0.125)	3.923** (0.126)
Observations		2891	2891	2891
R^2		0.043	0.009	0.019
Adjusted R^2		0.038	0.003	0.014
Residual Std. Error (df = 2874)		1.810	1.697	1.714
F Statistic (df = 16; 2874)		8.129**	1.545	3.501**

Note: *p < .05; **p < .01; regression coefficients are unstandardized and weighted by gender, age, and geographic location in the U.S.

Table 5, left column, for the model results). Simple means plots (Fig. 3, upper left plot) suggested that necessity framing affected DAC support more strongly for participants with prior awareness of DAC, especially decreasing support relative to the no-frame condition when DAC was

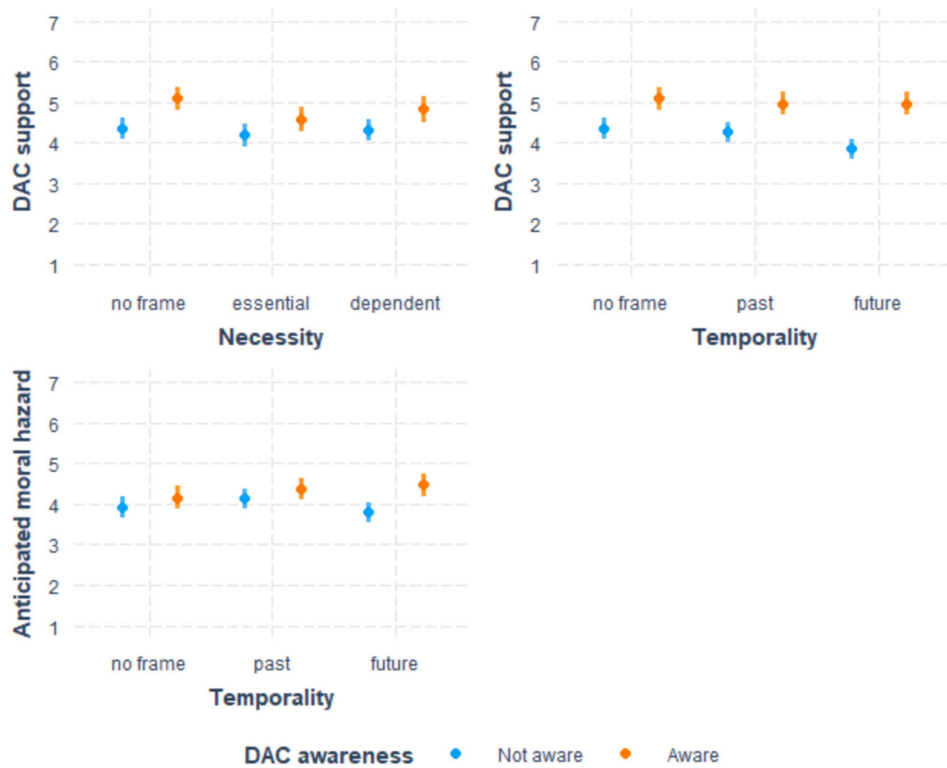

Fig. 3. Simple means plots showing interactions between experimental framing conditions and DAC awareness on DAC support and anticipated moral hazard *(whiskers denote 95 % CI).*

framed as essential ($p = .098$). Moreover, Fig. 3 (upper right plot) suggests that for participants without prior awareness of DAC, the future frame decreased DAC support relative to the no-frame condition ($p = .024$), whereas temporality framing did not affect DAC support among those with prior awareness ($ps > 0.050$). No interaction effects emerged for the outcome of relative financial support (Table 4, middle column). For the outcome anticipated moral hazard, there was a significant interaction effect between the future frame and DAC awareness. Simple means (Fig. 3, lower left plot) suggested that anticipated moral hazard was somewhat lower among those unaware of DAC when future (rather than past) emissions removal was emphasized ($p = .060$), whereas there was a trend for higher anticipated moral hazard in the future frame among those with prior awareness ($p = .128$). Tukey-adjusted post-hoc testing of these mean differences showed that only some of these trends reached statistical significance, suggesting that the moderating effect of DAC awareness is generally weak. Nevertheless, this pattern of results indicates that people's prior level of awareness and engagement with the technology may cause heterogeneous responses to different ways of framing DAC (H4).

4.4. Exploring moderating effects of climate change worry on framing effects

Climate change worry moderated the effects of the frames on all three of the dependent variables (H5; Table 6). In the DAC support model, the interactions between both of the necessity frames (essential and dependent) and climate change worry are positive and significant (Table 6, left column). As Fig. 4 (upper left plot) shows, the effects of necessity framing were more pronounced among participants with low levels of climate change worry, whereas those more worried tended to support DAC irrespective of the experimental condition. Contrast testing of the estimated marginal means confirmed this pattern, showing that DAC support was significantly lower for those in the essential ($p = .023$) or dependent ($p < .001$) frame compared to the control condition when climate change worry was low (-1 *SD*). In contrast, there was no difference in DAC support between the experimental conditions for high levels ($+1$ *SD*) of climate change worry ($p = .518$; $p = .989$; $p = .608$). This suggests that providing any kind of information about carbon removal has the potential to backfire among those not worried about climate change, lowering their support for DAC, whereas there is no negative (or positive) impact of this frame among the highly worried. The model further showed a significant main effect of climate change worry that is about the same size as the effect of DAC awareness; support for DAC is a half point higher on average for people who are more worried about climate change, all else equal (Table 6).

In the relative financial support model (Table 6, middle column) there is a significant interaction between temporality frame and climate change worry. As Fig. 4 (upper right plot) shows, climate change worry tended to have a positive association with relative financial support when no frame was provided but a negative association with relative support when either temporal frame was highlighted, but these associations were weak and contrast testing of the estimated marginal means yielded non-significant results ($ps > 0.05$). This suggests that the provision of additional information about emissions removal may have the potential to reduce financial support for DAC among those highly worried about climate change, instead increasing their focus on avoiding emissions through renewable energy and energy efficiency.

Perceptions that carbon removal use will encourage the prolonged use of fossil fuels (anticipated moral hazard; Table 6, right column) are influenced differentially by the necessity frame depending on the level of climate change worry. As Fig. 4 (lower left plot) shows, when climate change worry is low, highlighting DAC as essential or dependent both decrease the perception of DAC as a moral hazard. Fig. 4 also shows that the slope of climate change worry for the dependent frame is the steepest, and anticipated moral hazard is highest in the dependent frame when climate change worry is high. Testing of the simple slope contrasts confirmed that the slope for climate change worry is significantly steeper ($p = .028$) in the dependent frame (vs. when no frame is

Table 6
Moderation analysis by climate change worry for different outcomes.

		Dependent variable:		
		DAC support	Relative financial support	Anticipated moral hazard
		(1)	(2)	(3)
Framing condition (experimental treatment)	Essential (vs. control)	−0.274*	−0.111	−0.156
		(0.132)	(0.137)	(0.132)
	Dependent (vs. control)	−0.101	−0.085	−0.052
		(0.131)	(0.136)	(0.131)
	Past (vs. control)	−0.088	−0.133	0.225
		(0.128)	(0.133)	(0.128)
	Future (vs. control)	−0.320*	−0.058	0.074
		(0.128)	(0.133)	(0.128)
	Essential x Past	0.173	0.032	−0.013
		(0.184)	(0.191)	(0.184)
	Dependent x Past	−0.276	0.084	−0.244
		(0.184)	(0.190)	(0.184)
	Essential x Future	0.403*	0.143	0.044
		(0.184)	(0.190)	(0.184)
	Dependent x Future	−0.025	0.004	−0.150
		(0.184)	(0.190)	(0.184)
	Essential x CC worry	0.142**	−0.022	0.093
		(0.054)	(0.056)	(0.054)
	Dependent x CC worry	0.155**	−0.014	0.137*
		(0.054)	(0.055)	(0.054)
	Past x CC worry	0.039	−0.103	−0.014
		(0.054)	(0.056)	(0.054)
	Future x CC worry	0.024	−0.127*	0.016
		(0.054)	(0.056)	(0.054)
Climate change worry (mean-centered)		0.451**	0.024	0.296**
		(0.049)	(0.051)	(0.049)
Gender: male (vs. female)		−0.055	−0.0002	0.006
		(0.062)	(0.064)	(0.062)
Age: 35–54 (vs. 18–34)		0.019	0.173*	−0.012
		(0.075)	(0.078)	(0.075)
Age: 55 and older (vs. 18–34)		−0.063	0.030	−0.105
		(0.076)	(0.079)	(0.077)
DAC awareness: yes (vs. no)		0.452**	−0.192**	0.196**
		(0.064)	(0.066)	(0.064)
Constant		4.262**	3.706**	3.803**
		(0.108)	(0.112)	(0.108)
Observations		2891	2891	2891
R^2		0.218	0.012	0.104
Adjusted R^2		0.213	0.006	0.098
Residual Std. Error (df = 2874)		1.637	1.694	1.639
F Statistic (df = 16; 2874)		47.027**	2.094**	19.527**

Note: $^*p < .05$; $^{**}p < .01$; regression coefficients are unstandardized and weighted by gender, age, and geographic location in the U.S.

provided). Testing of the estimated marginal means further showed that anticipated moral hazard was significantly lower in the essential ($p =$ .027) and dependent ($p = .002$) frame compared to the no-frame condition when climate change worry was low (−1 *SD*), but did not differ between conditions at high levels (+1 *SD*) of climate change worry ($p =$ .986; $p = .997$; $p = .970$).

5. Discussion

The aim of this study was to examine the public support for and risk perceptions of DAC in relation to four frames that may or may not contribute to moral hazard. More specifically, we investigated if attitudes toward DAC would be affected by framing the removal of carbon dioxide as essential or as dependent on future mitigation efforts (i.e., a necessity dimension) and by emphasizing the removal of past emissions or of future emissions (i.e., a temporality dimension). Each of the four frames was tested against a neutral control group that did not describe the necessity or temporality of emissions removal at all. Two of the frames, namely the dependent and future frames, present a potential moral hazard, while the other two do not. We additionally studied whether these framing effects differed based on people's prior awareness of the technology or the degree to which they are worried about climate change.

Our results from a large survey that is representative of the U.S. population show that in general, the public neither strongly favors nor opposes the use of DAC, but does prioritize mitigation strategies such as renewable energies and energy efficiency over DAC. Regarding our first research question, we find that public support depends on the prior awareness of DAC. Those aware show more support than those without prior awareness overall, but at the same time allocate more money to conventional climate change mitigation than to DAC. They also anticipate a greater moral hazard.

Related to our second research question, results indicate a limited effect of framing on public support for DAC. In particular, we did not find evidence that varying the necessity of carbon removal (highlighting carbon removal as being essential or dependent on mitigation; H1) boosted or undermined public support overall, relative to a control group. Further, this framing also did not affect beliefs that carbon removal could present a moral hazard by prolonging the use of fossil fuels. However, emphasizing the removal of future emissions (H2b) decreased absolute support for DAC. This is in line with our expectations, as the removal of these future emissions could still be avoided by more aggressive mitigation efforts now and going forward. Conversely, there was no evidence that emphasizing the removal of past emissions (H2a) increased DAC support, and we did not find any effects of emphasizing past or future emission removal on relative support or perceptions of moral hazard, nor any interaction effects between the frames (H3).

Regarding our third research question, even though framing did not appear to affect public attitudes toward DAC negatively or positively in general, the specific characteristics of audiences seemed to play a role in the level of DAC support. More specifically, those without prior awareness had a tendency to be somewhat more affected by specific frames of DAC, for example showing lowered DAC support when future emissions removal was emphasized. These results lend some support to H4. Our analysis of climate change worry showed a consistent effect of worry on attitudes and beliefs about DAC. Climate change worry moderated the effects of the frames in the necessity dimension on both absolute DAC support and anticipated moral hazard, with more pronounced differences between the two framing conditions and the control conditions when climate change worry was low (H5). Conversely, those more worried about climate change tended to support DAC regardless of any experimental framing manipulation. Climate change worry also determined how the temporality dimension affected relative financial support for DAC, such that the two temporality frames decreased support relative to the control condition (particularly when future emissions removal was emphasized) only among those high in climate change worry. Apart from these moderating effects, higher climate change worry was also associated with higher absolute DAC support and anticipated moral hazard, but not with more relative financial support for DAC.

5.1. Theoretical implications

Our findings present a nuanced picture of the effects of different moral hazard frames and underlying individual factors on the public support for and risk perceptions of DAC, extending the existing literature in important ways. While comparing our results with other studies directly is complicated by the great variety in technology contexts, outcome measures, and how moral hazard is conceptualized, our finding that framing carbon removal in terms of moral hazard does not have strong effects on public support can be interpreted as consistent with recent findings that used similar frames and contexts [3,4,8,9,11,12]. Wenger et al. [12] studied three related facets of moral hazard among Swiss citizens, namely, a technological fix, moral hazard, and a climate emergency frame. They found that public support was not affected by any of these frames. Corner & Pidgeon [11] found similar results when

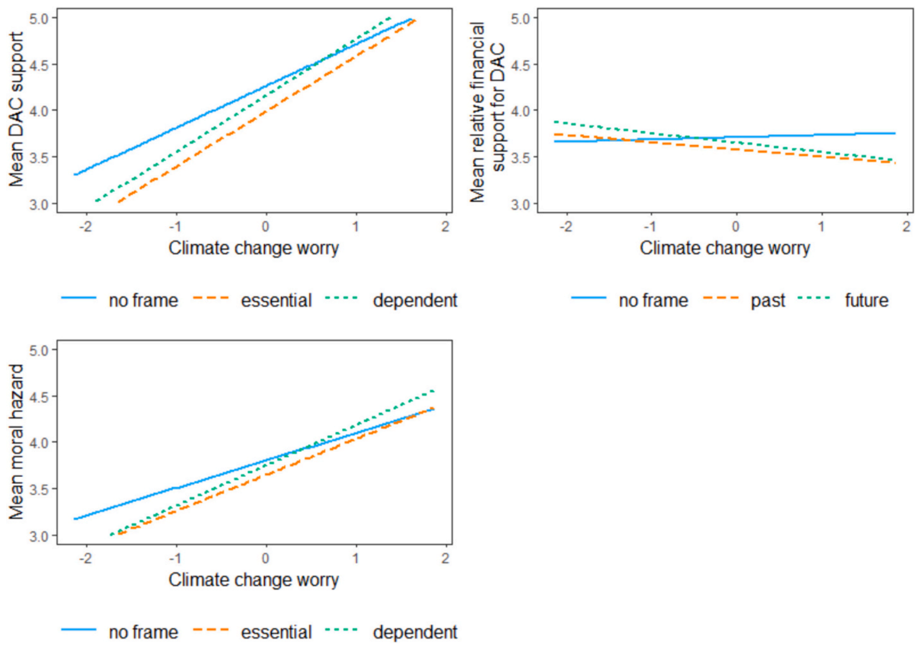

Fig. 4. Simple slopes plots showing interactions between experimental framing conditions and DAC support, mean relative financial support for DAC, and mean anticipated moral hazard moderated by climate change worry. All vertical axes are truncated by two points at both the lower and upper ends.

they tested a moral hazard frame and a counter moral hazard frame (i.e., a legitimization of the current lifestyle) in a U.K. sample and did not detect an effect of these frames on public support for geoengineering. Other studies have examined moral hazard risk in terms of its effect on climate change mitigation support (rather than support for DAC or other carbon removal technologies) by framing the availability of NETs in different ways [3,4,8,9]. The results of these studies are ambiguous and do not consistently point to a moral hazard risk, suggesting that the danger of undermining mitigation efforts is low [[8,9], see also [38]]. Andrews and colleagues used a series of economic games to test both facets of moral hazard together and found that geoengineering (including NETs) did not deter from mitigation efforts, but policy makers did perceive a moral hazard that decrease their support for the technology [22]. Taken together, previous findings on the moral hazard risk of NETs thus do not suggest that framing these technologies in certain ways is likely to sway public opinion much. Our results corroborate this notion in a large sample of the adult U.S. population and for two novel facets of the moral hazard argument.

Notably, our design allowed us to test the effects of moral hazard frames in more nuanced ways by considering underlying audience characteristics, namely prior DAC awareness and climate change worry. In line with previous studies [12,32,40], we find that a majority of the public is currently unaware of DAC. Prior awareness was associated with greater overall support for DAC, and also moderated the strength of some relationships between our measures, in particular the extent to which the three dependent variables were seen as related. A stronger effect of framing among those unaware is consistent with other research suggesting that public opinions are more malleable to new information before strong attitudes have formed [7]. This suggests that people's perceptions and attitudes toward NETs might change as these technologies receive greater public attention, and thus emphasizes the need for continued research on the level and determinants of public support.

Moreover, our research shows that certain parts of the public may be more susceptible to the impact of framing than others. Studies examining moral hazard in the context of NETs and climate mitigation support have considered the moderating influence of individual characteristics such as political orientation and found more pronounced effects of certain frames among politically conservative people [3,4]. However, evidence on such moderating influences of individual characteristics directly affecting the support of DAC or NETs more widely has been lacking [e.g., [11,12]]. Our research emphasizes the important role that worry about climate change could play in how people respond to certain frames and evaluate technologies such as DAC. Although we did not directly study political orientation, it is possible that this factor is correlated with the level of climate change worry; related studies have shown that political orientation plays an important role for climate change perceptions and actions [e.g., [26,41,42]]. To assess this requires future research investigating climate change worry, political orientation, and related constructs for public support of NETs.

One particular novelty of our research is the use of three distinct outcome measures that capture both support and risk perceptions of DAC in a more nuanced way. Previous research has focused primarily on the public's absolute support of NETs, which does not require any tradeoffs in the decision-making process [11,12]. By forcing participants to allocate a single budget between the development of carbon removal technologies and conventional climate change mitigation strategies of renewable energy and energy efficiency, we introduce an alternative and, in some ways, more realistic measure that takes into account policy constraints. Our results show that stated support for DAC and relative financial support for DAC when traded off against conventional climate change mitigation strategies correlate only weakly (and only among those with prior DAC awareness) and produce a distinct pattern of relationships with the experimental manipulations and the underlying audience characteristics. Notably, prior DAC awareness, engagement in pro-environmental behaviors, and climate change worry are positively related to absolute DAC support but are negatively related (or, in the case of climate change worry, unrelated) to relative financial support for DAC. We argue that these results do not reflect inconsistency but rather different types of decision making: people who are more worried about climate change and behave more pro-environmentally are more willing to support DAC, but when forced to choose between DAC and conventional mitigation such as renewables, they give greater priority to the latter. This illustrates the potential power of framing environmental technology and investment decisions as cost tradeoffs, which could be examined in more detail by future studies.

5.2. Limitations

The use of Google Survey as a means of data collection introduced benefits as well as limitations. The platform constrained the survey environment to a limited number of elements (ten), of limited length and following best survey practices as assessed by Google Survey. Their emphasis on minimizing response burden and associated content restrictions forced the omission of questions about political orientation and led us to rely on several single-item measures. Participants answered only a very small number of items (10 or fewer), each of which were displayed on a separate page. Google's sampling strategy together with these constraints mitigated concerns about halo effects and self-selection biases common to survey research [e.g., [43]], but also severely limited our ability to measure latent constructs, to assess the reliability of our measures, and to estimate more comprehensive models. Future studies could address such limitations by capturing latent constructs—such as DAC support or perceptions of moral hazard from DAC—with multi-item scales. However, our measures were strongly informed by the previous literature, which increases confidence in their validity. Moreover, it is a particular strength that we surveyed a sample of nearly 3000 individuals representative of the general U.S. internet-using adult population (over 90 % of the population). Within the measurement constraints of this survey environment, we had a relatively high-powered experimental design, which increased the interpretability of results.

The brief exposure participants experienced could be seen as increasing the realism of the treatment and decreasing the likelihood of finding framing effects. Future research might also investigate how longer exposures might affect the results of such framing interventions.

A final caveat to our results is that we did not pair DAC with issues of storage or reuse of carbon dioxide in this study, given that these technologies are complicated and evolving rapidly in their own right. More broadly, further research is also needed to examine how our findings may transfer to other types of technologies aimed at generating negative emissions, besides DAC, as other options may bring about different technical and economic configurations, which may be associated with particular perceptions of benefits and risks. DAC as a relatively new and unfamiliar technology likely evokes different concerns than more established, nature-based options such as afforestation.

6. Conclusions and practical implications

Our research investigates how framing carbon dioxide removal in terms of its necessity and temporality as well as individual characteristics affect public support for DAC. Overall, we find that people modestly support DAC in the U.S., and changing the framing around the technology only weakly affects this degree of support. This finding suggests that policy makers can be optimistic about introducing new technologies such as DAC as a means to reach current climate targets next to ongoing mitigation efforts. However, certain individual characteristics, such as prior DAC awareness and worry about climate change, both influence public support directly and also determine how individuals respond to the information provided by the frames. Notably, those more worried about climate change support DAC more, but also tend to prioritize the funding of conventional mitigation approaches over DAC when faced with a budget tradeoff between the two. Novel information about DAC could thus be carefully tailored to different target audiences. The differences in public support between those with and without prior DAC awareness also highlight that public support may be dynamic, as a majority of the population has had limited if any contact with DAC and its implications. Our result may suggest that greater awareness or knowledge about the technology lead to more qualified public opinions: it increases absolute DAC support, but at the same time the public may become increasingly aware that there might be moral hazards involved, and thus (even more strongly) favor emission avoidance over negative emissions in a direct tradeoff. Moreover, while simple framing of carbon removal appears unlikely to substantially alter public support, ongoing media coverage on the potential benefits and risks of the technology and its potential role in combating climate change risks might yet influence people's evaluations of DAC and NETs. Ongoing research is necessary to study these dynamics in more detail as the upscaling of the technology develops.

CRediT authorship contribution statement

Daniel Sloot: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ann Bostrom:** Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The research visit of Daniel Sloot at the University of Washington was supported financially by the Karlsruhe House of Young Scientists (KHYS). Data collection was funded through the Weyerhaeuser endowed Professorship at the University of Washington held by Ann Bostrom.

Appendix A

A.1. Overview of the survey

Have you heard that carbon emissions (CO2) can be removed directly from the air?

Indented intro 1 text:

The burning of fossil fuels releases carbon emissions (CO2) into the air, raising earth's temperature.

To reduce this global warming and its negative impacts, we need to stop burning fossil fuels and putting CO2 in the air. We can do this by switching to renewable energy or conserving energy.

Recently, scientists have shown that we can remove CO2 directly from the air by using large machines to filter it out.

Response options (select one): No, I have not heard this before / Yes, I have heard this before [randomize response order].

Have you heard that carbon emissions (CO2) can be removed directly from the air?

Indented intro 2 text:

Earth transforms sunlight's visible light energy into infrared light energy, which leaves Earth extremely slowly because it is trapped by CO2 and other greenhouse gases in the air.

So when people add CO_2 to the air by burning fossil fuels, energy leaves Earth even more slowly—raising Earth's temperature.

Recently, scientists have shown how to remove CO_2 directly from the air by using large machines to filter it out.

Response options (select one): No, I have not heard this before / Yes, I have heard this before [randomize response order].

To halt global warming in time to prevent worse climate catastrophes than we are seeing now will require removing CO_2 directly from the air, scientists around the world agree.

To what extent do you agree with this?

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

The need to remove CO_2 directly from the air depends on what the world does in the next 10 years. Rapid cuts in burning fossil fuels now mean relying less on removing CO_2 directly from the air.

To what extent do you agree with this?

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

Removing some of the CO_2 directly from the air that has already been released from burning fossil fuels is the only way to reduce CO_2 put in the air by humans in the past.

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

Removing CO_2 directly from the air is a way of making sure that burning fossil fuels in the future doesn't add to the amount of CO_2 already in the air.

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

Should direct air capture be used in the U.S. on a large scale to remove CO_2 and other greenhouse gases from the atmosphere?

Response options: Likert scale, Definitely not to Definitely yes, 7 stars.

If *removing CO2 directly from the air* and improving *renewable energy & energy efficiency* were funded by a single public budget, how would you spend that budget on them?

Response options: All on removing CO2 / Most on removing CO2 / Split equally between the two / Most on renewable energy & energy efficiency / All on renewable energy & energy efficiency / None on either / Other (please specify) [None option pinned, randomly reverse answer order].

How risky is directly capturing CO_2 from the air?

Response options: Likert scale, Not at all risky to Extremely risky, 7 stars.

Removing CO_2 directly from the air will encourage the prolonged use of fossil fuels.

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

Which of the following do you do to help slow or stop climate change?

[Select all that apply, randomly reverse order: Eat a plant-based diet / Talk with your friends about climate change / Use public transportation, walk or bike / Avoid airplane travel / Avoid using gas, oil, and all fossil fuels / Recycle / Other (please specify)].

How worried are you about climate change?

Response options: Not at all worried / A little worried / Somewhat worried / Very worried / Extremely worried [randomly reverse answer order].

How much will it cost to remove CO_2 directly from the air compared to slowing or stopping climate change other ways?

Response options (select one): A lot more / A little more / About the same / A little less / A lot less / Unsure [unsure pinned, randomly reverse order].

I am the type of person who acts environmentally friendly. To what extent do you agree with this?

Response options: Likert scale, Totally disagree to Totally agree, 7 stars.

A.2. Example of an introductory item as shown to the participants

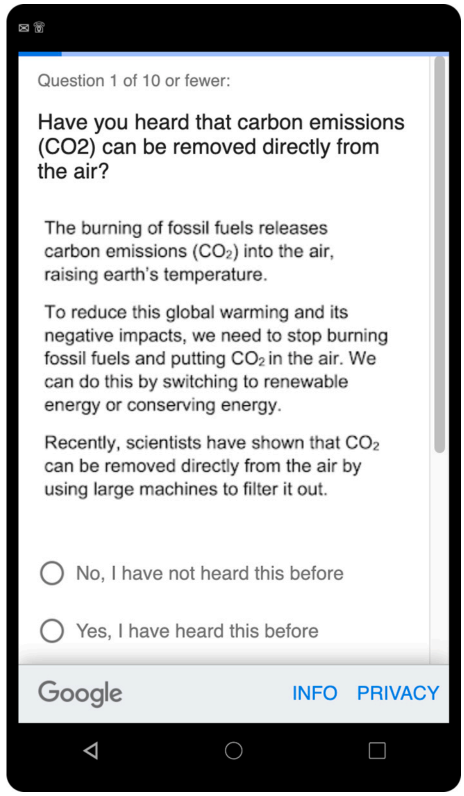

Fig. A2. Introductory item (intro version 1) shown on the Google paywall intercept survey platform.

Appendix B. Risk perception

In addition to the three outcomes reported in the main text, we also assessed people's risk perception of using DAC with one item: 'How risky is directly capturing CO2 from the air?' on a scale from 1 (not at all risky) to 7 (extremely risky). As Table B1 shows, risk perception was strongly related to anticipated moral hazard and we therefore refrained from reporting both outcomes in the main analysis. Table B2 displays the correlations between this item and the other measures for those unaware and aware of DAC. Table B3 shows the mean levels of risk perception across the different experimental conditions. Table B4 displays the regression results, showing that necessity and temporality framing did not affect participants' risk perception.

Table B1
Means, standard deviations, and correlations with confidence intervals for the total sample.

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. DAC support	4.19	1.86							
2. Relative financial support	3.61	1.70	0.07** [0.03, 0.10]						
3. Risk perception	3.71	1.61	0.17** [0.14, 0.21]	−0.08** [−0.11, −0.04]					
4. Anticipated moral hazard	3.84	1.74	0.39** [0.36, 0.42]	−0.06** [−0.10, −0.02]	0.42** [0.39, 0.45]				
5. DAC awareness	1.43	0.50	0.19** [0.15, 0.22]	−0.06** [−0.10, −0.02]	0.02 [−0.01, 0.06]	0.09** [0.05, 0.12]			
6. Climate change worry	3.14	1.39	0.44** [0.41, 0.47]	−0.06** [−0.09, −0.02]	0.06** [0.02, 0.09]	0.30** [0.26, 0.33]	0.13** [0.09, 0.17]		
7. PEB index	1.87	1.43	0.26** [0.22, 0.29]	−0.14** [−0.18, −0.11]	0.03 [−0.01, 0.06]	0.22** [0.18, 0.25]	0.16** [0.12, 0.19]	0.41** [0.38, 0.44]	
8. Beliefs about costs	3.67	1.27	0.01 [−0.04, 0.05]	−0.19** [−0.23, −0.14]	0.11** [0.07, 0.15]	0.14** [0.09, 0.18]	0.07** [0.03, 0.12]	0.15** [0.10, 0.19]	0.19** [0.14, 0.23]

Note. Values in square brackets indicate the 95 % confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$. The two questions on agreement with the frames are not part of the table because they are based on different sample sizes.

Table B2a
Means, standard deviations, and correlations for participants unaware of DAC (N = 1649).

Variable	*M*	*SD*	1	2	3	4	5	6
1. DAC support	3.89	1.83						
2. Relative financial support	3.70	1.74	0.04					
			[−0.01, 0.08]					
3. Risk perception	3.68	1.58	0.32**	−0.12**				
			[0.28, 0.36]	[−0.17, −0.07]				
4. Anticipated moral hazard	3.71	1.73	0.50**	−0.07**	0.51**			
			[0.46, 0.53]	[−0.12, −0.03]	[0.47, 0.54]			
5. Climate change worry	2.98	1.41	0.40**	−0.03	0.10**	0.30**		
			[0.36, 0.44]	[−0.08, 0.02]	[0.05, 0.15]	[0.26, 0.34]		
6. PEB index	1.67	1.32	0.29**	−0.11**	0.09**	0.24**	0.38**	
			[0.24, 0.33]	[−0.15, −0.06]	[0.04, 0.13]	[0.20, 0.29]	[0.33, 0.42]	
7. Beliefs about costs	3.58	1.24	−0.01	−0.11**	0.16**	0.10**	0.07*	0.15**
			[−0.08, 0.05]	[−0.17, −0.05]	[0.10, 0.23]	[0.04, 0.16]	[0.01, 0.13]	[0.09, 0.21]

Table B2b
Means, standard deviations, and correlations for participants aware of DAC (N = 1242).

Variable	*M*	*SD*	1	2	3	4	5	6
1. DAC support	4.59	1.83						
2. Relative financial support	3.49	1.66	0.14**					
			[0.09, 0.20]					
3. Risk perception	3.75	1.65	−0.02	−0.02				
			[−0.07, 0.04]	[−0.08, 0.04]				
4. Anticipated moral hazard	4.01	1.74	0.23**	−0.03	0.31**			
			[0.18, 0.29]	[−0.09, 0.02]	[0.26, 0.36]			
5. Climate change worry	3.35	1.35	0.45**	−0.08**	−0.00	0.27**		
			[0.41, 0.49]	[−0.13, −0.02]	[−0.06, 0.05]	[0.22, 0.32]		
6. PEB index	2.13	1.53	0.18**	−0.17**	−0.04	0.17**	0.42**	
			[0.12, 0.23]	[−0.22, −0.11]	[−0.10, 0.01]	[0.11, 0.22]	[0.37, 0.46]	
7. Beliefs about costs	3.76	1.30	0.01	−0.25**	0.06	0.16**	0.21**	0.20**
			[−0.06, 0.07]	[−0.31, −0.19]	[−0.00, 0.13]	[0.10, 0.22]	[0.15, 0.27]	[0.14, 0.27]

Note. Values in square brackets indicate the 95 % confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$. The two questions on agreement with the frames are not part of the table because they are based on different sample sizes.

Table B3
Mean levels of risk perception across experimental conditions.

Factor necessity	Factor temporality	Risk perception		
		Mean	SD	n
No frame	No frame	3.79	1.68	322
	Past	3.75	1.54	327
	Future	3.60	1.59	329
	Total	3.63	1.69	978
Essential	No frame	3.72	1.69	298
	Past	3.84	1.56	328
	Future	3.72	1.72	332
	Total	3.60	1.74	958
Dependent	No frame	3.72	1.65	311
	Past	3.60	1.53	324
	Future	3.63	1.55	320
	Total	3.60	1.69	955
Total	No frame	3.74	1.67	931
	Past	3.73	1.55	979
	Future	3.65	1.62	981
	Total	3.71	1.61	2891

Table B4
Weighted least squares regression results for risk perception.

		Dependent variable:
		Risk perception
Framing condition (experimental treatment)	Essential (vs. control)	−0.004
		(0.128)
	Dependent (vs. control)	−0.067

(*continued on next page*)

Table B4 (*continued*)

		Dependent variable:
		Risk perception
		(0.127)
	Past (vs. control)	0.017
		(0.124)
	Future (vs. control)	−0.177
		(0.124)
	Essential x Past	0.054
		(0.179)
	Dependent x Past	−0.092
		(0.179)
	Essential x Future	0.188
		(0.178)
	Dependent x Future	−0.017
		(0.179)
Gender: male (vs. female)		−0.251***
		(0.060)
Age: 35–54 (vs. 18–34)		−0.083
		(0.073)
Age: 55+ (vs. 18–34)		0.097
		(0.074)
DAC awareness: yes (vs. no)		0.166***
		(0.061)
Constant		3.839***
		(0.105)
Observations		2891
R^2		0.014
Adjusted R^2		0.010
Residual Std. Error		1.591 (df = 2878)
F Statistic		3.429*** (df = 12; 2878)

Note: *$p < .05$; **$p < .01$; regression coefficients are unstandardized and weighted by gender, age, and geographic location in the U.S.

Appendix C. ANOVA displaying the effects of necessity and temporality framing on climate change worry

	Df	Sum Sq	Mean Sq	*F*	*p*
Frame: necessity	2	6	3.136	1.617	0.199
Frame: temporality	2	0	0.027	0.014	0.986
Necessity x temporality	4	15	3.843	1.982	0.095
Residuals	2882	5588	1.939		

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103694.

References

[1] IPCC. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty; 2018.

[2] IPCC, Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022.

[3] V. Campbell-Arvai, P.S. Hart, K.T. Raimi, K.S. Wolske, The influence of learning about carbon dioxide removal (CDR) on support for mitigation policies, Clim. Chang. 143 (3–4) (2017) 321–336, https://doi.org/10.1007/s10584-017-2005-1.

[4] K.T. Raimi, A. Maki, D. Dana, M.P. Vandenbergh, Framing of geoengineering affects support for climate change mitigation, Environ. Commun. 13 (3) (2019) 300–319, https://doi.org/10.1080/17524032.2019.1575258.

[5] A. Pamplany, B. Gordijn, P. Brereton, The ethics of geoengineering: a literature review, Sci. Eng. Ethics 26 (6) (2020) 3069–3119, https://doi.org/10.1007/s11948-020-00258-6.

[6] R.W. Rauchhaus, Principal-agent problems in humanitarian intervention: moral hazards, adverse selection, and the commitment dilemma, Int. Stud. Q. 53 (4) (2009) 871–884, https://doi.org/10.1111/j.1468-2478.2009.00560.x.

[7] K.T. Raimi, Public perceptions of geoengineering, Curr. Opin. Psychol. 42 (2021) 66–70, https://doi.org/10.1016/j.copsyc.2021.03.012.

[8] M.M. Austin, B.A. Converse, In search of weakened resolve: does climate-engineering awareness decrease individuals' commitment to mitigation? J. Environ. Psychol. 78 (2021) 101690 https://doi.org/10.1016/j.jenvp.2021.101690.

[9] P.S. Hart, V. Campbell-Arvai, K.S. Wolske, K.T. Raimi, Moral hazard or not? The effects of learning about carbon dioxide removal on perceptions of climate mitigation in the United States, Energy Res. Soc. Sci. 89 (2022) 102656, https://doi.org/10.1016/j.erss.2022.102656.

[10] J. Jebari, O.O. Táíwò, T.M. Andrews, V. Aquila, B. Beckage, M. Belaia, et al., From moral hazard to risk-response feedback, Clim. Risk Manag. 33 (2021) 100324, https://doi.org/10.1016/j.crm.2021.100324.

[11] A. Corner, N. Pidgeon, Geoengineering, climate change scepticism and the 'moral hazard' argument: an experimental study of UK public perceptions. Philos trans a math Phys, Eng. Sci. 372 (2031) (2014), https://doi.org/10.1098/rsta.2014.0063.

[12] A. Wenger, M. Stauffacher, I. Dallo, Public perception and acceptance of negative emission technologies – framing effects in Switzerland, Clim. Chang. (2021) 167 (3–4), https://doi.org/10.1007/s10584-021-03150-9.

[13] D.P. van Vuuren, S. Deetman, J. van Vliet, M. van den Berg, B.J. van Ruijven, B. Koelbl, The role of negative CO2 emissions for reaching 2 °C—insights from integrated assessment modelling, Clim. Chang. 118 (1) (2013) 15–27, https://doi.org/10.1007/s10584-012-0680-5.

[14] M.G. Lawrence, S. Schäfer, H. Muri, V. Scott, A. Oschlies, N.E. Vaughan, et al., Evaluating climate geoengineering proposals in the context of the Paris agreement temperature goals, Nat. Commun. 9 (1) (2018) 3734, https://doi.org/10.1038/s41467-018-05938-3.

[15] van Vuuren DP, Stehfest E, Gernaat, David E. H. J., van den Berg M, Bijl DL, Boer HS de et al. Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies. Nat. Clim. Chang. 2018;8(5):391–7. https://doi.org/10.1038/s41558-018-0119-8.

[16] B.K. Sovacool, Reckless or righteous? Reviewing the sociotechnical benefits and risks of climate change geoengineering, Energ. Strat. Rev. 35 (2021) 100656, https://doi.org/10.1016/j.esr.2021.100656.
[17] S. Fuss, W.F. Lamb, M.W. Callaghan, J. Hilaire, F. Creutzig, T. Amann, et al., Negative emissions—part 2: costs, potentials and side effects, Environ. Res. Lett. 13 (6) (2018) 63002, https://doi.org/10.1088/1748-9326/aabf9f.
[18] O. Rueda, J.M. Mogollón, A. Tukker, L. Scherer, Negative-emissions technology portfolios to meet the 1.5 °C target, Glob. Environ. Chang. 67 (2021) 102238, https://doi.org/10.1016/j.gloenvcha.2021.102238.
[19] M. Jobin, M. Siegrist, Support for the deployment of climate engineering: a comparison of ten different technologies, Risk Anal. 40 (5) (2020) 1058–1078, https://doi.org/10.1111/risa.13462.
[20] T. Satterfield, S. Nawaz, G.P. St-Laurent, Exploring public acceptability of direct air carbon capture with storage: climate urgency, moral hazards and perceptions of the 'whole versus the parts', Clim. Chang. 176 (2) (2023) 1–21, https://doi.org/10.1007/s10584-023-03483-7.
[21] S. Valluri, V. Claremboux, S. Kawatra, Opportunities and challenges in CO2 utilization, J. Environ. Sci. 113 (2022) 322–344, https://doi.org/10.1016/j.jes.2021.05.043.
[22] T.M. Andrews, A.W. Delton, R. Kline, Anticipating moral hazard undermines climate mitigation in an experimental geoengineering game, Ecol. Econ. 196 (2022) 107421, https://doi.org/10.1016/j.ecolecon.2022.107421.
[23] B.K. Sovacool, C.M. Baum, S. Low, Determining our climate policy future: expert opinions about negative emissions and solar radiation management pathways, Mitig. Adapt. Strateg. Glob. Chang. 27 (8) (2022) 58, https://doi.org/10.1007/s11027-022-10030-9.
[24] D. Gordic, J. Nikolic, V. Vukasinovic, M. Josijevic, A.D. Aleksic, Offsetting carbon emissions from household electricity consumption in Europe, Renew. Sust. Energ. Rev. 175 (2023) 113154, https://doi.org/10.1016/j.rser.2023.113154.
[25] S. Gössling, J. Broderick, P. Upham, J.-P. Ceron, G. Dubois, P. Peeters, et al., Voluntary carbon offsetting schemes for aviation: efficiency, credibility and sustainable tourism, J. Sustain. Tour. 15 (3) (2007) 223–248, https://doi.org/10.2167/jost758.0.
[26] M.V. Mossler, A. Bostrom, R.P. Kelly, K.M. Crosman, P. Moy, How does framing affect policy support for emissions mitigation? Testing the effects of ocean acidification and other carbon emissions frames, Glob. Environ. Chang. 45 (2017) 63–78, https://doi.org/10.1016/j.gloenvcha.2017.04.002.
[27] D. Sloot, N. Lehmann, A. Ardone, Explaining and promoting participation in demand response programs: the role of rational and moral motivations among German energy consumers, Energy Res. Soc. Sci. 84 (2022) 102431, https://doi.org/10.1016/j.erss.2021.102431.
[28] K. van den Broek, J.W. Bolderdijk, L. Steg, Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals, J. Environ. Psychol. 53 (2017) 145–156, https://doi.org/10.1016/j.jenvp.2017.07.009.
[29] A. Bostrom, A.L. Hayes, K.M. Crosman, Efficacy, action, and support for reducing climate change risks, Risk Anal. 39 (4) (2019) 805–828, https://doi.org/10.1111/risa.13210.
[30] L. Whitmarsh, D. Xenias, C.R. Jones, Framing effects on public support for carbon capture and storage, Palgrave Commun 5 (1) (2019) 1–10, https://doi.org/10.1057/s41599-019-0217-x.
[31] C. Braun, C. Merk, G. Pönitzsch, K. Rehdanz, U. Schmidt, Public perception of climate engineering and carbon capture and storage in Germany: survey evidence, Clim. Pol. 18 (4) (2018) 471–484.
[32] K.S. Wolske, K.T. Raimi, V. Campbell-Arvai, P.S. Hart, Public support for carbon dioxide removal strategies: the role of tampering with nature perceptions, Clim. Chang. 152 (3–4) (2019) 345–361, https://doi.org/10.1007/s10584-019-02375-z.
[33] B. Sütterlin, M. Siegrist, Public perception of solar radiation management: the impact of information and evoked affect, J. Risk Res. 20 (10) (2017) 1292–1307.
[34] A.M. McCright, S.T. Marquart-Pyatt, R.L. Shwom, S.R. Brechin, S. Allen, Ideology, capitalism, and climate: explaining public views about climate change in the United States, Energy Res. Soc. Sci. 21 (2016) 180–189, https://doi.org/10.1016/j.erss.2016.08.003.
[35] A. Bostrom, G. Böhm, A.L. Hayes, R.E. O'Connor, Credible threat: perceptions of pandemic coronavirus, climate change and the morality and Management of Global Risks, Front. Psychol. 11 (2020) 578562, https://doi.org/10.3389/fpsyg.2020.578562.
[36] P. McDonald, M. Mohebbi, B. Slatkin, Comparing Google Consumer Surveys to Existing Probability and Non-probability Based Internet Surveys, Google Inc, Mountain View, CA, 2012.
[37] K. Sostek, B. Slatkin, How Google Surveys Work, Google Inc, Mountain View, CA, 2018.
[38] Ranney MA, Clark D, Reinholz D, Cohen S. Improving Americans' modest global warming knowledge in the light of RTMD (Reinforced Theistic Manifest Destiny) theory. In: J. van Aalst, K. Thompson, M. M. Jacobson, & P. Reimann, editor. The Future of Learning: Proceedings of the Tenth International Conference of the Learning Sciences. International Society of the Learning Sciences, Inc. International Society of the Learning Sciences, Inc; 2012, pp. 2–481 to 2–482.
[40] E. Cox, E. Spence, N. Pidgeon, Public perceptions of carbon dioxide removal in the United States and the United Kingdom, Nat. Clim. Chang. 10 (8) (2020) 744–749, https://doi.org/10.1038/s41558-020-0823-z.
[41] T. Gregersen, R. Doran, G. Böhm, E. Tvinnereim, W. Poortinga, Political orientation moderates the relationship between climate change beliefs and worry about climate change, Front. Psychol. 11 (2020) 1573, https://doi.org/10.3389/fpsyg.2020.01573.
[42] C. Wolsko, H. Ariceaga, J. Seiden, Red, white, and blue enough to be green: effects of moral framing on climate change attitudes and conservation behaviors, J. Exp. Soc. Psychol. 65 (2016) 7–19, https://doi.org/10.1016/j.jesp.2016.02.005.
[43] L. Chang, J.A. Krosnick, National Surveys via Rdd Telephone Interviewing Versus the internet, Public Opin. Q. 73 (4) (2009) 641–678, https://doi.org/10.1093/poq/nfp075.