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Social attitudes towards climate interventions: Are European publics uninformed about carbon removal and solar radiation management?

Benjamin K. Sovacool [a,b,c,d,*], Livia Fritz [c], Chad M. Baum [c], Lucilla Losi [c], Ramit Debnath [e], Hans Jakob Walnum [f], Finn Müller-Hansen [h], Elina Brutschin [g]

[a] Department of Earth and Environment, Boston University, United States
[b] Institute for Global Sustainability, Boston University, United States
[c] Department of Business Development and Technology, Aarhus University, Denmark
[d] Bennett Institute for Innovation and Policy Acceleration, University of Sussex Business School, United Kingdom
[e] Collective Intelligence and Design Group, University of Cambridge, United Kingdom
[f] Western Norway Research Institute, Norway
[g] International Institute for Applied Systems Analysis, Austria
[h] Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, Germany

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ABSTRACT

Climate interventions such as carbon removal and solar radiation management are now being considered by researchers, policymakers, and the private sector to address climate change. We examine European public perceptions of these interventions through five nationally representative surveys: Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). We combine this quantitative data with qualitative data from a total of 10 focus groups, with one urban and one rural focus group in each country. We find that public concerns within the five countries can be organized into themes such as climate change attitudes, technology perceptions, and governance. We also offer a comparative assessment of public perceptions organized around the relational themes of familiarity, policy support, aversion to tampering with nature, environmental identity, trust in actors, and experiences of climate change. Stated knowledge and familiarity with carbon removal and solar radiation management influence attitudes towards climate interventions. The great variety of attitudes and preferences confounds attempts to push climate policy or oversight of climate interventions towards applying "one-size-fits-all" policy options. Engaging with these diverse views in the policy process is therefore crucial for equitable deployment and minimizing societal backlash.

1. Introduction

Given the phlegmatic pace of current climate mitigation efforts (Stoddard et al., 2021), juxtaposed against continued underinvestment in efforts to build resilience via climate adaptation (Feldman 2012; Tall et al., 2021), other types of climate interventions are now being considered by researchers, policymakers, and the private sector. As Morrison et al. (2022) recognize, there is a consensus beginning to emerge that interventions aiming at emission reductions alone are not sufficiently fast to implement politically to keep international climate targets in reach.

To put this challenge in perspective, the carbon budget to stay within the 1.5 C target without overshoot is already exhausted as of 2025 (Climate Change Tracker, 2025). If the global community managed to reduce greenhouse gas emissions starting in 2024 at the same rate they increased over the industrial era—an immense challenge—the rate of reduction would still be insufficient to meet a 2-degree carbon budget, surpassing it by 31 % (Katz-Rosene, 2024). Another startling fact: half of all greenhouse gas emissions have been emitted in the past 25 years, and the weight of cumulative carbon dioxide emissions is more than the total mass of everything built by humans which is still standing erect on earth (Wallace-Wells, 2022). New projections from Bilal, Känzig (2024) warn that every 1 ° increase in global warming results to a 12 % decline in global Gross Domestic Product, suggesting that the social cost of carbon now exceeds $1000/ton, and also that the macroeconomic damages from climate change are six times greater than previously estimated. The

* Corresponding to: Science Policy Research Unit (SPRU), University of Sussex, Jubilee Building, Room 367, Falmer, East Sussex BN1 9SL, United Kingdom.
E-mail addresses: B.Sovacool@sussex.ac.uk (B.K. Sovacool), livia.fritz@btech.au.dk (L. Fritz), cmbaum@btech.au.dk (C.M. Baum), lucilla.losi@btech.au.dk (L. Losi), rd545@cam.ac.uk (R. Debnath), hjw@vestforsk.no (H.J. Walnum), brutschin@iiasa.ac.at (E. Brutschin).

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authors caution that these magnitudes of economic loss are comparable to the damage caused by fighting a war domestically and permanently for as long as 100,000 years.

Consequently, some in the global energy and climate policy and research community are beginning to assess the role of carbon dioxide removal (CDR) — from technological options such as enhanced rock weathering (ERW), biochar, and direct air capture to land-based methods such as reforestation and soil carbon sequestration — in rapidly reducing atmospheric CO_2 and storing it permanently (Low et al., 2022; Sovacool et al., 2023a). Others are exploring temperature reduction options such as solar radiation management (SRM), in the form of stratospheric aerosol injection (SAI), marine cloud brightening or sunshades (Baum et al., 2024a). While carbon removal is increasingly mainstreamed, tested in pilots (Smith et al., 2024) and included into national climate policy goals (Lamb et al., 2024), SRM proposals are still mostly discussed theoretically and are politically controversial (Parson et al., 2024; Low et al., 2024). Both sets of interventions could have a profound and lasting impact not only on climate change policy deliberations, but actual deployment patterns and attendant impacts on community wellbeing and ecosystem vitality (Anderson and Peters, 2016; Carton et al., 2020; Aldy et al., 2021; MacMartin et al., 2022).

In this study, we examine European public perceptions of these interventions through five nationally representative surveys: Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). We combine this quantitative data with qualitative data from a total of 10 focus groups, with one urban and one rural focus group in each country. In doing so, we aim to advance empirical and methodological objectives, and achieve topical, thematic, and spatial novelty. Empirically and topically, the study examines ten technologies at the climate intervention frontier. Among these, three focus on SRM, which aims to reduce global temperatures by reflecting sunlight back into space. These are SAI, space-based geoengineering, and marine cloud brightening (SAPEA, 2024). The remaining seven technologies concentrate on carbon removal, which involves large-scale carbon dioxide sequestration. This category includes restoring or planting vegetation, carbon storage in soils, direct air capture with subsequent carbon dioxide storage, ERW, and bioenergy combined with carbon dioxide capture and storage (Sovacool et al., 2023). Thematically, our survey instrument explores salient aspects of climate interventions such as public attitudes, perceptions of technologies, governance, familiarity, policy, values, and identity. This approach is particularly relevant for climate interventions, as the ongoing debates surrounding their deployment now focus less on scientific questions of technology design and more on potential societal impacts, especially the environmental and ethical considerations and social and political ramifications (McLaren and Corry, 2025). Methodologically and spatially, this study employs a unique dataset compiled from five nationally representative surveys and focus groups across five novel locations within Europe.

Specifically, we make a novel contribution to the development of climate intervention policy and governance by moving beyond a "one-size-fits-all" perspective toward a more context-sensitive understanding of public attitudes. While previous studies have documented broad differences between the Global North and Global South (Baum et al., 2024a; Brutschin et al., 2024; Low et al., 2024a, 2024b), there is also notable variation within Europe itself — for example, Austria has shown particularly high skepticism toward both CDR and SRM compared to other European countries.

To better understand what drives such differences across countries with otherwise similar geographical, cultural, economic, and political contexts — and to avoid oversimplified generalizations — we focus on five European case studies: Austria, Germany, Italy, Norway, and the UK. This design reduces the influence of structural differences that dominate Global North–South comparisons, enabling more precise insights into European-centered perceptions of climate interventions. In addition, our approach addresses gaps identified in Sovacool et al. (2023b)'s review of the CDR literature, which found that most studies focus narrowly on the United States or United Kingdom and typically examine only 1–3 climate interventions. Of the 57 studies cataloged, fewer than a quarter used a cross-country design, only three employed mixed methods, and none compared the five countries investigated here across a broader set of 10 interventions. By combining a comparative European focus with methodological breadth, we not only identify key drivers of attitudinal differences but also provide practical outputs: guidance for identifying trusted institutions for public outreach, and a toolkit for mapping public values to preempt social opposition during prospective deployment.

2. Research design

Our study is part of the project Geoengineering and Negative Emissions Pathways in Europe (GENIE), a multi-institutional assessment of carbon removal and solar geoengineering approaches funded by the European Research Council. Our two core research methods were a nationally representative survey and focus groups. The large-N survey, given its statistically significant sample sizes and screening of participants to ensure representativeness, provides insights into aggregate, nationally representative preferences – but gives less sense of rationales and processes of reasoning that underpin preferences. Focus groups aim to map such rationales, with the in-depth treatment and detail that comes with deliberation, and for attention to local or national contexts that can inform further situated (or locale and context-specific) assessment.

Focus groups were run concurrently with the data collection for the survey, since they were not meant to verify or validate in any predetermined way the responses of the survey. Similarly, the survey was not meant to verify or validate results of the focus groups. Both forms of data collection were conducted independently, with the primary goal to triangulate between them. We were also cognizant of the strengths of using both methods together, namely that the focus groups produce qualitative data that can "add color" and detail to the quantitative data; but the quantitative data also "adds a degree of statistical power," representativeness, and comparability to the qualitative data.

In the interests of transparency, other papers have been published using the same dataset on the topic of public attitudes and preferences. This includes research on:

- Social perceptions of CDR and SRM comparing the Global North and Global South (Baum et al., 2024a);
- Focus group perceptions of CDR globally (Low et al., 2024a);
- Ecologies of participation and public involvement for CDR and SRM (Fritz et al., 2024a);
- Focus groups perceptions of solar geoengineering (Low et al., 2024b);
- Climate beliefs and perceptions of CDR and SRM globally (Fritz et al., 2024b);
- Drivers and public attitudes and support of CDR and SRM globally (Brutschin et al., 2024);
- Influence of demographics such as age, gender, and income/poverty on CDR and SRM perceptions (Sovacool et al., 2024a);
- Ethnic minorities, Indigenous groups and sense of place (Sovacool et al., 2024b);
- Public views of experts and governance of CDR and SRM (Fritz et al., 2025);
- Climate emotions and perceptions and support of CDR and SRM (Baum et al., 2025).

However, none of this previous research has examined trends at the national level, combining both survey and focus group data, and none of this has focused on European countries in depth.

2.1. A large-scale nationally representative survey

We conducted an online survey in a total of 30 countries (N = 30,284 participants, at least 1000 in each) and 19 languages, with alternate templates for handheld mobile device and desktop use. Each survey was nationally representative of country populations in terms of age (18−74), gender, and geographic region along with broad quotas for education and income, with surveys conducted from August to December 2022. Here, we utilize data from five of those surveys to provide a European-centric perspective: Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). An overview of the demographics of our respondents is offered in Appendix A. We chose these countries because their geographical, cultural, economic and political settings are quite similar compared to the global distribution – and in view of growing policy and regulatory discussions in the European context (SAPEA, 2024; Fridahl et al., 2023; Edenhofer et al., 2025). This makes comparisons between the countries less dependent on strong differences regarding these dimensions and enables us to draw more direct conclusions regarding European-centered perceptions of climate interventions.

The survey investigated public perceptions of climate-intervention technologies using measures related to perceptions of risks and benefits, support for different technology-related activities, and support for various policy options along with questions on sociodemographic characteristics. These were examined alongside covariates such as beliefs about climate change and the environment, trust in actors and institutions, aversion to tampering with nature, and credibility of sources of information. Survey design, especially the information texts presented to participants, was revised and finalized by extensive piloting, input from external researchers, professional translators, and programmers and survey experts at Norstat, a European-based data collection company (https://norstatgroup.com/), and by drawing on soft-launch results. For more details on survey measures, readers are directed to Appendix B.

2.2. Ten public European focus groups

To triangulate findings from the survey, we also ran two focus groups in each country for Austria, Germany, Italy, Norway and the United Kingdom. Recruitment aimed at 8 participants per focus group. Due to technical difficulties and dropouts, the lowest number of participants was 5. Recruitment was conducted in collaboration with Norstat. Participants were selected from a pool based on screening questions about their gender, age, place of living (rural or urban), education level, income and occupation type to represent different demographics. Furthermore, people denying climate change were screened out given that the survey exercises identified such participants were a small fraction of the overall population and to moreover ensure a common base of understanding of climate change for the focus groups. Participants received information material on different climate interventions before the focus group meeting. A moderator guided the discussions using a list of questions prepared by the authors and translated to the national language of each country. For more details about our focus groups, readers are directed to review Appendix C.

2.3. Data analysis

We use two approaches to analyze the rich mixed-methods data from the survey and focus groups. First, we code the transcriptions of the focus group discussions into themes using qualitative software. These themes are discussed considering the counterpart survey results in Section 3.1. Second, we used the sections from the survey to guide additional analysis of the focus group transcripts, resulting in the findings presented in Section 3.2.

As a strength of this approach, the study adheres to two important tenets in the research methodology literature. The first is an ethics of reflexivity, listening and care in how we present the viewpoints from our sample of the public, some of whom do live in communities vulnerable to environmental injustice or the impacts of climate change. This aligns with the call by Cueva et al. (2024) for research that employs an approach towards "emancipatory empiricism" that decenters the views of experts or policymakers versus those from everyday people. Whitmarsh et al. (2025) add that doing so with a plurality of methods (as is done in the current study) can reveal rich insights from "listening" to diverse publics about their experiences and concerns.

The second is that of not positioning our research or findings through any predetermined theory or conceptual framework; instead we let our findings emerge inductively from the data itself (Glaser and Strauss, 2017; Charmaz, 2015). This approach has the advantage of facilitating discovery, flexibility, and being more adaptive, not least by enabling respondents to better draw on their real-world experiences (in the case of the focus groups). It was also advantageous in terms of its process, given it focuses on a cyclical, recursive relationship between data collection, data coding, and analysis.

Conversely, this inductive and data-grounded approach necessarily entails that the current research did not follow an explanatory or experimental research design, one that would deductively test certain hypotheses or themes in the literature. Additionally, the survey and focus groups, by nature, cannot get into the kinds of "deep" discussions that might take place over days or even weeks: the survey was only 15–20 min long, and the focus groups were limited to 2 h. This means the results are of a more "light" nature given the limited amount of time respondents had to elaborate on influencing factors. Moreover, whereas the focus group results are inherently qualitative in nature, the results highlighted in the current paper are mainly descriptive and narrative. We do strive to mitigate this shortcoming, however, by offering qualified generalizations that are context-specific, as well as based on thick patterns (Turnheim et al., 2015).

3. Results and discussion: climate interventions in a comparative European context

In this section, we present our Results and Discussion, organized by a thematic analysis of the national level survey and focus group data followed by a comparative assessment across the five countries.

3.1. National themes within the five countries

Three recurring themes arose at the national level: those about general attitudes about climate change, technology perceptions including hopes and concerns, and issues of governance and trust. For each of these sections, we order the discussion alphabetically starting with Austria and Germany and ending with Italy, Norway and the United Kingdom.

3.1.1. General climate change attitudes

As concern about climate change influences people's attitudes towards climate interventions, we start our discussion with climate change attitudes expressed in the focus groups and discuss them in the context of our survey results. The data from our focus groups reveal climate worries across rural and urban Austria. In contrast to these in-group dynamics, numerous focus group participants suspect low awareness of and attention given to the issue in the wider population – a tendency that one participant also sees reflected in voting behaviors: *"Unfortunately, there still isn't a consensus among the population. I think a quarter to 30 %, I don't know the exact number, but when you look at how many people vote for the climate change denying party, then I worry."* (Austrian Focus Group, Urban) This is consistent with a large proportion of Austrians in the survey expressing concern about climate change: Asked how, if at all, worried they are about climate change, 56 % of respondents in the Austrian survey say they are "very" or "extremely worried" about

climate change and another 29 % declare being "somewhat worried" (cp. Appendix D).

While general concerns about climate change are relatively high, 35 % of survey respondents think that climate change will "not at all" harm them personally or do so only "a little bit", compared to 65 % expecting climate change to "somewhat" or "a great deal" harm them personally. The focus group discussions show a mixed sense of personal affectedness beyond generic mentions of extreme weather events, with several participants – albeit being concerned – perceiving climate change predominantly as a problem that manifests elsewhere or that will unfold in the distant future. In the Austrian groups, comparatively strong emphasis on North-South dimensions of climate change politics can be observed, including concerns over historic responsibility and the right to develop for Global South countries.

Views on adequate responses to climate change further varied in the Austrian focus groups. At times echoing discourses of climate delay (Lamb et al., 2020), we find repeated calls for global action on climate change, as individual countries' efforts – particularly small ones such as Austria - are in vain if big, high-emitters do not do their share, urging that the burden must neither be placed on the poorest countries, nor disproportionally on individuals. Perspectives on how much changes in individual consumption practices can contribute to tackling the problem diverge among participants. While some see the potential of social tipping points or "domino effects" resulting from such changes, others argue that as long as high-impact practices like deforestation of the rainforest and polluting industries are not stopped, putting responsibility on individuals is futile.

Further critical remarks about focusing on individuals as main agents of change include questioning the origins of individual responsibilities and highlighting the need for strong policy and supply-side efforts. For example, one participant in Austria argues: *"What I wanted to say about who I think is responsible for change, individual or on a large meta-level, in my opinion it's always the capitalist narrative to always shift the responsibility onto the individual. The demand creates the supply and so on. I don't agree. I think politics has the largest responsibility; they're sitting at the big lever in terms of CO2, oil prices which influences an individual's consumer behavior. I think it's the responsibility of the main economic players and of politics."* (Austria Focus Group, urban)

Moving to Germany, when asked about their level of worry regarding climate change, 64 % of respondents in the German survey report being "very" or "extremely worried", while an additional 23 % indicate they are "somewhat worried". Similarly, focus group data highlights climate concerns across both rural and urban areas of Germany. Participants consider overall awareness in the general population and salience of climate change in public debate to be high. They strongly perceive climate change as an inter-generational issue, with the few personal experiences with climate change reported relating primarily to changes in seasons and extreme weather events, with mentions of impacts on forestry, and agriculture. Projecting into the future, the more representative national survey results, however, reveal that 77 % of German respondents expect climate change to harm them personally "somewhat" or "a great deal".

Regarding adequate responses to tackling the problem, a multitude of perspectives can be traced in the focus group discussions, including changes in individual consumption behavior, and in land use and production systems. We, furthermore, find arguments locating responsibilities for action abroad, with repeated concerns being expressed about irresponsible deforestation practices in *"South America, Asia, where entire rainforests are being destroyed to create plantations for palm oil or beef cattle"*, as one participant explains (Germany Focus Group, Rural). Such statements are illustrative of wider frustrations about how domestic efforts are in vain, if major polluters such as China, India, Russia or the US do not follow suit.

Italian respondents in the survey join Austrians and Germans in their concern about the environment and even overtake them in their self-reported environmentally friendly behavior and its importance. Mirroring these results, the participants in the Italian focus groups, when prompted to reflect on what concerns them and their community in relation to climate change, report various kinds of worries but very few of these reflect immediate and personal conditions. The participants to the urban focus groups report concerns over air pollution or natural disasters, such as floods, but most often mention these concerns in relation to future generations or other geographical areas, such as those affected by melting glaciers or rising sea levels, or countries from the Global South. "*We are privileged because we live in a developed country, even if Italy sometimes doesn't seem so, but we see many countries abroad where there is dryness, hunger and uncontrolled immigration to developed countries*" (Italian focus group, Urban).

The participants residing in Italy's rural areas, instead, mention more often immediate environmental concerns relating to their surrounding areas, such as the observable rapid changes in weather and seasons, especially draught. "*Last summer we witnessed the Po river* [a major Italian river, Ed.] *completely dry, it's a really bad feeling. I realized that things can change in a day. We could have no drinkable water in a short period of time*" (Italian focus group, Rural). To put these insights into context, it must be underlined that these focus groups took place in October 2022 which followed an unusually hot, long and dry summer for the whole country accompanied by a few violent cloudbursts, as highlighted by this participant: "*we had an extremely long summer, with no water, it was also physically impactful. […] Environmental disasters are closer to our world*" (Italian focus group, Rural).

When it comes to addressing climate change, a few participants from both Italian focus groups mention their personal efforts aimed at reducing their carbon footprint, while others highlight with frustration the lack of policy action and the fact that this represents a "global concern". "*My biggest concern is the fact that people don't talk about it. […] In the recent elections, none of the parties had the focus on the environment*" (Italian focus group, Rural). "*Scientists have been warning us for years. We have been talking about climate change since the 90's. We are in 2022 and the problem was disregarded completely. I see something* [policy action, Ed.] *but I don't see enough*" (Italian focus group, Urban). Participants also stress the role of capitalism and economic motivations as hindrances to climate action, as the participant providing the following extract, who implicitly equates any climate action with an economic loss: "*We think about money but not where we live. We are doing fine now and it's fine the way it is. People living in the future will think about it*" (Italian focus group, Rural).

Norwegian respondents scored the lowest among all countries in the survey regarding levels of environmental identity, indeed having the lowest mean scores among all 5 European countries. Norwegians also have a comparably low score connected to experiences of climate change. Only 11.8 per cent of all Norwegians answered yes to the question, "Have you personally experienced the effect of a major disaster (e.g., flood, heatwave, wildfire, blizzard) in the last three years?".

The focus group discussions do, however, show that Norwegians have concerns about climate change, particularly regarding the impact on future generations. *"I wouldn't say that I'm concerned right here and now, but it's more for the future that others mentioned. For the kids and grandkids, the changes affect everything. So in the end, even we here in Norway will be affected too."* Some express that even if they haven't personally experienced significant effects of climate change, they are aware of the global consequences. "*No, I think that, like many other Norwegians, am kind of middle of the tree. Mainly because I've not felt the climate changes and consequences of these myself. I've of course heard now it is in other countries, but one tends to think 'oh, this isn't any of my concern'. But still, subconsciously, it has affected me a little and I try to have solidarity with other countries and think about those countries where there will be more immediate climate changes in the coming 10 years and where we can already see the consequences."* The focus groups revealed that Norwegians tend to view climate change as primarily affecting other countries and future generations. This aligns with the survey findings, as most participants

mentioned that they have not personally experienced significant effects of climate change. However, they also expressed awareness of the global consequences and solidarity with other nations currently facing immediate climate challenges.

In the United Kingdom, all focus groups shared a common concern about the accelerated impacts of climate change. Urban participants often described high temperatures and flooding as the most felt climate impacts that worry them about what the future generation may have to endure. This is in line with the survey results, in which the UK had the highest share of respondents reporting personal experience with climate change impacts (41 %). In the rural focus group, the participants revealed strong concerns about *'what the world is going to be like for their children'*. However, only a slight majority (53 %) of survey respondents expressed that they were "very" or "extremely worried about climate change.

The comparison of survey results on climate change concerns across countries showed differences partly explicable with varying actual and expected exposure to climate change impacts. Italy is a notable exception here, with strong concerns but little reported experience with impacts. The focus groups revealed different motivations and understandings of these questions, which might further drive differences in survey responses.

3.1.2. Technology perceptions: hopes and concerns regarding CDR and SRM

Reflecting the by far highest levels of familiarity among the methods presented, *Austrian* focus group participants widely consider afforestation, and ecosystem restoration desirable methods and "ideal accompanying" measures to decarbonization efforts. Discussions around afforestation are illustrative of an overall clear preference for ecosystems-based CDR approaches expressed in the focus groups. These were often described as being "natural", accelerating established and well-known practices that should be complemented by a much-needed decrease in deforestation in countries such as Brazil - a key concern that participants kept circling back to. Focus group discussions reveal that regarding DACCS or BECCS, and ERW participants grapple with siting concerns and the likelihood of meeting NIMBYism, trade-offs, and land-use conflicts, with analogies drawn to past experiences with biofuel production and its competition with food production. These observations substantiate the survey finding according to which concerns over unintended side-effects are highest for DACCS, BECCS and ERW among the carbon removal methods gauged.

Results from the Austrian focus groups, furthermore, reveal low familiarity paired with overall strong skepticism towards the SRM approaches discussed, widely confirming survey results showing that ¾ of respondents have never heard of approaches like SAI. Participants refer to them as utopian and compare them to science fiction. They are worried about side effects, misuses such as militarization, and generally see them as representing too big of an interference with natural systems. They also talk about the geopolitics of implementing such technologies and how only few high-tech countries or even individuals such as tech billionaires would gain, while potential negative impacts would be unevenly distributed.

For the SRM approaches as well novel CDR technologies, Austrian focus group participants detect a risk of mitigation deterrence which leads many to call for tackling the problem at its roots instead. Survey results corroborate these finding for a more representative sample of the Austrian population: respondents in Austria tend to agree that the SRM approaches as well DACCS and to a lesser extent BECCS "would decrease the motivation to reduce CO2 emissions."

Both survey results and focus group data show that *German* publics are clearly the most positive towards conventional, ecosystem-based CDR methods, all while being cognizant of trade-offs and constraints related to competing land use, including for agricultural and residential purposes. While for conventional CDR methods, particularly afforestation and reforestation, survey respondents are confident that they "can be done safely in a controlled fashion" (mean value 5.74 on a scale where 7 equals "strongly agree"), concerns over unintended side-effects of SAI are high (mean value 4.62 on a scale where 7 equals "strongly agree).

For novel CDR methods involving geological storage such as DACCS, participants anticipate local opposition and are vocal about concerns relating to siting, storage safety and risks of leakage, with analogies being drawn to both fracking and nuclear waste: *"The problem with underground storage is that in our region is a place where nuclear waste is supposed to be stored, and we do not know what will happen. Of course, CO_2 is not as dangerous, but the people living there are always affected"* (German Focus Group, Urban)

For SAI and space-based geoengineering German participants acknowledge the hypothetical benefits related to lower temperatures (i.e. *"the benefit would be the inverse of the damage of climate change")*. Overall, most participants are, however, very skeptical and contest even framing these as benefits as – in the words of one participant - they seem more *"about preventing catastrophe"*. Unpredictable changes in weather and precipitation, high costs, unequal impacts across regions and unequal capacities in poorer countries as well as potential irreversibility of some impacts are widely shared concerns.

Survey respondents in Germany tend to agree that all the SRM approaches would "decrease the motivation to reduce CO2 emissions". Among the CDR methods these concerns are the highest for DACCS, BECCS, ERW and Blue Carbon (with values close to four). In the context of discussing SRM, one participant expresses such concerns about mitigation deterrence and the limits to "technofixes": *"The problem is that if we offer a technological solution to the world with which the problem is solved, people will not change their behaviour. They will eat too much meat and fly too much because they think that there will be the mirror or we will put it into the ground. This is the wrong approach."* (Germany Focus Group, Urban).

When it comes to the various CDR and SRM technologies investigated in the survey, results indicate that Italian respondents are not familiar with any of the interventions except afforestation. This is reflected in the conversations in the focus groups, in which multiple participants highlight their difficulties in understanding the material or their desire to know more. Moreover, in line with the results from the survey, CDR technologies receive more favor compared to SRM, although several participants describe CDR and SRM both as ways to reduce the symptoms without curing the problem, "*like taking a painkiller when you have a headache*" (Italian focus group, Urban), and highlight the need for a cultural change among single individuals and communities alike. "*Maybe much less could be enough. For example, here in Sicily, public transport doesn't work so well. I am forced to take the car even for short distances*" (Italian focus group, Rural).

CDR technologies receive the most favor in both urban and rural focus groups, with rural participants expressing less concerns. Afforestation is perceived to be the most natural, effective, cheap, efficient and long-term intervention with no unknown side-effects and providing shared gains. BECCS, DACCS and ERW are critiqued by the participants for a variety of reasons. On BECCS, shared concerns refer to storage safety and leaking risks, with associations drawn to wastelands. To this point, some participants suggest that if it was described as "*recycle*" rather than "*storage*" of carbon, it would provoke fewer negative feelings. Beyond storage, for DACCS concerns revolve around the need to build new plants and the energy they consume to function, which production generates additional CO_2. ERW raises doubts for its need for energy and the need for "*more and more stones*" to crush. Interestingly, this only concerns the urban participants as the rural ones perceive this intervention as more natural, less expensive and free of storage hazards. "*I think that is a natural restoration of nature. It's not like something imposed or something chemical. It is something natural*" (Italian focus group, Rural).

Italian participants mention disappointment or concern that most of the gains seem economic in nature and directed towards private companies, e.g., fossil fuels and constructions in the case of DACCS. Opinions

are more positive when the gains identified include either no-one, as for ERW, or all individuals as in the case of BECCS, in generating residual heat that can be redistributed to the neighboring communities. SRM interventions are often described as "*science fiction*", "*too innovative*", "*not real solutions to the problem*", and participants report "smiling" when reading the corresponding material beforehand. Economic disparities between geographical areas are often mentioned in relation to the perceived high economic costs and technological equipment that the implementation of these technologies would require. "*The sun shields should be over the entire planet or over a specific area. So, the rich countries would benefit and what about the poor countries, do they instead suffer under the sun rays?*" (Italian focus group, Urban). However, after some discussion a few participants of the rural focus group open up towards these interventions, considering them less invasive than CDR and deferring to experts and global leaders for a just and equal implementation. "*This is more science fiction, more impactful, but I would not underestimate it at all. Speaking about the future and thinking about the future we plan and innovative things, I think this could be a valid alternative*" (Italian focus group, Rural).

When assessing benefits and risks, Norwegians perceived afforestation reforestation and soil carbon sequestration as having more benefits than risks. However, technologies like space-based geoengineering, marine cloud brightening, and SAI were perceived as having higher risks than benefits. Survey respondents strongly emphasize benefits for afforestation and reforestation, with a mean score of 4.77–5.81 (on a scale from 1 – strongly disagree to 7 – strongly agree), while the mean scores on the risk side ranged between 4.12 and 2.23. Space-based geoengineering, marine cloud brightening, and SAI all tended to have higher scores on the risk side than the positive side.

In the focus groups, the Norwegian participants mostly addressed potential risks and side effects of various large-scale environmental interventions, such as space-based solutions, marine cloud brightening, and deforestation. *"The risks might be if it doesn't work, and it pollutes even more. Sending up equipment into space does pollute a lot as well as developing all the products you'd need on that big a scale. And if it doesn't work, you've maybe polluted more than you've gained."* The concerns raised include increased pollution, uncertainty about the effectiveness and side effects of these interventions, and the potential destruction of cultivated land: *"But when it comes to 3, that is marine cloud brightening, I'm afraid that if one sprays sea salt, one will destroy large parts of cultivated land."* Additionally, there are worries about the release of carbon and the long-term environmental costs: *"The risk is that we'll run into the problem again. The carbon will be released again, and we'll be back to square one. Another risk is that there will be a lot of forests, in Norway we already have a lot of forests. It says that on a bigger scale, we don't know the complete costs and side effects, and I'm not sure what other side effects there might be other than that at some point in time, it'll be released again if we chop trees or dig the earth/soil. We pretty much do that anyway."*

Participants had mixed opinions about climate engineering as a potential solution to climate change in the UK. UK participants expressed concern about the lack of testing and limited knowledge of most of these technologies, both in urban and rural settings. During the focus groups, they wanted to re-read the briefs to get a better understanding of the context. But urban UK participants also felt hopeful on learning about the potential of sea grass to storage $C0_2$, quoting "*…it grows really fast, and it's good for fish, we can do it in the UK and it's in the sea so people aren't going to grow food there anyway."* The focus group participants highlighted that most of the climate interventions were unknown to them, and this lack of awareness restricts them from making any judgments about their suitability. The participants emphasized that scientists are the most suitable individuals to discuss the risks and benefits of these interventions; otherwise, large businesses such as fossil-fuel firms could easily manipulate the communications surrounding these solutions to profit from the climate crisis.

We discovered a knowledge gap when it came to SRM, which included adding aerosols to the stratosphere, making clouds brighter in the ocean, and space-based geoengineering. More than two thirds of the people who answered our survey said they had never heard of SRM. Participants stated that understanding the concept of SRM is challenging due to its lack of testing. For example, "*they seem like things you'd see in a movie more than anything else, like spraying the particles"; "I don't understand it to know how it would work. I was very confused"*. Both urban and rural participants further associated naturalism with the contexts of carbon dioxide removal approaches, highlighting them as slightly *more holistic* and environmentally friendly options. One respondent said they are *"very positive, storing carbon and different ways of doing that to what naturally happens"*. It was echoed across the focus groups that they do not have enough information on SRM techniques.

3.1.3. Governance and role of trust in actors

Regarding governance mechanisms for the implementation of both conventional and novel CDR approaches, Austrian focus group participants identify the need for incentives for farmers, landowners and communities. Participants also identify – though in other words – the Polluter Pays principle as a way of publicly financing what they perceived to be high cost, high energy technologies, most notably DACCS.

In terms of governance of the SRM approaches, focus groups participants identify the need for a globally coordinated approach, for example under the auspices of the UN, but at the same time consider such coordination highly unlikely, even unthinkable. Mirroring survey results on high levels of trust in university actors – contrasted by low levels of trust in national government and politicians (see more on this point in Section 3.2), Austrian focus group participants consider experts and scientists as important actors in the governance of CDR and even more so SRM approaches, demanding more information and unbiased advice from them. Misconceptions among some participants, for example, on the risks of removing too much CO2 thereby harming plants give importance to public engagement and communication by scientists in the field. Furthermore, both survey results (mean value for trust in industry = 2.81 on a 1–6 scale where 6 equals high trust) and focus group discussions reveal that Austrian respondents take a particularly critical stance towards the role of industry actors and corporations when it comes to implementing climate technologies, due to mistrust of commercial motives and profit-seeking as well as the above-mentioned risks of delaying emissions reductions.

In Germany, when asked about actors and measures important for governing the different CDR methods, coordinated governmental efforts, strong regulation for zoning and incentive mechanism are brought forward as essential. For conventional CDR methods relating to or competing with agricultural practices, the EU is seen as key actor complementing national-level actions. Resonating with the storage concerns mentioned earlier, governmental coordination and the provision of a regulatory framework for private sector activities in this field are particularly emphasized for methods like DACCS, as explained by this participant: *"This is like nuclear power; it cannot be done by a company alone. We do not know how dangerous a CO2 storage facility would be. It is similar to wind turbines as well. The state has to manage it, but companies can develop it. Musk cannot just be able to start building, for example, not in Germany."* (German Focus Group, urban)

Reflecting survey findings that show high levels of trust in university actors but low trust in the national government and politicians, German focus group participants view experts and scientists as key players in the governance of CDR and, even more so, SRM approaches. They emphasize the need for more information, research, assessments and impartial guidance from these experts. Debates about delegating decision authority to experts are particularly pronounced in the German groups and often tied to skepticism about public participation in decision-making, as one participant elaborates regarding SRM: *"If the world ends, it is too late anyway, and I would not include people. There would be endless discussions on democracy and human rights, and some would fly to the moon. I think scientists and engineers should provide information, but they should*

also make the decision because they have the knowledge. We have climate change, but not everyone accepts it." (German Focus Group, Urban)

Moreover, like in the Austrian case, both survey results (with a mean trust level of 2.9 on a 1–6 scale where 6 indicates high trust) and focus group discussions highlight that German publics hold a particularly critical view of industry actors and corporations in the implementation of climate technologies. This skepticism stems from distrust of commercial motives and profit-seeking behavior, as well as concerns about the potential for these actions to delay necessary emissions reductions. Arguably this limited trust is also reflected in strong support among German survey respondents for establishing an international organization to conduct oversight and set standards for CDR and SRM technologies alike.

In Italy, "the government" is often the default answer to the question on the figures that should make the decisions regarding the governance and the implementation of these technologies, but while reflecting, the Italian focus groups participants express themselves differently considering CDR and SRM. SRM technologies are perceived as vast and expensive efforts, unsuitable and unfeasible to sustain by single countries. To overcome this obstacle, participants advocate for international collaborative efforts of countries, such as through the EU or UN, because "*we cannot all launch in space a satellite, there are only 2–3 superpowers that can do it*" (Italian focus group, Rural). Instead, participants perceive CDR interventions to be more related to the geographical areas in which they are deployed and, thus, needing a national or local administration with in-depth knowledge of the territory. "*I think it should be managed by the national government. […] The government provides the guidelines and then these have to be followed at the local level*" (Italian focus group, Rural).

In line with the results from the survey, however, scientists and technical experts are the most trusted actors and those that "*in an ideal world*" would provide the indications to follow. Some of the participants would prefer a collaboration between scientists and the government, while others call for an executive scientific committee "*so that there are no issues between different governments and interests, and none prevails*" (Italian focus group, Urban). In the conversations, expert knowledge is often invoked when participants have doubts over the application of the technologies or when they do not understand them fully. "[…] *this way we would make carbon dioxide fluid, and then I'm sure chemists know what to do with it*" (Italian focus group, Urban).

When it comes to the role of the general population in the decision-making concerning these technologies, Italian participants are ambivalent. Some clearly state that they would not like to be involved in any decision, or that they do not care who takes the decision "*as long as they* [the decision makers, Ed.] *do something*". Most participants struggle to identify a role for the general public in decision-making and some suggest that there shouldn't be any. "*I would like to be an aerospace engineer but since I am not, I do my things in my field and each one of us has their own. I think that all those who have the expertise in this setting should be involved, but only them*" (Italian focus group, Rural). However, there is agreement on the need for the population to be informed by the national government through, e.g., awareness campaigns on various platforms, such as television, the internet, and in schools. Such campaigns should aim at communicating developments and technical information about these technologies in accessible ways, without excluding their economic aspects. "*I would like to know the economic aspects. If you invest in research or in the environment, the entire community will benefit. We need to understand the value of this aspect*" (Italian focus group, Urban).

Norwegians have a high level of trust in governments and international organizations such as the UN and EU to implement CDR and SRM. The importance of global cooperation, government involvement, the role of local governments, economic incentives, and the involvement of scientists, industry representatives, and the public in decision-making processes was emphasized both in the survey and by the focus group. Norwegians scored high related to trust in the industry (3.49), universities (4.38), government (3.27), UN (3.8) and NGOs (3.38), on a scale from 1 to 6, where the highest score represents high trust. The values associated with the government and the UN were above the other countries, while Italy scored higher on trust in industry, universities and NGOs. The high level of trust in governments and the UN to implement CDR and SRM is reflected in focus group interviews. Many participants emphasized the importance of global cooperation and government involvement in addressing environmental issues, as well as the significance of international organizations such as the United Nations (UN) and the European Union (EU) in managing and implementing CDR and SRM. One participant said *"I don't think that one specific country should be responsible and be the implementer of it. It's more a world problem, and like the others, I think that an organisation within the UN should be responsible and manage it. And where each country contributes with their share to it, and that each country via their politicians are part of voting and managing the decisions that the UN implements. I think that none of these suggestions are suggestions that one single country can be in charge of, it needs to be the world and do it via the UN."* Additionally, the role of local governments, economic incentives, and the involvement of scientists, industry representatives, and the general public in decision-making processes were also highlighted in Norway.

In the UK, both urban and rural participants stressed the importance of who communicates and builds awareness around these technologies. Participants highlighted *people who are neutral* like scientists should be involved in the decision making for technologies where there are a lot more unknowns. The designation of scientists as trustworthy actors was put forward due to their knowledge and training in 'developing' these products. For example: *"… I'd rather they listen to the scientists who actually know how this can be used most effectively…"*. Participants from the rural UK also highlighted the role of science communication that works in the interest of the public. For example: *"there should be simplified papers for non-scientific folk to understand exactly what these measures are, what the proposals are, so that we may not be the ones who are making the decisions or ultimately saying yes or no"*. Beyond scientists, participants urge the need to form a global consortium like the UN to oversee decision making. Some highlighted that it is important to see the scale of deployment. For example, *"Just the areas that are affected, they should make the decision. That's the fairest way to do it"*. Similarly, we found that engaging local knowledge and synthesizing it with trustworthy actors like scientists was stressed by the participants as the right way to design policies and governance rules, especially if the climate intervention techniques involved using local resources like farmlands, for storing carbon in soil. For instance, *"I think farming bodies should be involved in the decision-making process. That's where it's going to happen. It's going to be in crop fields."* On the flip side, urban participants demonstrated significant distrust in big businesses taking over such solutions and trying to make money out of the climate change problem. For example, *"the companies that make money out of things that are currently polluting, oil and gas producers and oil and gas producing countries"*. Respondents further highlighted that these solutions seem feasible only for *"countries that can afford it"*.

In summary, there is a high variance between countries regarding trust in governments to civil society actors or universities. Across all countries, trust in experts such as scientists is highest and trust in industry comparatively low. This seems to result in calls to establish oversight by expert groups, rather than leaving the private sector unregulated.

3.2. Comparative themes across the five countries

Looking across rather than within all five countries, we further analyze six dimensions of our survey data: familiarity, policy support, aversion to tampering with nature, environmental identity, trust in actors, and experience of climate change.

3.2.1. Familiarity

Across all five countries respondents are most familiar with forestry, soil management, and marine biomass and blue carbon and least

familiar with marine cloud brightening, atmospheric aerosol injection, and ERW. When looking at specific countries, the Germans and Austrians appear to be express greater familiarity with ecosystem-based options, relative to the other countries considered, and the Norwegians with novel or "engineered" carbon removal options especially those coupled to carbon storage such as DACCS and BECCS (See Fig. 1).

Austrian respondents express greater familiarity with conventional, nature-based carbon removal methods, particularly afforestation and reforestation and soil carbon sequestration. Likewise in the focus groups familiarity is clearly the highest with those approaches that participants repeatedly refer to as natural, established, tried and tested practices. Arguably forestry and agriculture are small, but traditionally important sectors in the Austrian economy (OECD, 2024; Kirchner et al., 2015) and unlike any of the novel CDR methods such as DACCS or BECCS, forest sinks, soil sinks and harvested wood products are highlighted in the Austrian long-term low emissions development strategy (LT-LEDS) (Buylova et al., 2021).

Overall, focus group participants repeatedly express a desire to be better informed and expect scientists and other experts to share their knowledge, particularly on novel CDR technologies and SRM proposals in simple and accessible ways.

As for the other countries, German respondents also report the highest familiarity with ecosystem-based CDR. Comparing across the five countries, we find the highest familiarity with afforestation and reforestation, soil carbon sequestration and marine CDR among German respondents. Like in the other countries, a clear majority of German respondents say they have never heard of the SRM approaches introduced to them.

According to the survey, Norwegians are most familiar with "afforestation and reforestation," with only 13 % percent reporting they are not familiar at all, followed by "Soil carbon sequestration" with 38 % not familiar. Familiarity with BECCS, and DACCS was comparatively high with 46 % and 50 % not being familiar, much less than in the other countries (see appendix D). One possible explanation for these measures' comparable high familiarity levels is that carbon capture and storage (CCS) has been a topic of public debate in Norway for years. The Norwegian government has also made significant investments in CCS

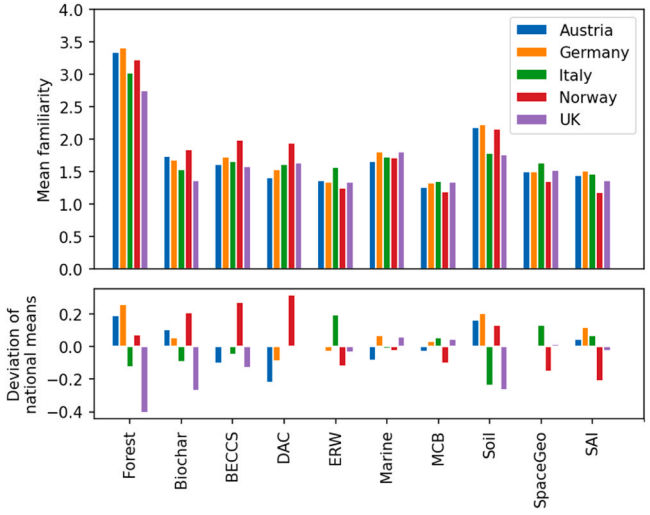

Fig. 1. Familiarity of climate interventions among five European countries. Source: Authors, the upper panel shows the mean based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to a five-point Likert scale where 0 =never heard of it, and 5 =very familiar. The lower panel highlights deviations of the country means from the overall mean. SAI=stratospheric aerosol injection. MCB=marine cloud brightening. DAC=direct air capture. BECCS=bioenergy with carbon capture and storage. ERW=enhanced rock weathering.

policy, and Norway aims to become a key partner in Europe for future CO_2 storage.

Italian respondents do not seem to deviate from the general trend. They report being more familiar with CDR technologies than with SRM ones. Among these two families of technologies, afforestation and reforestation are by far the most known interventions and marine cloud brightening the least known. Moreover, compared to other countries, Italians seem to be express slightly greater familiarity with space-based geoengineering and ERW. Discussions in the focus groups mirror in part this result as ERW is mentioned as familiar by only a couple of participants.

In the UK, the familiarity with conventional, nature-based solutions was greater than that with other climate interventions. This may stem from the familiarity and benefits of the UK's physical environmental attributes, such as its extensive coastline. For example, one focus group participant noted that this might yield specific benefits given that: *"there's so much coastline in the UK, and some kind of sea-grass can absorb maybe 10 or 20 times as much as the rainforest does, which is insane" (UK Focus Group Rural.* And its rich forestry attracts tourism, thus helping the local community. For example, one participant said that the *"local Scottish community sees increase in tourism due to beautiful regrown forestry" (UK Focus Group Urban)*. Additionally, the most common reason for supporting nature-based interventions was the perception that forests and soil carbon are *'environmentally friendly'*. However, overall, UK respondents reported less familiarity across all climate interventions than those in other countries. For example, a high percentage of the UK respondents reported not being at all familiar with afforestation and reforestation (26 %) and soil carbon sequestration (57 %). These numbers are similar for respondents in Italy, though much lower than in the other countries.

3.2.2. Policy support

In the following, we first present results on the support of different policies on SRM followed by support for CDR policies across all five countries. The most preferred option for SRM at a national level entailed information and education campaigns, followed by policies to enable SRM; at an international level there was support, though to a somewhat lower extent, for testing, evaluating, and oversight. Bans and moratoria were the least preferred policy option across all five countries. There was also very little support for "none" or no policy interventions (see Fig. 2).

In addition to a strong desire for being better informed, Austrian survey respondents express a greater preference for restrictive and prohibitive policies towards SRM compared to their Italian and Norwegian counterparts. These Austrian results might tentatively be interpreted in the context of skepticism and precautionary positions towards, or even outright rejection of, technologies in general perceived to "intervene in nature". Examples are the particularly controversial debates and restrictive policies around GMOs in Austria (Seifert, 2021) as well as the national political consensus against nuclear power since the 1970s. Scholars from the field of Science and Technology Studies have come to describe this stance as Austria's "technopolitical identity" (Felt, 2015).

Reflecting very low levels of familiarity with the SRM approaches, German respondents first and foremost express a desire to be better informed, followed by support for establishing an international organization to conduct oversight and set standards for these technologies. Compared to the other countries, support for such an oversight organization is particularly pronounced in the German sample. Support for restrictive measures is higher than in Italy or Norway, while similar in Austria and lower than in the UK.

In the focus groups, Italian respondents highlight the wish to be more informed about SRM and the need for more exploration and testing of these technologies. Despite the low familiarity that Italians report, they still seem to support further development of these interventions more than restrictions. The only policies for which Italian respondents were relatively less supportive were those where international governing

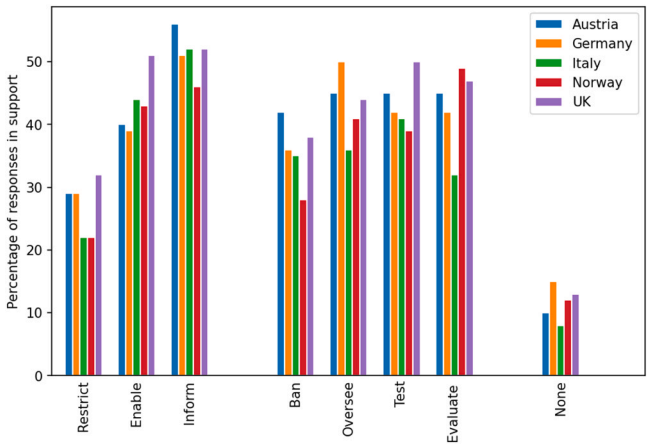

Fig. 2. Policy preferences for solar radiation management among five European countries. Source: Authors. Note: Figure showing the mean value per country based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to a yes/no scale where 1 =support and 0 =does not support. For the policy options, "RESTRICT" refers to "independent national government policies that restrict use of the technology (e.g., to ban or how to regulate"; "ENABLE" to "national-level support and funding by governments that enable the technology (e.g., through grants, subsidies, or tax incentives) for public and private research and development"; "INFORM" to "Information and engagement campaigns to consult and inform the public on the different technologies"; "BAN" to "International ban or moratorium on technologies deemed risky"; "OVERSEE" to "Establishment of international or regional organization to conduct oversight and set standards for the technologies"; "TEST" to "Creation of new international scientific agency to explore different technologies and start testing and development"; and "EVALUATE" to "Generating special report at international level (e.g., by Intergovernmental Panel on Climate Change) to evaluate and assess technologies".

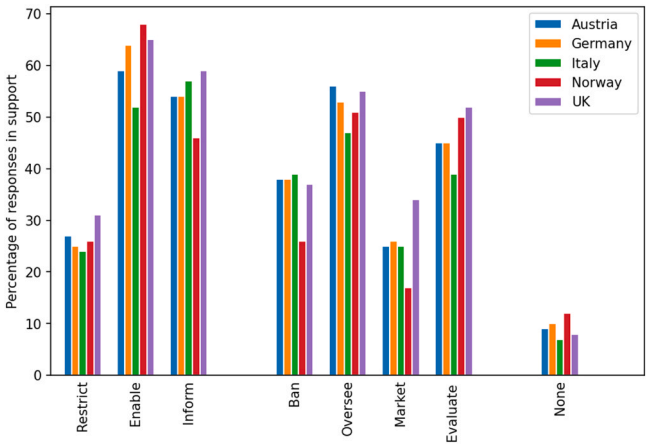

Fig. 3. Preferences for policy support for carbon removal and negative emissions interventions among five European countries. Source: Authors. Note: The figure showing the mean per country based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to a yes/no scale where 1 =support and 0 =does not support. For the policy options, "RESTRICT" refers to "independent national government policies that restrict use of the technology (e.g., to ban or how to regulate"; "ENABLE" to "national-level support and funding by governments that enable the technology (e.g., through grants, subsidies, or tax incentives) for public and private research and development"; "INFORM" to "Information and engagement campaigns to consult and inform the public on the different technologies"; "BAN" to "International ban or moratorium on technologies deemed risky"; "OVERSEE" to "Establishment of international or regional organization to conduct oversight and set standards for the technologies"; "MARKET" to "Global-level market for trading carbon credits and/or offsets"; and "EVALUATE" to "Generating special report at international level (e.g., by Intergovernmental Panel on Climate Change) to evaluate and assess technologies".

bodies would oversee or evaluate SRM. This could reflect a preference among Italian respondents on experimentation rather than regulation (see also Table 3), also in light of the fact that national and international government institutions are the least trusted actors in the Italian context.

On SRM policy, Norway had the highest proportion of respondents supporting a special report at international level to evaluate and assess SRM (49 % in support) and the lowest for an international ban or moratorium (28 %). The relatively lower support for bans, for both CDR and SRM, could indicate that Norwegians are slightly more optimistic that climate intervention may play a key part of solving climate issues. This is also reflected in Norway's current policy support schemes for CCS, and of late direct air capture and direct ocean capture. This is also supported by which also can explain why the comparably higher levels of support in Norway for supportive CDR versus SRM policy options (see Fig. 3).

Similarly, in the UK preferences for carbon removal and negative emissions policy support were strongest for national mechanisms to enable the technology or campaigns to inform the public, as well as international policy approaches that would oversee or evaluate CDR. Bans and restrictions were the least preferred option along with efforts to couple carbon removal options with carbon markets (See Fig. 3).

In Austria, public perceptions of CDR policies may be shaped by a prevailing ban on carbon storage that the government introduced in 2011 due to environmental and safety concerns of geological storage; though somewhat controversial debates around lifting this ban and including CCS and CDR technologies in the national climate plan have recently resurfaced (Brad et al., 2024). In August 2024 – after months of delay – the then conservative-green coalition government submitted its national climate and energy plan to the European Commission, including a recommendation to lift the ban on CCS in Austria (see e.g. Kurier, 14.08.2024). Regarding enabling policies, Austrian focus group discussions make clear that well-designed incentives will be needed for farmers and landowners to engage with conventional CDR methods and even more so for implementing technologies like DACCS where participants identify a potential collective action problem, namely with benefits being global while burdens and potential risks are on local communities.

Overall, German respondents are broadly favorable of national-level support and governmental funding for enabling CDR. Restrictive policies at the national level as well as a global-level market for trading carbon credits and/or offsets are among the least preferred options for CDR governance in Germany. Disaggregating results also reveals that support among German respondents for an international ban on engineered CDR is even higher than for the SRM technologies. At the same time, support for enabling national-level support and funding for engineered CDR is much higher than for the SRM approaches.

Regarding CDR policy support, Italian results show a similar pattern to SRM, though with levels of support generally higher. Also in this case, despite their lower levels of reported familiarity, Italian respondents express a strong desire to be informed through public campaigns along with support for international institutions to undertake more assessment and evaluation of CDR. In agreement with the other countries, Italians seem to also disapprove the creation of a global-level market for trading carbon credits and/or offsets. This mirrors the specific concerns expressed by the participants of the focus groups regarding private actors, especially fossil fuel companies, possibly gaining most of the benefits from the implementation of these technologies.

Norwegian survey participants expressed the highest support for enabling policies (public funding, 68 %), evaluation (50 %), and regulation (oversee, 51 %). However, their support for a ban on CDR or a global-level carbon market was generally low (26 % and 17 %, respectively). The high support for an international-level special report to

assess and evaluate CDR (and SRM) is also reflective of the trust Norwegians have at the international level.

The UK had similarly ambivalent and moderate comparative views of enabling policies for CDR (and SRM), grounded perhaps in positive public feelings about net-zero implementation policies (Lezaun et al., 2021) but counterbalanced against rapid changes in government policy and the sheer nascency of the UK carbon removal market (Herman and Sovacool, 2024).

3.2.3. *Aversion to tampering with nature*

Table 1 indicates that respondents somewhat agree with various statements that we should leave nature alone and that altering the environment will lead to unintended consequences, further contributing to humanity's downfall. Interestingly, most respondents were more neutral about the riskiness of technological solutions.

Of the items, Austrian respondents expressed strongest agreement with the notion that humans should leave nature alone, and to a somewhat lower extent that "altering nature will be our downfall" and that "human being have no right to meddle with nature". ". While showing similarities to the Austrian results on most elements of the aversion to tampering with nature items, German respondents were more likely to disagree that "people who say we shouldn't tamper with nature are naïve" (mean=3.69), the lowest of any country. Interpreted in the context of our focus groups, this can be seen as call for taking public concerns about the risks of novel technologies seriously, rather than dismissing them as irrational or naïve. Italian respondents, meanwhile, were broadly stronger in their aversion to tampering with nature than Germans or Austrians, though with some key exceptions. On the one hand, they expressed the strongest agreement that "altering nature will be our downfall". On the other, Italians were also rather technology-positive, expressing relatively stronger agreement than the other countries that "people who say we shouldn't tamper with nature are just being naïve", along with being somewhat more neutral on the riskiness of technological fixes. An ambivalent position thus emerges that is concerned for the integrity of the environment while still skeptical of the role of technology as a way to get out of the climate crisis. Norway stands out among the set of countries, with mean scores that are the lowest on 4 out of the 5 questions. Overall, this indicates a much lower degree of affinity for nature or that intervening in nature is something harmful or to be avoided. One possible explanation could be the importance of the Oil and Gas industry as a crucial sector for jobs and wealth creation, along with the emergence of climate solutions in the country which are largely technical, such as electrification of oil and gas platforms, CCS and electrification of the vehicle stock. Together these might reinforce such a techno-optimist worldview. Finally, in the UK, respondents were in general averse to the idea of tampering with nature, though to an extent that was in the middle among the countries considered.

Looking at the distribution of responses to the items for aversion to tampering with nature (see Figure A1 in appendix D), we can see that there was a greater divergence of agreement for "people who say we shouldn't tamper with nature are just being naïve" (with a standard deviation, σ, of 1.78). This was closely followed by "Human beings have no right to meddle" (σ= 1.71). These two items are also notable for being the only ones where the mean of participants in one of the countries tended more to disagree: Germany for "people… being naïve"; Norway for "human being have no right to meddle". "Technological fixes are risky" is the least controversial statement in this category (σ= 1.54), with all country means being very slightly above 4.0. Overall, the variation across participants within a given country is much larger than the differences between countries, as shown in Fig. 4. Previous studies show that views on tampering with nature strongly influence people's attitudes towards climate interventions (Corner et al., 2013; Wolske et al., 2019). Here, we also find a negative correlation (-13 %) between the mean of all responses in this category and the strength of support for climate interventions.

3.2.4. *Environmental identity*

Table 2 illustrates that, in general, Austrians, Germans, and Italians express greater levels of environmental identity than those in the UK or

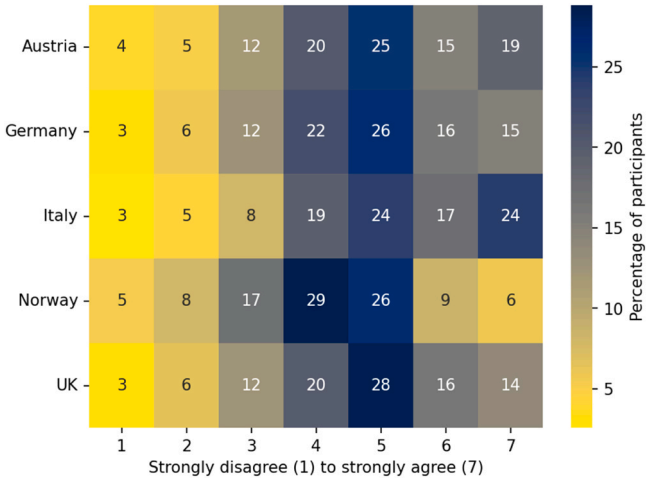

Fig. 4. Agreement to statements on aversion to tampering with nature across countries within our survey. Source: Authors. Share of participants agreeing to different statements on tampering with nature (except for "people … being naïve", see Table 1).

Table 1
Aversion to tampering with nature among respondents from five European countries.

	Technological fixes are risky	People who oppose are naïve	Human beings have no right to meddle	I would prefer to live in a world where humans leave nature alone	Altering nature will be our downfall
Austria	4.47	4.44	4.6	5.38	4.7
Germany	4.48	3.69	4.5	5.21	4.62
Italy	4.27	4.84	4.79	5.62	5.57
Norway	4.1	4.46	3.73	4.5	4.14
UK	4.42	4.11	4.4	5.02	4.91

Source: Authors. Note: based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to (1 = Strongly disagree, 2 =Disagree, 3 =Somewhat disagree, 4 =Neither agree nor disagree, 5 =Somewhat agree, 6 =Agree, 7 = Strongly agree). Full item for "people who oppose are naïve" is "people who say we shouldn't tamper with nature are naïve"; full item for "technological fixes are risky" is "people who push for technological fixes to environmental problems are underestimating the risks". Green shows more positive perceptions, yellow ambivalent, and red low levels of support for each question.

Table 2
Environmental identity among respondents from five European countries.

	I am concerned about the environment	*Being environmentally friendly is important*	*I behave in an environmentally friendly way*
Austria	4.89	4.55	4.51
Germany	4.69	4.33	4.34
Italy	4.86	5	5.01
Norway	3.51	3.52	3.8
UK	4.41	4.13	4.22

Source: Authors, based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to [seven-point scale: 1 = "totally disagree", 4 = "neither agree nor disagree", 7 = "totally agree"]. Green shows more positive perceptions, yellow ambivalent, and red low levels of support for each question.

Norway (the lowest scorer in this category). Italy also leads with respondents indicating that environmental lifestyles are important and that they behave already in an environmentally friendly way.

Across the three items, survey respondents in Austria – although less than their Italian counterparts - self-report comparatively strong environmental identities relative to the set of countries. While rather strong levels of environmental identity were also mirrored in the focus groups, participants in those groups tended to caution that concern for environmental and climate issues was likely to be low in the general population. Interpreted in the context of our survey results, this might point to misconceptions and an underestimation of environmental concerns and climate beliefs in the wider population, also found in other national contexts (Mildenberger and Tingley, 2019; Sparkman et al., 2022). Responses of German participants are similar to those of their Austrian neighbors, although focus group participants in Germany more accurately estimated the level of environmental and climate concern to range from moderate to high in the general population, as indicated by our survey results.

Compared to the other countries considered here, Italians self-report to be the most environmentally friendly population. Indeed, beyond expressing as much concern as other countries, they assigned strong importance to behaving in an environmentally friendly way. Eurostat reports that Italy is the country in Europe with the highest rate of waste recovering by recycling (Eurostat, 2020). Thus, it might be the case that respondents associate activities such as home waste sorting as indicative of environmentally friendly behavior.

Norwegian respondents had the lowest scores among all countries on environmental behavior and concerns – this mirrors the results for aversion to tampering with nature (see Table 2). The average scores for Norwegians were all below the mid-point of 4, expressing slight disagreement: i.e. 3.51 for the statement "I think of myself as someone who is concerned with the environment," 3.52 for "Being environmentally friendly is a part of who I am," and 3.80 for "I am the type of person that behaves environmentally." A possible explanation here, also reflected in the focus interviews, is that few Norwegian respondents report having personally experienced major disasters in the last three years (see Section 3.2.6). Overall, Norwegians tended towards highlighting that the most severe consequences of climate change would be for other countries and for future generations.

Finally, survey respondents in the UK express moderate levels of environmental identity. This also mirrors the results for aversion to tampering with nature (see Table 2); though, unlike for the Norwegian participants, there was still slight agreement for each of the items.

3.2.5. *Trust in actors*

Table 3 illustrates trust in different types of actors across the countries. Trust in scientists, or the lack thereof, is shown to play an important role for public perceptions of climate change, and the severity of climate denialism in particular (Alvarez et al., 2023). Trust in industry actors has also been identified as a key variable for public support of climate intervention technologies (Brutschin et al., 2024). The authors specifically find that those with higher trust in these actors were more likely to support deployment of CDR and SRM – a smaller role for trust in national governments was also identified, specifically in relation to novel forms of CDR and SRM.

Adding to these studies, our survey results provide consistent evidence that universities and NGOs are the most trusted versus national governments the least trusted. The levels of trust expressed in industry and corporations in the field of climate change and international institutions such as the United Nations is notably more mixed.

Asked to assess how much they trust the selected groups and institutions when it comes to the responsibility and ability to use CDR and SRM technologies, Austrian respondents placed the highest trust in universities and scientific institutes, mirroring focus group results on the

Table 3
Trust in institutions and actors among respondents from five European countries.

	Industry	Universities	Government	UN	NGO
Austria	2.81	4.35	2.69	3.15	3.62
Germany	2.9	4.29	2.86	3.19	3.55
Italy	3.69	4.54	3.11	3.47	4.02
Norway	3.49	4.38	3.27	3.8	3.38
UK	3.25	4.25	2.83	3.26	3.68

Source: Authors, based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Rankings are scaled to [six-point scale: 1 = "No trust" to 6 = "Very high trust"]. Full items for the institutions and actors are: "industry and corporations in the field of climate technology" for "industry"; "universities and scientific research institutes" for "universities"; "national governments and official agencies" for "government"; "international government institutions (e.g., United Nations)" for "UN"; and "non-governmental organizations (e.g., environmental and climate groups) for "NGO". Given that the mid-point of the scale is 3.5, we use green to show more positive perceptions, yellow ambivalent, and red lower levels of support for each question.

critical role of experts and scientists. Even more pronounced than in the four other countries surveyed, trust in the ability of the national government to govern these technologies responsibly is the lowest among the different actor groups. Austrian survey results also stand out with particularly low levels of trust in industry and corporations in the field of climate technology. Levels of trust among German respondents are very similar to those found in Austria, expressing distrust in governments and industry actors regarding their responsibility and ability to use climate-intervention technologies. Italians report a similar trend with universities being the most trusted institutions and the national government the least trusted. The comparatively high scores for industry and NGOs stand out for this country, which is in contrast to results from the focus groups, where industry is not negatively discussed and NGOs were not mentioned at all. In comparison, Norwegians have the highest trust in the national government (mean=3.27) and in the UN (mean=3.80). The high trust in the government may reflect the active role taken by the Norwegian state in CCS development, as well as a comparably higher support for technological fixes (see Table 1) and the policy style of cooperation known as the "Nordic model," which emphasizes strong cooperation between industry organizations and the Norwegian government (Midttun and Witoszek, 2020; Ervasti et al., 2008). Additionally, due to being a relatively smaller country, Norway has also emphasized cooperation globally for tackling the climate crisis, which might also explain the relatively high trust in the UN. For the UK, respondents placed the least trust in the national government and higher levels of trust in the universities. This highlights the critical role of scientists in interfacing with the public. This was reflected in the focus group discussions as well, where the respondents stressed that scientists should be the ones communicating about climate intervention and take the lead in educating the population. The trust levels placed in the industry and UN were, similar to other results for the UK, in the middle of the countries considered.

3.2.6. *Experience of climate change*

Our analysis of European perspectives also finds that experience with climate change is correlated with support for climate interventions. This finding reinforces a common thread in the extant literature (Merk et al., 2015; Jobin and Siegrist, 2020; Cox et al., 2020, 2024; Fritz et al., 2024; Nawaz et al., 2023; Scott-Buechler et al., 2024).

For example, more than a third of Austrian survey respondents report having experienced a major natural disaster in the last three years (See Fig. 5, Panel A). While participants in the Austrian focus groups tend to more strongly emphasise the climate impacts for future generations and vulnerable communities in the Global South, they do also mention some experiences with climate change impacts in Austria today, including heatwaves and droughts, changes in seasons and the melting of glaciers.

German respondents overall express slightly greater climate worry than their neighbours (64 % vs. 56 % say that are “very” or “extremely” worried), with 38.5 % of respondents reporting having experienced natural disaster in the last three years (see Fig. 4); yet the results of the two countries are comparable. Focus group participants in Germany predominantly perceive climate change as an inter-generational issue, anticipating impacts on their children and the next generation though they are not unaffected.

Interestingly, very few Italians report experiencing personally the effects of a major natural disaster: only 15.7 % of the respondents. This result is particularly puzzling considering the geographical location of Italy and the characteristics of its territory which is known to be vulnerable to natural disasters such as extreme heat, drought, or floods (EU Risk Data Hub, 2022) – major floods did actually occur in the Marche region of Italy a month or two prior to data collection. Participants in the focus groups were at least somewhat cognizant about natural disasters, specifically droughts (see Section 3.1.1).

Norway stands out concerning little personal experiences with climate impacts, with 11.6 % of Norwegians indicating that they have personally experienced the effects of a major natural disaster in the last three years – this is also echoed by the greater emphasis in the Norwegian focus groups on climate impacts on future generations and the global consequences. It is important, though, to note that the context of the survey here, for instance, there were extreme weather events in the south and east of Norway in summer 2023 (Rüther et al., 2024). Had the survey been conducted some months later, maybe the findings would have been different. Additionally, there was a dry in the summer of 2018 (Beitnes et al., 2022), which was ahead of the time period requested, which was the last three years from 2022.

The respondents in the UK were the most likely to state that they had experienced the effects of a natural disaster in the last three years, at 41 %. Looking at the focus groups, participants were especially vocal about climate impacts in urban areas. Heatwaves and flooding were the most discussed impacts among such participants, while rural participants highlighted their concerns about the intergenerational impacts of climate change more directly. In general, participants expressed their

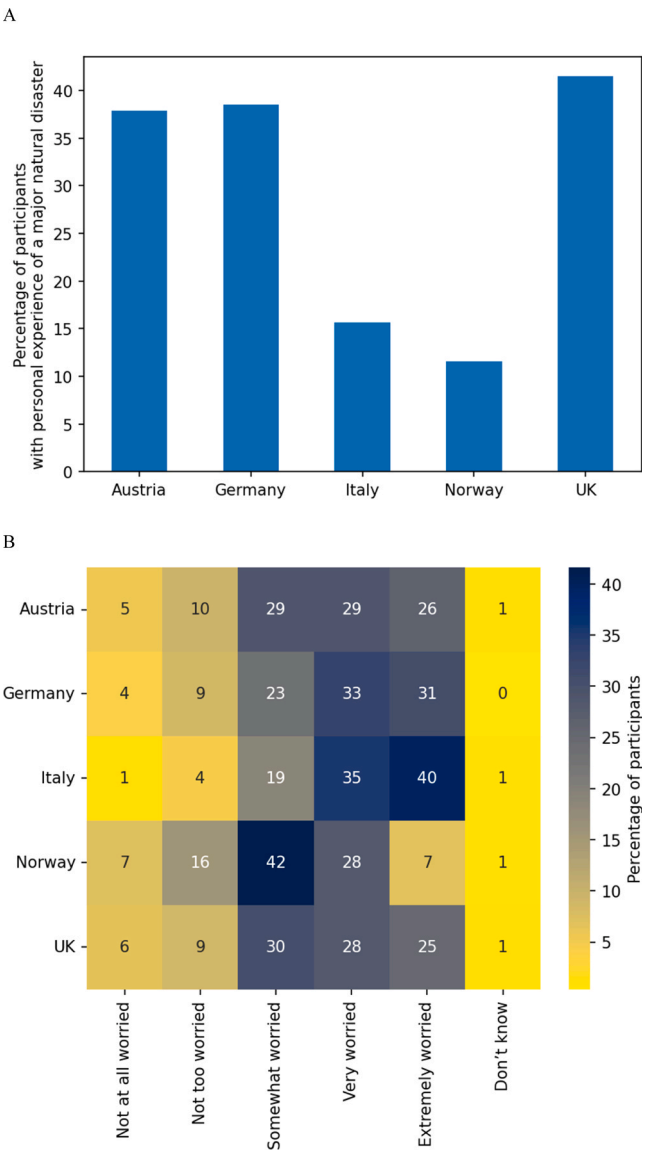

Fig. 5. Personal experience of natural disasters and worry about climate change. Source: Authors, based on a representative survey of Austria (N = 1005), Germany (N = 1025), Italy (N = 1002), Norway (N = 1002) and the United Kingdom (N = 1028). Panel A shows the percentage of participants indicating personal experience with major natural disasters (e.g., floods, heatwaves, blizzards, wildfires) over the last three years. Panel B shows how worried respondents are about climate change and global warming.

anxiety about rapidly escalating impacts and how they may impact their children and the next generation.

4. Conclusion

This study draws on five nationally representative large-N surveys and ten focus groups (one rural and one urban in each of Austria, Germany, Italy, Norway and the UK), to provide mixed-methods insights into the national contexts on perceptions and perspectives on climate interventions. Triangulating results from surveys and focus groups allows us to identify and explain detailed patterns of differences and convergences across a set of European countries. In terms of knowledge and literacy, most of our respondents across the five countries lack familiarity with most of these options. Although qualitative statements from focus-group respondents provide a sense climate interventions could play a role in tackling climate change, such options remain difficult for them to understand.

In terms of regional variation among the countries, our evidence suggests that Germans and Norwegians express the greatest familiarity with climate interventions. Also, Germans emerge as the most supportive across all the countries considered for better policy evaluation and oversight. Universities and scientific research institutes emerge as the most trusted actors in the space of climate intervention governance, while national governments were the least trusted. Respondents in Austria, Germany and the UK also reported stronger, more direct experiences of climate change impacts than others, which also seemed to inform their perceptions.

However, our evidence also points to a large degree of similarity, confirming previous research (Visschers et al., 2017; Bellamy et al., 2021; Contzen et al., 2024). In terms of knowledge and understanding of climate interventions, most of our respondents across the five countries lack familiarity with most of these options. Although qualitative statements from focus-group respondents provide a sense of how climate interventions could play a role in tackling climate change, it must be underscored that such options remain difficult for them to understand. Across our data, most respondents also reported greater concern about climate change, but were broadly averse to tampering with nature, and tended to hold moderate environmental values. We also find that the variation across respondents within countries is much larger than the differences between (the means of) countries. As a result, this signals the potential for nascent polarization when it comes to debates of climate intervention (see also Brutschin et al., 2024); at the same time, it could also suggest the stronger possibility of regional discussions at the European level to reach some kind of consensus on how to govern and regulate these techniques.

In the context of policy design, our study infers that embedding oversight in trusted scientific institutions rather than relying solely on national governments or private companies is a key ingredient for effective governance (see also Fritz et al., 2025). Yet legitimacy cannot be taken for granted; it must be cultivated through upstream deliberative mechanisms like citizens' assemblies, mini-publics and targeted outreach to under-represented rural and lower-education constituencies before any large-scale deployment decisions are taken (e.g. Fritz et al., 2024).

We therefore offer three clear implications for debate and discussions of climate interventions. First, governance design must leverage trusted scientific institutions as communication bridges while developing context-sensitive policies that accommodate local diversity. Second, proactive integration of public ambivalence and ethical concerns related to the deployment of these techniques is needed to promote greater equity and justice substantively or symbolically, particularly on SRM, given evident knowledge gaps identified in our data. Finally, as a third point, future research on this topic must expand beyond Europe's relatively homogeneous contexts.

The current paper usefully focuses a narrow lens on intra-European perspectives of CDR and SRM, in a way that provides insights into how discussions in this context will evolve in the future. At the same time, it thereby identifies how such countries are fundamentally similar – though there are greater disagreements among their own citizens – and as a result how the insights that result cannot be used to infer, or indeed generalized, to regions facing disproportionate climate impacts.

As climate interventions transition from discussions of pilots to prospective deployment and use, our study underscores that a nuanced understanding of public perspectives and concerns and ample opportunities for bottom-up engagement must be embedded into policy and governance architectures at an early stage. Going forward, engaging with these diverse views that exist within countries, both within Europe and beyond, emerges as a crucial prerequisite for ensuring equitable and just deployment of climate interventions and providing policymakers and regulators with the necessary input to develop policies and frameworks that are enriched through public consultation.

CRediT authorship contribution statement

Livia Fritz: Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Chad M. Baum:** Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis, Data curation. **Sovacool Benjamin:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Hans Jakob Walnum:** Writing – review & editing, Writing – original draft. **Finn Müller-Hansen:** Writing – review & editing, Writing – original draft, Visualization. **Loci Lucilla:** Writing – review & editing, Writing – original draft. **Ramit Debnath:** Writing – review & editing, Writing – original draft. **Elina Brutschin:** Writing – review & editing, Writing – original draft.

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.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2025.104287.

Data availability

The data that has been used is confidential.

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