Using decision pathway surveys to inform climate engineering policy choices

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Over the coming decades citizens living in North America and Europe will be asked about a variety of new technological and behavioral initiatives intended to mitigate the worst impacts of climate change. A common approach to public input has been surveys whereby respondents' attitudes about climate change are explained by individuals' demographic background, values, and beliefs. In parallel, recent deliberative research seeks to more fully address the complex value tradeoffs linked to novel technologies and difficult ethical questions that characterize leading climate mitigation alternatives. New methods such as decision pathway surveys may offer important insights for policy makers by capturing much of the depth and reasoning of small-group deliberations while meeting standard survey goals including large-sample stakeholder engagement. Pathway surveys also can help participants to deepen their factual knowledge base and arrive at a more complete understanding of their own values as they apply to proposed policy alternatives. The pathway results indicate more fully the conditional and context-specific nature of support for several "upstream" climate interventions, including solar radiation management techniques and carbon dioxide removal technologies.

climate change | geoengineering | pathway surveys | deliberation

Governments worldwide are facing a host of public policy controversies that involve tough tradeoffs across economic, environmental, temporal, and social objectives. These choices typically involve multiple stakeholders and uncertainty as to the effectiveness of policy responses. Although the acceptance of policy initiatives is never guaranteed, more broadly supported options will emerge when the views of constituent stakeholders are understood in advance and when policy design anticipates and responds to the reasons behind public support or opposition.

Nearly all experts agree that human-caused emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) are already responsible for significant changes to the earth's climate. These changes include higher mean temperatures, shifts in rainfall amounts and location, sea-level rise, and more frequent and severe droughts and storm events (1). However, policies aimed at mitigating the effects of climate change are controversial, in large part due to disagreements about the sources and extent of climate change or the perceived quality of the associated policy options (2). Recent reports of the Intergovernmental Panel on Climate Change (IPCC) thus call for further policy initiatives, wherein citizens will be asked about new technological and behavioral initiatives intended to mitigate the worst impacts of climate change.

In such contexts, the responsibility of public officials is twofold: help citizens and other stakeholders become better informed about the nature and distribution of the risks and benefits of proposed actions, then find ways to listen to and act on their ideas. A fundamental challenge is to develop methodologies that accurately capture public input, including learning about how different groups within society think through or evaluate a range of policy options. Eliciting and understanding public opinion is challenging, however, because people use diverse mental models to interpret information and make sense of policy options (3). Peoples' assessments of options are also filtered through what Kahneman (4) and others have referred to as "fast and slow" thinking. Fast and slow thinking includes a variety of cognitive processes that involve deliberative attention to problems as well as heuristics (or "rules of thumb"), which are efficient but can also be responsible for judgmental errors (e.g., anchoring on selected aspects of a problem).

New, large-scale technologies that raise difficult ethical questions and involve uncertain outcomes significantly compound this challenge. A primary example is climate engineering technologies designed to capture and store CO_2 or to reflect sunlight away from the earth. Both have recently come under consideration due to rapid increases in global temperatures and increased concerns about the vulnerability of global ecosystems (5, 6).

Carefully designed surveys will continue to play an important role in shaping public policies (7, 8). In the context of climate mitigation and adaptation actions, however, we question a primary dependence on conventional surveys. This concern arises because many climate mitigation options, such as large-scale geoengineering technologies, are unfamiliar and could represent an "unprecedented human intervention into nature" (9). In such situations, our worry is that some survey approaches may encourage quick responses that fail to incorporate key factual information and overly reflect the automatic choices and political ideologies characteristic of "fast" thinking, in contrast to slower and more deliberative thinking needed for unfamiliar, multidimensional decisions.

In addition, survey research reveals two kinds of motivation that reduce the accuracy of participants responses: solution aversion, wherein people contest policies suggested by environmental scientists (10), and social desirability, wherein respondents edit reported behavior to avoid embarrassing themselves (11). Scholars of public participation are calling for new methods that increase response accuracy and can help to "open up" citizens'

Significance

A growing number of scientists now believe that climate engineering technologies could be required to control global temperatures and protect ecosystems. Decision makers often rely on surveys to inform them about citizens' views, but when novel technologies are involved results can fail to reflect the assumptions, knowledge, and values that underlie people's choices. To bridge this gap, we describe a new, behaviorally and cognitively responsive "decision pathway" survey (n = 800) that mimics the conversational depth of small-group deliberations by adopting a broader context that includes competing objectives, civic priorities, factual information, and risk–benefit tradeoffs. Results yield important insights into citizens' reasoning strategies and the ethical and governance concerns influencing the conditional nature of climate engineering policy choices.

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analytic and participatory appraisal of new technologies and policies (12). A related trend in public participation is the adoption of more deliberative designs, endorsed in both the United States (13) and the United Kingdom (14), particularly because they are viewed as providing opportunities for discussion, reflection, and learning (15).

This paper describes a "decision pathway" approach to surveys that addresses these challenges by combining the strengths of interactive deliberative designs with the larger and more representative sampling provided by surveys. We begin by reviewing the literature on public attitudes toward climate change, including recent shifts to consider climate change in reference to both in situ policy contexts (e.g., urban planning) and emerging mitigation or adaptation options (e.g., greater dependence on nuclear power). We follow with a discussion of the potential contribution of decision-making theory to design and implement deliberative surveys (14, 16). We then summarize empirical results from a climate-change pathway survey of a representative sample of US citizens ($n = 800$). To ensure informed responses and to address the technical and social complexity of required decisions, the survey design follows the lead of earlier "mental models" work (3) and incorporates tutorials on leading climate engineering techniques (e.g., carbon capture and storage, solar radiation) to encourage reflection on—and possibly changes to—participants' values, reasoning strategies, and policy choices. We summarize these findings and their implications for the development of a broader methodological toolkit to aid decisions about novel and controversial technologies.

Surveying Public Views on Climate Change

Previous Results. Support for policies that address climate change has been linked to people's mental models (17), and their beliefs about, and perceptions of, the associated risks (18). Surveys by Leiserowitz (19) focused on the role of positive or negative associations with iconic climate imagery (e.g., melting glaciers). Kahan et al. (20) examined a fuller suite of worldview measures and their relationship to different climate change information sources and agents; results showed a strong association between proegalitarian political values and support for environmental initiatives or government controls on industry, in contrast to opposition for these initiatives by individuals showing individualist and strongly hierarchical or authoritarian political values (20). His results are consistent with survey results showing strong differences between liberal and conservative respondents (21) as well as other research that finds predictive power in some (though not all) world views as they concern climate mitigating behavior (22, 23).

Extensions of this line of inquiry are leading to a new body of applied climate research. At the center of this shift is the recognition that climate initiatives must be nested in broader social debates about public priorities and understood in reference to nonclimate policy contexts such as conservation priorities, energy generation choices, and urban planning initiatives. For example, placing climate response measures within standard governance and operating procedures has been a crucial factor in implementing climate actions at the municipal level (24).

Surveys focused on climate mitigation policies typically agree with results from a recent German study that recommends a focus on risk ethics and fairness, as much as on technical effectiveness or economic efficiency, because the general public is "almost totally unfamiliar with climate engineering" (25). Additional studies in the United Kingdom and the United States reinforce the importance of interpreting opinions as highly responsive to technical information and driven by sociopolitical factors (10, 24, 26). Information uncertainty is also reflected in a UK Royal Society report (27), which highlighted sources of uncertainty regarding the safety and technical feasibility of two distinct geoengineering approaches: carbon dioxide removal technologies (CDRTs), designed to reduce CO_2 levels in the atmosphere, and solar radiation management (SRM) techniques, designed to reflect the sun's light and heat away from the earth's surface.

The Survey Challenge. Overall, recent surveys show that citizens in North America and Europe are generally supportive of actions to reduce the adverse effects of a changing climate, including climate deniers, when questions are better framed to address their point of view (10). In the context of novel initiatives such as large-scale geoengineering, people's understanding is low, however, and strong ethical discomfort exists. Together these findings suggest that views about geoengineering are still emerging and thus require "upstream engagement."

Upstream conditions contravene the usual assumptions for surveys—that people understand the questions asked of them and have thought sufficiently about the topic to express clear, considered, and relatively stable responses. Instead, it is likely that survey responses to novel technologies will reflect psychological biases such as the prominence effect (28), by which people deal with unfamiliar choices by giving undue weight to one dimension of a choice and largely ignoring other concerns. Many people also respond to these choices as "taboo" and so oversimplify or resist responding (29). Survey results therefore can be misleading because participants are not well informed, ignore contextual considerations, or provide answers that are reactive and highly malleable (30). The need instead is for designs that can help people first distinguish the specifics of new technologies and their associated policies, then reflect and deliberate upon their risks and benefits (31, 32).

Small-group deliberations, individual interviews, and town-hall-style meetings have been particularly useful for providing more defensible insights into public opinions. These methods face four central challenges: presenting well-articulated scenarios that anticipate questions of scale; communicating information and policy framings in a balanced manner; maintaining open deliberations; and articulating the broader beliefs and worldview logic within which such decisions are embedded (14). These results may be discounted by decision makers because the number of people involved is relatively small (typically fewer than 100), and rejected by researchers because costs tend to be high (intensive preparation for each group, complex qualitative data analysis, etc.) as are the time and intellectual burdens placed on participants. One strategy is to combine interview and small-group results with telephone or web-based surveys so as to calibrate results from multiple techniques (32, 33). Alternately, larger samples have been used in "deliberative polling," which combines conventional polling with small group discussions, online participation, and social media (34). This approach allows individuals to answer a question, participate in discussions via actual or virtual forums, and then return to the original question, thereby tracking how positions might change or evolve over time.

Decision Pathway Design Considerations. Decision pathway surveys (35, 36) represent another potentially helpful approach to incorporating public input that focuses less on outcomes ("would you support policy A, yes or no?") than on helping people to understand tradeoffs between benefits and costs and to articulate their own reasoning processes. In addition to asking respondents to select a preferred technology or policy, a decision pathway survey attempts to identify the main considerations that give rise to these expressions of support, helping participants to think more deeply about their own perspective while also providing balanced information about the policy context and technological risks and benefits.

The design itself incorporates the many calls to operationalize two-way interactions between decision makers and the public alongside opportunities to reflect on one's own thinking as discussion unfolds and new evidence is provided (37). Its philosophical roots draw from principles of communicative action and exchange of reasons while also meeting criteria essential to good deliberation (e.g., representation, quality of procedures, and the quality of both information and outcomes) (38). Most deliberative work has been conducted face to face in small groups, thereby providing opportunities to challenge and be challenged by the collective conversation. Only a few efforts have sought instead to embed deliberative principles into survey designs in ways that include larger sample sizes and retain a focus on values but also permit room for learning via tutorials and reflection on answers provided (39, 40).

The primary concept underlying the deliberative elements of a pathway survey is that when answers are sought that require people to evaluate unfamiliar topics, such as geoengineering policies to address climate change, their preferences will not be fully formed. Instead, both values and choices will be constructed in relation to people's existing mental models, their understanding of what is being asked of them, and the various cues that (intentionally or unintentionally) are provided. This perspective is based in the behavioral decision theory known as "constructed preferences" (16), which maintains that preferences are often built rather than simply revealed in the course of an elicitation procedure. A constructive approach suggests a survey should recognize the role of fast thinking but also activate slow thinking in a manner that mirrors reasoning strategies most people would recognize as indicating thoughtful decision making (41). For example, one widely used prescriptive model for "thinking through a problem" comes from the five basic steps known through the acronym "PrOACT" (42): understand the problem context, clarify objectives, define alternatives, identify consequences, and highlight key tradeoffs. Iteration is realized by providing opportunities for participants to revisit earlier questions in light of new information pertaining either to facts (e.g., the likely consequences of actions) or to values (e.g., competing social priorities or political allegiances).

A second design consideration is that questions must be cognitively appropriate because the constructive processes underlying a response can be highly sensitive to how a problem is presented (43, 44). A third consideration is that the survey design must strike a balance between being concise and informative: enough information needs to be provided so people feel they are sufficiently well informed to answer the questions asked of them yet not overwhelmed with unnecessary detail. Finally, surveys need to be respectful: if questions trigger emotional responses, then the survey should deal with these appropriately, perhaps with the help of a concluding open ended "comments" section.

Reasoning About Climate Change Policies: Pathway Design, Methods, and Results

The pathway survey investigated how participants viewed a variety of policies designed to deal with climate change. Within this broader context, we emphasized climate engineering technologies that either capture and store carbon dioxide before it is released into the atmosphere or that reflect sunlight (and the accompanying solar heat) before it reaches the earth's surface. We focused explicitly on the reasoning processes used by individuals when considering climate change policies, keeping in mind that any survey design will influence participants as they "construct" a response (16, 45). This is especially the case for "new and unfamiliar" topics that necessitate a transparent and theoretically defensible basis for why one approach or frame is justified.

A generalized six-step decision-making approach, based on the PrOACT framework (42), was adopted to (*i*) provide an explicit decision context; (*ii*) elicit broad policy objectives; (*iii*) present preferred policy options to address climate change and reflect upon the associated ethical and values logic; (*iv*) compare the consequences (i.e., benefits, costs, and risks) of different climate engineering options; (*v*) encourage reflection on key tradeoffs; and finally, (*vi*) reconcile and summarize participants' responses by stating how to best increase the benefits of climate engineering and decrease the associated risks. These final questions, along with an open-ended comments section, encouraged reflections on respondents' knowledge about and confidence in their answers and elicited suggestions for future improvements in the survey design.

Survey Structure and Sequence. Fig. 1 depicts the pathway structure, grouped into four main types of questions: value positions, geoengineering design, policy tradeoffs, and tutorials. The first tutorial included a visual primer on climate change science along with the statement that "the actions currently in place are unlikely to reduce CO_2 emissions by a large enough amount to avoid some of the more extreme effects of climate change." The second tutorial included background information on climate engineering, including an introduction to solar reflection (SR) and carbon dioxide removal (CDR). Both tutorials had been tested and used previously in published work with deliberative small groups (31).

Participants. Respondents were drawn from a YouGov survey panel in 2013. A total of 1,813 panel members were contacted and 910 individuals completed the survey, for a completion rate of 50.5%. These a priori panelists were matched to the general US population using propensity scores for gender, age, race, education, party identification, ideology, and political interest according to the full 2010 American Community Survey sample. Data on voter registration status and turnout were matched to this frame using the November 2008 Current Population Survey; interest in politics and party identification were matched using the 2007 Pew Religious Life Survey. These weights were applied to produce the final sample of 800. Informed consent was obtained from all participants, who were paid a nominal amount; completed surveys generally required 20–25 minutes.

Results.

Decision context. Opening questions identified participants' (*i*) initial positions regarding concern about and perceived causes of climate change and (*ii*) stated social priorities or concerns linked to these positions. Four primary pathways were broadly representative of respondents' initial perspectives (Fig. S1): not at all concerned about climate change (18%), not very concerned (20%), fairly concerned (30%), and very concerned (31%). Linked to these response patterns were four substantively different views about the primary cause of climate change: 46% of those "not at all" concerned about climate change viewed its causes as "entirely natural," whereas 42% of those "not very" concerned think of climate change as "mainly caused" by natural processes. In contrast, participants who were "fairly concerned" view the primary source of climate change as "both human and natural" (58%), and those "very concerned" perceive climate change as mainly (44%) or entirely (16%) due to human actions.

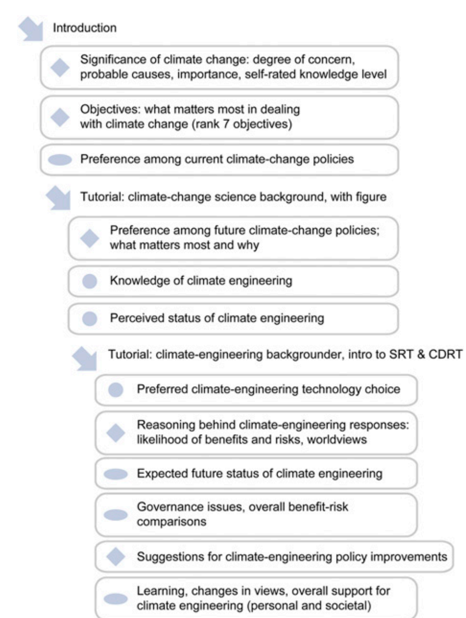

Fig. 1. Decision pathways design sequence. ◆, value positions; ⬬, policy tradeoff; ●, climate engineering design; and ◣, tutorial.

The same contrast in thinking occurs with respect to the importance of climate change relative to other social considerations. One-hundred percent of those "not at all" concerned about climate change regarded it as "not at all important" relative to all other societal problems, with budget cuts selected as the most important issue facing society today. Conversely, 83% of "very concerned" participants stated that climate change is "one of the most important issues facing society" with employment or healthcare selected as secondary social issues.

Objectives. In an effort to understand the reasoning underlying these four levels of concern and accompanying beliefs, all participants were subsequently asked to rank seven possible objectives driving options for addressing climate change. The objectives reflected content and language drawn from initial interviews and pretests of the survey design; they also reflected a key aspect of prescriptive decision analysis, which posits that alternatives should reflect the objectives or "what matters" to underlying decision pathways (30): preserving quality of life for future generations; avoiding high costs to taxpayers; encouraging technological innovation; avoiding large-scale efforts to manipulate nature; ensuring that negative consequences of policies are not primarily felt by poor people or countries; reducing the government's ability to control what citizens do; avoiding irreversible effects on the environment.

Across all participants, a concern for future generations was most often ranked first, with effects on poor people or countries considered the least important (Fig. S2). For those "not at all" concerned about climate change, 58% identified their top objective as "reducing the government's ability to control what we do." Conversely, approximately three-quarters of those "fairly" or "very" concerned about climate change selected either "preserving the quality of life for future generations" or "avoiding effects on the environment that can't be undone" as their primary objectives.

Alternatives and consequences. The next questions addressed both initial preferences for policy alternatives and, after exposure to a short tutorial, examined participants' perceived willingness to consider large-scale engineered climate actions. Initial policy options ranged from market and regulatory policies to those focused on rebuilding infrastructure to cope with climate change impacts (e.g., building barriers against rising sea levels, improving protection from floods). Participants characterizing themselves as "not very concerned" were split between moving to renewable energy sources that would produce fewer greenhouse gases, such as solar, hydro, or wind (38%), rebuilding infrastructure (23%), and encouraging the use of transportation alternatives such as public transit or fast rail (17%). In contrast, a majority of those "fairly concerned" and "very concerned" favored investment in renewable energy sources (55% and 65%, respectively).

At this juncture, the survey introduced a discussion of new policy alternatives, highlighting large-scale geoengineering of climate systems in the form of carbon capture and storage and solar radiation. A short tutorial was introduced showing how the sun's energy is absorbed by and released from the earth, including the statement: "Recent scientific reports argue that all the actions currently in place are unlikely to reduce CO_2 emissions by a large enough amount to avoid some of the more extreme effects of climate change." This was followed by questions about the perceived urgency of future climate change actions, ranging from "do nothing more" through to "continuing existing policies, but testing large-scale climate engineering techniques."

Fig. 2 indicates that a large majority (70%) of those "not at all concerned" about climate change chose to "do nothing more," with most of the remainder of this group supporting new transportation alternatives. The primary shifts in consideration of new alternatives occurred across the remaining three groups. Continuing current policies but adding actions to help people adapt to climate change impacts now received moderate levels of support (~30%) from those previously identified as "not very concerned," "fairly concerned," and "very concerned." Support for continuing current policies but adding actions that would test "large-scale climate engineering techniques" received slightly higher levels of support, ranging from 26% to 36% of respondents.

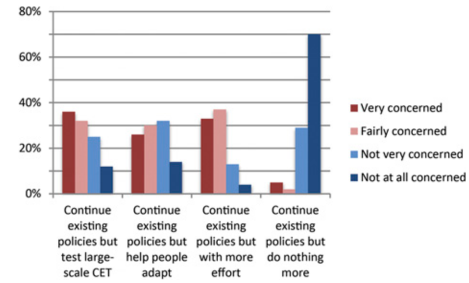

Fig. 2. Preference among future climate policies.

To elaborate people's thinking about geoengineering and to clarify their objectives, participants were then asked to choose the one sentence from five choices that best represented their views. A majority of those "most concerned" about climate change favored implementing climate engineering policies, either immediately or after further research. Of those "not at all concerned" about climate change, 43% wanted to slow down and wait; another 20% responded that climate engineering needed further testing because "governments are not ready to oversee and regulate these global programs."

Climate engineering alternatives. Finally, respondents were asked to choose between two well-described options: sunlight reflection technologies (SRTs) and CDRTs, based on wording used in prior research (31). Depending on their selection, respondents were then asked to rank specific SRT and CDRT options and to also identify how these might be governed.

Four SRT choices were described: placing large mirrors in space to reflect light away from the earth; brightening clouds above the oceans so they reflect more sunlight; injecting reflective particles into the atmosphere to reflect sunlight back into space; and modifying urban buildings or surfaces to increase reflectivity. The top choice, for all four major pathway groups, was to adopt technologies that increase reflectivity of buildings or road surfaces, followed by using large mirrors to reflect light and heat away from the earth. Three CDRT choices were also described: capturing CO_2 from the atmosphere and storing it in large industrial machines; capturing CO_2 by planting new forests; and capturing CO_2 by fertilizing algae and plankton (which would absorb CO_2 and deposit it at the bottom of the ocean). The top choice for all four groups was to plant new forests and then secure CO_2 through long-term sequestration, followed by additional biotic infrastructure (algae/plankton). Although these two options were favored by over 80% of participants, their logic and conditions varied considerably. For example, a large majority of "concerned" respondents agreed with the need to "adopt a centralized government plan" on the condition that "it did not overly manipulate nature," whereas those "not concerned" preferred policies that "allow people to make their own choices."

Tradeoffs. Most decision theorists argue that tradeoffs, which involve the integration of factual and value perspectives as part of an integrated response to decisions, need to be both transparent and cognitively manageable. This is a challenging task in the context of climate engineering technologies, requiring that the different benefits and risks be identified, their likelihoods assessed, and relative importance weights assigned.

To address these tasks, we followed the recommendations of deliberative researchers who emphasize the need to understand how people perceive risks (46) yet recognize that "members of a varied cross-section of publics are perfectly capable of debating quite complex issues of environmental science, technology and policy . . . if given the right tools and sufficient opportunity to do so" (14). Participants were presented with a list of possible benefits and risks of climate engineering and asked to rate each item on two dimensions: (*i*) the relative importance of the effect (high, medium, low) and (*ii*) an assessment of its probability or likelihood of occurrence (likely, unlikely, don't know). The leading

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potential benefit of climate engineering across all groups was "reducing the rate of ice cap melting," with high importance assigned by 45% of respondents. Reducing temperature increases, the frequency of extreme weather events, and buying time for the transition to post–fossil-fuel economies were the other benefits identified. The leading climate engineering risks were unexpectedly high costs and a lack of agreement among governments (perhaps resulting in conflict). The potential for global cooling was ranked lowest among all risks and reducing shifts in rainfall patterns was lowest in importance among all benefits.

A striking pattern of skepticism concerning the achievement of benefits through climate engineering technologies is evident. All seven categories of risks associated with climate engineering technologies were rated as more likely than any of the seven categories of benefits, with increased costs (72%), government conflict (70.5%), and unequal distribution of costs and benefits (68%) rated the highest. These quite high percentages compare with only 30% of respondents who rated reductions in global temperatures due to geoengineering as likely or 25% of respondents who thought that geoengineering technologies are likely to succeed in reducing snowcap melting.

The last questions in this sequence provided an opportunity for respondents to again reflect on the relative importance of addressing climate effects in light of future individual or government support of climate policies. An overall pattern is that most people, whatever their perspective, saw their own views about climate engineering governance as likely to be held by others. For example, participants classified as "very concerned" agreed with "taking actions to reduce climate change" (85%) and also believed that most fellow citizens would share this perspective (59%). Similarly, 91% of the "not at all concerned" respondents strongly agreed with the statement "I personally oppose actions aimed at reducing climate change," again with the majority (61%) believing that other citizens would share their view. Overall, participants also showed high levels of uncertainty with respect to the importance of government oversight: about one-third of participants were unsure about both their own and others' opinions concerning the need for novel governance structures.

A slightly different pattern was evident on questions about adopting new technologies such as nano-scale materials. Those supporting these technologies believed they were a minority, whereas those rejecting the use of nano-scale materials saw themselves as a majority. Specifically, respondents who are "very concerned" about climate change strongly supported the use of nano-scale materials but only 18% believed that the rest of society also would be supportive. In contrast, those "not at all concerned" about climate change strongly opposed the adoption of nano-scale technologies (70%) and believed that their views generally were representative of society as a whole (60%).

Reconciling opinions, policies, feelings, and worldviews. In a final series of questions, participants were asked their overall feelings and thoughts about risks, benefits, and uncertainties associated with the development of climate engineering.

Across all participants, the potential risks of climate change were again seen as larger than the accompanying benefits. Overall levels of comfort with undertaking large-scale engineering responses to address climate change are low: despite the earlier tutorials, nearly 40% agreed or strongly agreed with the statement that they are "very uncomfortable with climate engineering as a response to climate change," whereas only 28% said they are "very comfortable" with climate engineering technologies. Much of this skepticism relates to low levels of confidence regarding the anticipated success of climate engineering technologies. However, about one-third of respondents again reported that they were "not sure" of how they feel, which is unsurprising given the upstream nature of the technologies discussed and suggests that levels of public support for climate engineering responses are unlikely to stabilize for some time.

Final value reflections were provided by a closing set of worldviews questions, modeled on work by Kahan et al. (20). Over half the sample felt that "government interference in citizens' daily lives is too high," in contrast to only one-fifth of respondents who state that "government should limit individuals' choices if this results in an advancement of society's goals." Even after the tutorial reminder that "some scientists are suggesting that additional policy tools might be needed so that the[se] more extreme effects of climate change are avoided," over one-third of participants (36.8%) strongly agreed with the statement that "government should stop telling people how to live their lives."

Discussion

This climate engineering pathways case study describes and obtains input on a controversial social issue for which only scant data on public perspectives have been collected (47). However, citizens desire (and deserve) a say in government decisions that could significantly affect their future well being. The charge to policy makers and analysts is clear: Create methods for describing and communicating these effects in ways that recognize the embeddedness of climate change in other social issues while encouraging deliberation and informed engagement.

Deliberative processes with demographically representative small groups have been key to providing an effective means for two-way, in-depth discussions about complex and often upstream decisions (14, 45). But reliance on results can be reduced because only small numbers of people are involved. Survey results also provide inputs to policy development, although some worry that conventional survey methods may be least applicable in domains characterized by problems with new technologies, diverse value and ethical perspectives, and critical uncertainties—a description that aptly characterizes many emerging technologies associated with climate change.

Decision pathway survey designs seek first to inform people, about both their own values and the facts relevant to multisided public policy choices, and then to provide decision makers with information about both what and how citizens think without reliance on more costly, and less scalable, qualitative research methods. By placing climate change mitigation policies within a broader policy and personal context, pathway survey responses are less prone to "group think" biases and the tendency of groups faced with difficult choices to converge prematurely on a single point of view. By including tutorials and the explicit consideration of key value tradeoffs, pathway surveys also may encourage reflection and more careful thinking, thereby reducing the influence of both overly quick automatic responses and political ideologies.

These results show an initially strong distinction between four levels of concern and perceived causes of climate change. Those less concerned about climate change prioritized budget cuts as their leading policy/social priority, with reduced government control a key objective. Preferred policies included renewable energies and infrastructure rebuilding; even when faced with a tutorial and strongly worded reminder concerning the rationale for geoengineering, those not/less concerned still saw the problem as nonurgent and preferred to do nothing more than current efforts. Conversely, those more concerned about climate change saw it as the top policy social priority, with education and healthcare as secondary. The main objectives behind this reasoning were preserving quality of life for future generations and avoiding irreversible effects of new policies. These groups also viewed investments in renewable energy policies as essential, much more so than those not concerned.

Results underscore both the nuanced responses of participants and the need for survey methods that can capture and reflect this conditional reasoning. As one example, consistent support for geoengineering exists when interventions involve mostly natural means, including use of biotic infrastructure (e.g., planting new forests, cultivating algae and plankton) and improvements to the built infrastructure (e.g., modifying buildings and surfaces to increase reflectivity), across the spectrum of concerns. In all other cases, however, support for geoengineering initiatives was conditional. Significantly, all groups rated all seven categories of risks associated with geoengineering as more likely than all categories of benefits.

Those most concerned about climate change generally favor implementing climate engineering policies and investment in renewable resources (55–65%), including the adoption of centralized government planning, on the condition that interventions do not overly manipulate nature. This support is offered even though these participants regard the risks of climate engineering as more likely than its benefits. Conversely, those least concerned still support some geoengineering interventions but are more likely to want to do nothing more or to slow decisions down, often asking for further testing of the new technologies. These participants, generally mistrustful of government involvement, nonetheless were somewhat supportive of initiatives involving renewables (38%) but also favored investment in rebuilding infrastructure and encouraging the use of public transit.

To what extent did adoption of a decision-pathways survey approach help respondents to learn new information about climate change or reevaluate their own perspectives toward a range of possible policies? Although this study lacked a control group (for making explicit comparisons with results from more conventional surveys), we assume that those least concerned about climate change presumably saw less need to learn because their self-reported knowledge levels already were moderate or excellent; this finding clearly poses a challenge to risk communicators. Many other respondents noted that they had "learned a little bit more about climate change" and took the opportunity of responding to the final, open-ended question to state their favored solutions to climate change (e.g., wind and solar power) as a way to protect the earth and human health. However, with a quarter of respondents answering "unsure" to many questions, it is clear that preferences remain malleable and further shifts in respondents' positions are likely to occur over time.

Future research in the design of pathway surveys will examine these issues and capture more of the benefits of interactive deliberative processes while avoiding some of their limitations. The goals of helping citizens to be open to new information while improving their understanding and articulation of their views toward specific policy initiatives, and to accomplish this while keeping in mind the broader social and political context, are only going to become more important over time. In the context of controversial policy decisions such as the future of climate engineering techniques, pathway surveys can play a role in helping decision makers listen to citizens as part of public engagement practices that encourage informed deliberation.

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