# Choosing Carbon Mitigation Strategies Using Ethical Deliberation

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ABSTRACT

Anthropogenic greenhouse gas emissions change earth's climate by altering the planet's radiative balance. An important first step in mitigation of climate change is to reduce annual increases in these emissions. However, the many suggested means of limiting emissions rates have led to few actual changes in policy or behavior. This disconnection can be attributed in part to the difficulty of convening groups of stakeholders with diverse values, the polarizing nature of current political systems, poor communication across disciplines, and a lack of clear, usable information about emission mitigation strategies. Here, electronically facilitated ethical deliberation, a method of determining courses of action on common goals by collaborative discussion, is used to evaluate Pacala and Socolow's climate change stabilization strategies based on economic, technological, social, and ecological impacts across a wide range of spatial and temporal scales. Few previous analyses of climate mitigation strategies include all of these factors; rather, short-term technological feasibility studies and economic cost–benefit analyses predominate. After accounting for tradeoffs among disparate criteria, strategies involving end-user efficiency (e.g., efficient buildings and vehicles), wind, and solar power rank highest, while carbon capture and storage, hydrogen fuel cells, and biofuels options rank lowest. This electronically facilitated deliberation method offers an alternative to oppositional debate or cost–benefit analysis for assessing strategies where both quantitative and qualitative factors are important, information from disparate disciplines is relevant, and stakeholders are geographically dispersed.

## 1. Introduction

Few scientists or policy makers now dispute the importance of mitigating human-based emissions of greenhouse gases (GHGs), especially carbon dioxide, to the atmosphere. The possible results of increasing emission rates include catastrophic and rapid changes to earth's climate system with consequent impacts on human welfare (Bernstein et al. 2007). In 2004, Pacala and Socolow proposed a portfolio of options or ''wedges'' for reaching a $CO_2$ emissions reduction goal of stabilized emissions at 2004 levels. These consist of 15 different strategies, each of which would reduce $CO_2$ emissions by 1 GtC $yr^{-1}$ in 50 yr. Although each of these wedge strategies would have the same impact on the global emissions budget, they differ substantially in technological complexity and feasibility, economic costs, societal impacts, and ecological effects. Choosing which strategies to implement, when to implement them, in what order, or even how much to invest in their implementation requires systematic assessment and comparison of each strategy.

Although several sources have carefully evaluated the technological feasibility or the economic costs and benefits

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of each stabilization wedge (e.g., Creyts et al. 2007; Reilly et al. 2007), fewer sources (e.g., Patz et al. 2008) have assessed social or ecological implications (Robertson et al. 2008), and little effort has been made to integrate assessments across themes. Barriers to such integrated assessment include a lack of information about noneconomic costs, requirements for broad interdisciplinary expertise, representation of a global distribution of stakeholders and, perhaps most important, profound differences in both tools and language for evaluation of impacts in different intellectual disciplines. The demand for integrated scientific analyses of decision-making processes is strong (Brewer and Stern 2005). Ethical deliberation offers a means to address these challenges constructively by developing an alternative to strict cost–benefit analysis that incorporates disparate information of varying quality and character and accounts for fundamental differences in methods and valuation.

## 2. Methods

The process of ethical deliberation is based on the model of ''deliberation'' (Walton 1998) in which participants seek a common goal. We use the term ''ethical deliberation'' as a way of emphasizing a systematic effort to include a wide range of value considerations in the deliberative process, as opposed to merely practical or instrumental considerations. Informal logic (Walton 1998), electronic deliberation (Sunstein 2006), and discourse ethics (Habermas 1993) inform the conceptualization and implementation of this process, where deliberators make ''rational choices between different available courses of action'' (Habermas 1993). Much like the Deliberative Mapping process developed by Burgess et al. (2007), ethical deliberation is designed for contentious issues with incomplete information and competing ethical positions, especially where risk, complexity, and uncertainty are important (Renn 2008), as with climate change and its impacts (CCSP 2009). In ethical deliberation, a conscious effort is made to include moral considerations at every step of the deliberative process, and, in this experiment, particular effort is made to recognize and incorporate the full range of values—practical, moral, and ethical—at stake in choosing mitigation strategies for global $CO_2$ emissions, thus placing considerations of efficacy, efficiency, and cost effectiveness within a larger framework. The process seeks answers to the following questions: (i) what goals should we pursue? (ii) how should we prioritize competing goals? and (iii) by what means or alternatives should we pursue a selected goal? In each question the ''should'' includes evaluations of ''right'' and ''wrong'' as defined by the deliberating individuals. These values depend on the cultural and social context of the deliberation, but we consider the method to be ethical because it incorporates such considerations with equal weight to more commonly included measures of comparing choices. Finally, this method requires that deliberators behave ethically within the discussions, avoiding strategic discourse in favor of open cooperative discourse.

The method of ethical deliberation entails three discrete steps: characterization of a goal that explicitly includes deliberator-driven ethical values, systematic description of alternative means including evaluation of obstacles and side effects, and, finally, collaborative comparison, assessment, and ranking of means. This final step, collaborative comparison, is both iterative and ordinal so as to better capture nonnumeric and unknown values, to allow the deliberators to address individual concerns, and to accommodate negotiation. In this example, participants were selected based on their interest in climate change policy and with the aim of building a group with diverse membership. The deliberative body consisted of 10 people, both graduate students and faculty members, representing eight academic disciplines (psychology, earth systems science, ecology, engineering, environmental policy, atmospheric/oceanic science, geophysics, and philosophy). The group met face-to-face for one week at the University of Montana and afterward deliberated online through a wiki (a collaborative multieditor Web site) and weekly instant messaging (Skype) meetings for the following four months. In total, 10 online full group meetings occurred, in addition to several smaller informal electronic meetings among subsets of participants. Not all deliberators attended every online meeting; all, however, participated in the entire weeklong workshop where the initial goal and the subsequent process were determined. Because most of the deliberation occurred through online fora, this model accommodates deliberative bodies of individuals who cannot all be in one place at one time, potentially promoting a higher participation rate through reduced transaction costs (Luskin et al. 2003). All of the participants in this example are affiliated with academic institutions, so each had access to broadband communications as well as some training in academic methods of discourse. Although small group size and homogeneity (i.e., university affiliation) enhance achievement of a collective goal (Baland and Platteau 1999), incorporation of participant diversity is instrumental in the ethical deliberation model. Therefore, any diverse group of deliberators working collaboratively could use this method; tests with a pool of deliberators drawn from the general public would be useful.

In step one, goal characterization, the group reached a consensus statement: ''Anthropogenic climate change will have negative consequences on the planet, today

TABLE 1. Impact areas for wedge evaluation.

| | Criteria | Scoring |
|---|---|---|
| Social | 1. Human health<br>2. Equity<br>3. Institutional barriers<br>4. Political barriers<br>5. Informational barriers | Temporal and spatial impacts on social criteria scored using STIM |
| Technological | 1. Available inputs<br>2. Scalability<br>3. Robustness | Assessment of current viability and robustness |
| Financial | 1. Financial costs/benefits | Temporal and spatial costs and benefits scored using STIM |
| Ecological | 1. Primary productivity<br>2. Biodiversity<br>3. Biogeochemical cycling<br>4. Water quality<br>5. Water cycle<br>6. Air quality | Temporal and spatial impacts on ecological criteria scored using STIM |

and in the future. In order to avoid massive decay of human health and quality of life, rates of emissions need to be curbed at or near current levels. Though there is great opportunity for individual nations to lead the way, climate change is a global problem and therefore requires global solutions. The best immediate responses to climate change are those that are socially responsible, technologically feasible and robust, financially viable, and ecologically sustainable.'' The four qualities for alternative assessment include both standard measures (technologically feasible and financially efficient) and more ethical considerations (socially responsible and ecologically sustainable).

Through further discussion we determined that a useful group mission would be to apply these guiding principles to evaluate and rank the wedges proposed by Pacala and Socolow (2004). From this foundation, four impact areas were defined: social, technological, financial, and ecological. Then, assessment criteria for each of the impact areas were established (Table 1). Members of the group divided into teams to systematically compile relevant information from a wide range of publicly available sources, including scholarly journals, popular media, government publications, nongovernmental organizations, and industry publications, adding text, figures, and links to the wiki. Each member belonged to several teams, ensuring interactions among all members. The wiki format allowed multiple users to edit and comment on a single wedge, identifying and addressing areas of disagreement or missing information. The information compilation process was collaborative, utilizing the diverse expertise of the deliberators; information was incorporated into the wiki only by unanimous consent of the entire team, sometimes after further discussion and advocacy. No single deliberator provided all of the information about any alternative. This approach favored clarity and simplicity in exposition. Because information compilation was distinct from ranking and assessment, choices about what information to include or exclude were not driven by political motivations. The existence of a shared information pool, developed by the deliberators themselves, removed a common barrier to consensus due to the use of different statistics and facts by opposing parties.

To ensure that the full range of spatial and temporal impacts associated with each wedge were thoroughly evaluated, we developed a tool for evaluating the financial viability, social impacts, and ecological sustainability associated with each wedge—the Spatiotemporal Impacts Matrix (STIM) (Table 2). The temporal dimension was evaluated according to impacts in the short-term (<10 yr; relevant to political/policy cycles), lifetime (10–50 yr; impacts that adults today could expect to experience), and intergenerational (>50 yr; impacts that today's children and grandchildren will experience but we will not) categories. Similarly, spatial impacts were evaluated in terms of individual/local impacts (those that would be most felt by small populations or families), community/regional impacts (felt by a state or country), and global impacts (those with worldwide effects). These impacts were noted in a $3 \times 3$ matrix with a plus symbol indicating a positive impact, a zero indicating a neutral impact, or a minus sign indicating a negative impact. Although this evaluation framework inevitably led to the loss of some information about the impacts of wedge implementation in each area and for each temporal and

TABLE 2. Spatiotemporal Impacts Matrix. Plus sign, minus sign, and zero denote overall positive, negative, and neutral impacts, respectively.

| | Short term (<10 yr) | Lifetime (10–50 yr) | Intergenerational (>50 yr) |
|---|---|---|---|
| Individual/local | +/−/0 | +/−/0 | +/−/0 |
| Community/regional | +/−/0 | +/−/0 | +/−/0 |
| Global | +/−/0 | +/−/0 | +/−/0 |

spatial scale, it had the advantage of promoting comparability and simplicity in an already highly complex decision-making problem. STIMs were not used in assessing technological viability, since the group felt that scaling considerations did not apply.

The completed STIMs served dual roles, providing quick graphical summaries of large amounts of data and establishing a framework in which diverse impacts could be compared and evaluated by individuals with differing levels of expertise. When insufficient information existed to score a wedge in a particular impact area or scale, this was noted in the assessment. However, since the goal was to proceed despite missing data, teams rarely left cells in the STIMs blank, even if some assessments were subjective or based on weak data. For example, rarely are the intergenerational consequences of an energy project considered or analyzed, so members were forced to speculate or to cite clear conjectures from the literature. Dietz and Stern (2008) describe a number of ''potential difficulties'' in decision making, including dealing with multiple spatial and temporal scales, complex problems, and qualitative characterization of risk. The STIM method does not directly solve these problems, but it does ensure that such difficulties are directly and consistently addressed.

Finally, using the data in the wiki, the established criteria, and the STIMs, all members of the deliberative body undertook three rounds of preferential voting in which an ordinal rank was assigned to each strategy, with 1 representing the most preferred and 15 representing the least preferred. Each round was separated by a series of formal and informal discussions using online instant messaging. Wedges with significant disagreement (i.e., high variance in rankings) were discussed and advocated for or against by members. Wedges that one or more members declined to rank were also discussed in detail, sometimes with new factual information added to the descriptions. Both the preference voting scheme and the discussions were designed to capture tradeoffs among nonquantitative values, such as between public health impacts and biodiversity impacts. Because the participants had a wide range of backgrounds and expertise, they could effectively advocate for particular rankings, or assist one another to compare impacts appropriately. The goal was to end with rankings and variances that highlighted areas of strong agreement, reflected our disparate viewpoints, and identified areas where incomplete information played a significant role in the assessment.

The process included components necessary for successful deliberation according to Gregory et al. (2005): agreed-upon ground rules (problem definition), a context to create understanding (deliberation via the wiki and synchronous chats), and techniques to integrate views (assessment criteria and Spatiotemporal Impacts Matrix).

The wiki content, including all of the wedge assessment material, is available online (http://tinyurl.com/climate-deliberation).

## 3. Results

The final rankings (Fig. 1, bottom) contain three kinds of information. First, the mean ranks show our assessment of the relative quality of each strategy, with the lowest mean ordinal score corresponding to the highest average preference. Second, the rank span and standard deviation indicate the degree of controversy for each strategy. For example, the highest-ranked strategy, efficient buildings, was ranked as one of the top three by all participants. Its high mean ranking is evidence of a positive assessment in all four impact areas, and its small deviation reflects little dissension and good-quality information in all areas. In contrast, nuclear power ranked eighth overall and had the largest standard deviation, reflecting ongoing controversy, and the largest span, reflecting positive technological assessment, neutral economic assessment, and negative social and ecological assessments. The third type of information shown in Fig. 1 is the number of ''no ranking'' scores for specific wedges. This option was exercised in cases where group members either felt that implementing the strategy was unacceptable under any circumstances (a deontological barrier) or that insufficient information existed to evaluate the strategy.

The mean rankings of some wedges changed substantially during the voting process (Fig. 1), especially the carbon sequestration and ecological strategies, with rank variance decreasing in each round of voting. The reduction in variance from the first to second round (Fig. 1, top and middle) was confined to the eight wedges with the highest rankings (lowest ordinal scores); the seven wedges with the lowest rankings (highest ordinal scores) showed an increase in variance. Conversely, over half of the reduction in variance from the second to third rounds (Fig. 1, middle and bottom) occurred with respect

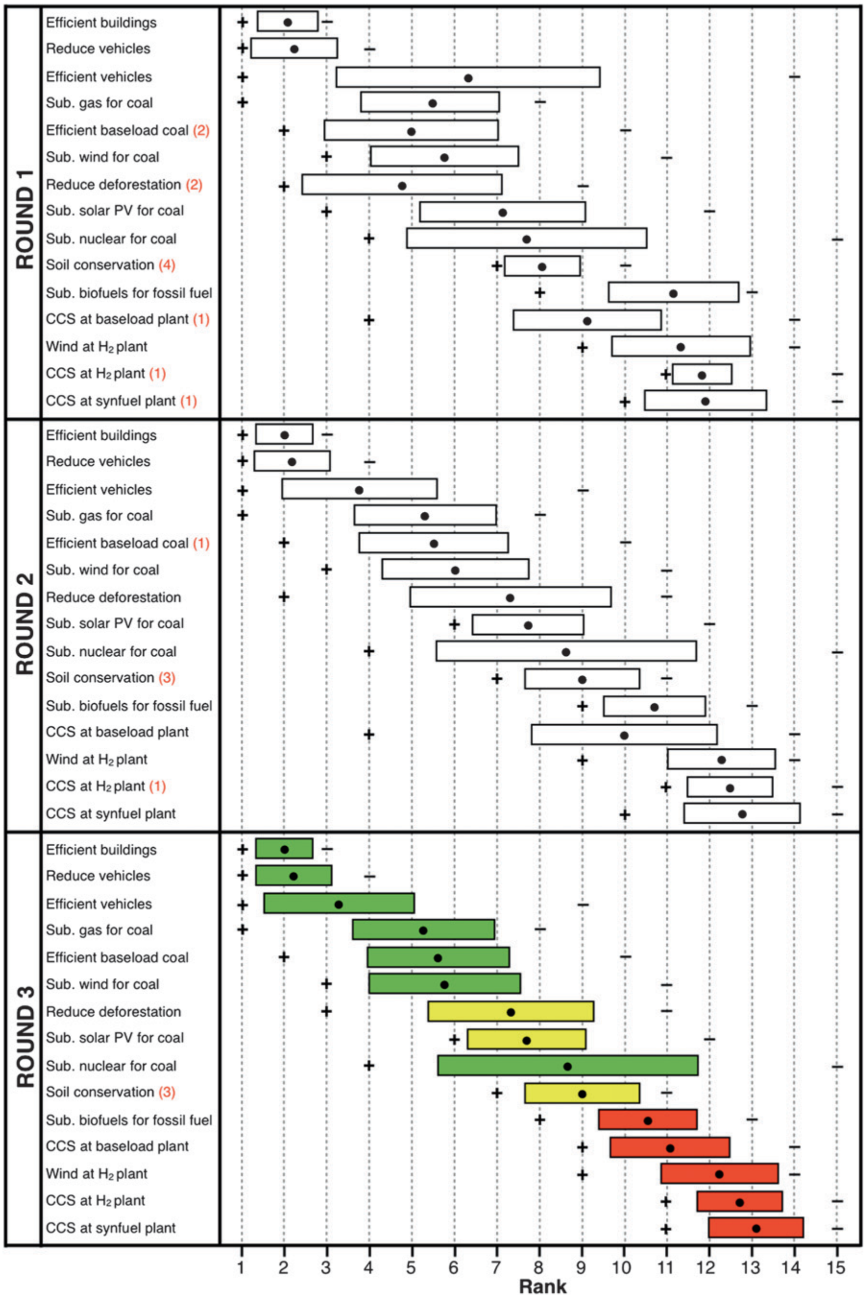


FIG. 1. Mean rankings of carbon mitigation strategies for all three rounds of voting. Bar length shows the standard deviation ($1\sigma$) of ranks, plus and minus symbols show the highest and lowest single ranks, respectively. Participant abstentions (no ranking votes) are indicated with red numbers to the right of the wedge name. The wedges for each round are listed in order of the final rankings, allowing a systematic comparison of the changes in rank mean, standard deviation, and span. For the final round, strategies recommended by the deliberative group are highlighted in green, those with special qualifications in yellow, and those not recommended in red. Sub. stands for substitute.

to the seven wedges with the lowest ranks (highest ordinal scores), suggesting a preferential approach to the deliberation. From the perspective of controversy, nearly all the reduction in variance from round to round was associated with the eight wedges with the largest variance, evidence that the deliberations followed the most controversial wedges and resulted in convergence toward consensus. Further demonstrating the latter notion, the fractional decrease in total variance between the second and third rounds (10%) was smaller than between the first and second rounds (15%). The number of no ranking scores decreased from round to round as well, culminating in the final round of voting where only one alternative had scores of no ranking. This convergence of ranks among participants and reduction in no ranking scores demonstrates the importance of expert discussion to the deliberation. The final rankings were fairly consistent among all participants (Fig. 1, bottom), with large standard deviations remaining correlated with strategies that are commonly considered controversial, such as nuclear power, or strategies where the assessments were incomplete because of missing information deemed fundamental to evaluation, such as reducing deforestation.

The results of our deliberative process indicate that end-user efficiency strategies are the best for immediate $CO_2$ emissions mitigation. Improving building efficiency has the highest mean rank, reflecting positive impacts on both greenhouse gas emissions and human health, low barriers to implementation, and cost savings. The reduced use of vehicles and improved vehicle efficiency are also highly favored based on global social trends toward increased urbanization, positive side effects on human health, positive side effects on the biosphere, and very low technological barriers. Alternative and green energy strategies are also recommended by the group, with some qualifications, especially a need for additional developments in photovoltaic (PV) technologies to reduce the need for heavy metals, reduce the energy costs of panel production, and reduce significant equity barriers to implementation in developing and underdeveloped communities.

Strategies related to management of the biosphere, specifically conservation tillage and forest management, are cautiously recommended. However, because of fundamentally insufficient information about the long-term effectiveness of these methods and about their impacts on human and nonhuman living systems, we recommended that additional resources be invested in research related to land use management prior to wholesale investment in implementation.

Finally, biofuels, hydrogen fuel cells, and strategies related to carbon capture and sequestration (CCS) are not recommended. These strategies are not demonstrably technologically feasible at the required scale, entail extremely expensive infrastructure investments, and have significant social costs related to the transmission of technology. With respect to CCS, the global distribution of suitable sequestration reservoirs is too different from the global distribution of energy demand and population, disconnecting the social and ecological costs from their emissions sources.

## 4. Discussion

Despite the popularity of cost–benefit analysis and the importance of technological feasibility studies for evaluating policy alternatives, these processes have had little success in turning suggestions into real change, in part because they do not readily incorporate qualitative values that may be very important to stakeholders. The process of ethical deliberation outlined here provides a framework that enables decision makers to integrate a wider range of information, including information about impacts that may be difficult to quantify in purely financial terms and information with ethical or cultural components. Supplementing this deliberation model, our use of novel interactions by wiki content development and instant messaging platforms allows the deliberation to be asynchronous or synchronous, geographically dispersed, and relatively immune to several common pitfalls of adversarial discourse. These three innovations—incorporating qualitative values, broadening representation across disciplines and interests, and leveraging electronic connectivity—provide a route toward increasing stakeholder investment and the efficient implementation of favorable strategies.

Conversely, traditional methods of choosing among a set of strategies have weaknesses that often influence their outcomes or preclude a final consensus entirely, especially cost–benefit analysis and feasibility studies. In particular, these methods usually attempt to translate noneconomic values into some finite quantity for incorporation into a decision-making algorithm. In doing so, the final outcome becomes highly sensitive to the assumptions used in the translation. One common example in the climate change mitigation context is incorporating costs to future generations. The choice of a discount rate, the rate of correction for a temporal gap between cost and benefit, dominates calculations at long time scales. In our ethical deliberation process, no explicit price or numerical value need be placed on generational costs or benefits, or indeed other components that contribute to the group assessment of strategies. In fact, individual deliberators may give different weights to different considerations, incorporating greater flexibility and diversity into the decision-making process.

This inherent flexibility of the ethical deliberation process is further enhanced by a combination of face-to-face and online interactions. Initial group interactions in person built among deliberators the necessary trust and respect necessary for organizing the rest of the research effort and for negotiating the ultimate strategy assessments. In our case, once group members established relationships necessary for efficient interactions by meeting in person, their subsequent interactions were mostly information and task driven, consistent with many online interactions (Luskin et al. 2003). Several known problems with debate, such as disagreement over the basis of facts or domination of discussion by a single party (bullying) (Walton 1998), never arose in the deliberation and, in fact, are unlikely or impossible in a deliberation structured around asynchronous collaboration by deliberators with a wide range of background expertise.

In addition to demonstrating the viability of the ethical deliberation process in general and its efficacy in the context of global climate change, we developed two specific new tools for evaluating climate change mitigation alternatives. The set of impact areas (social, technological, financial, and ecological) and the STIMs may be useful in future ethical deliberative processes regarding climate change or other policy issues that entail the evaluation of outcomes in multiple domains across a range of spatial and temporal scales. These contributions also serve to validate the use of ethical deliberation as a process to explore uncertainty and resolve ambiguity in information from different areas of knowledge.

Our final rankings and recommendations share many similarities with those from a cost–benefit analysis undertaken by McKinsey & Company (Creyts et al. 2007; hereafter McKinsey analysis). Of their five recommended clusters of abatement, three figured prominently in our results: increased building and appliance efficiency, moving to higher energy efficiency in vehicles and using less carbon-intense vehicle fuels, and decreasing the carbon generated by electricity production. Although carbon capture and storage ranked more highly in their report, their conclusions are in agreement with our assessment that it is expensive and unproven. The McKinsey analysis involved computing the value of specific abatement options and ranking them from lowest to highest while also examining their stage of development, technical and commercial feasibility, ability to be quantified, and the extent to which they were supported by other forces such as economics or politics. In addition to the shorter time frame and lower cost of ethical deliberation relative to an expert consultation model such as the McKinsey analysis, electronically mediated ethical deliberation is more easily modified and therefore more adaptive, an important strategy for decision making under uncertainty (CCSP 2009). The process described here incorporates all the qualities advanced by Renn (2008) for risk management decision making, including efficiency, values reflection, and integration of expert knowledge. Since our process was not a public one, we cannot comment on whether the process would be deemed politically legitimate if undertaken in the public arena. However, public participation in environmental decision making via the Internet has been successfully undertaken (Dietz and Stern 2008), and we believe that electronically mediated ethical deliberation could likewise be effective in lieu of or combined with other analytic deliberative processes such as Deliberative Mapping (Burgess et al. 2007).

Finally, we note that several strategies for climate change mitigation and adaptation, most notably a host of geoengineering strategies, have been proposed since Pacala and Socolow (2004). The flexibility of the ethical deliberation method allows any or all of these to be incorporated into the deliberation with the same process as the original wedge strategies. The online deliberation wiki needs only to be expanded to accommodate descriptions of new strategies along with supplemental STIMs and additional rounds of preferential voting, a substantial advantage over static white papers. At the present time, we hypothesize that most of the proposed geoengineering strategies would not be recommended for implementation based on likely low-feasibility ratings.

## 5. Conclusions

An electronically mediated deliberative process that diverges from strict cost–benefit analysis is able to integrate a much wider range of information of varying quality and context with far fewer resources. The process incorporates qualitative values not otherwise considered in mitigation strategy deliberations and capitalizes on new communication tools for enhanced flexibility. When applied to the problem of mitigating anthropogenic $CO_2$ emissions, ethical deliberation generates a robust ranking of mitigation strategies comparable to conclusions drawn from much more complicated and costly efforts. This ranking should be used to inform policy decisions related to global climate change, with efficiency strategies and sustainable energy strategies implemented immediately and extensively. Additional investment should be made in research on land use management strategies and caution exercised with respect to CCS strategies. Electronically mediated ethical deliberation should be implemented by other bodies seeking to confront the challenge of anthropogenic climate change or indeed other complex decisions with important noneconomic considerations and diverse stakeholders.

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