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Research Article

Carbon Capture and Storage in the United States: Perceptions, preferences, and lessons for policy

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ABSTRACT

Although Carbon Capture and Storage (CCS) technologies can potentially play an important role in climate change mitigation efforts, commercial CCS projects are still rare. Knowledge about the technical challenges of these technologies is rapidly advancing, but the challenges related to their public acceptance are still under-investigated. Here we try to close this research gap by investigating public perceptions of CCS and public attitudes towards policies to scale up these technologies in the United States, where most existing industrial-scale CCS projects are operating. Based on a demographically representative sample of US residents, we find that awareness of CCS is very low. Using a conjoint experiment, we show that policies that outlaw the construction of new coal- and gas-fired power plants without CCS find higher public support than CCS subsidies and increases in taxes on unabated fossil fuel power generation. Public support decreases with rising costs of CCS deployment and decreasing minimal distance requirements of CCS plants from residential areas. Our results provide insights into the political feasibility of a large-scale deployment of CCS and show that specific policy design choices play an important role in influencing public support for policies to scale up these technologies.

1. Introduction

Rapid decarbonization is essential to reach the Paris Agreement goal of limiting global average temperature increase to well below two degrees above pre-industrial levels, and to avoid the most adverse impacts of climate change (IPCC, 2018; Rockström et al., 2017). Beside greenhouse gas emission reductions, technologies that allow removing greenhouse gases from the atmosphere or preventing their release have increasingly drawn attention as complementary decarbonization strategies. These include negative emission technologies (NETs) and Carbon capture and storage (CCS). CCS technologies capture carbon dioxide (CO_2) at the source of production, transport it, and store it in suitable underground geological formations for permanent storage. Despite the limited development of CCS projects to date, the technology plays an important role in several climate change mitigation pathways. Many scenarios produced by Integrated Assessment Models compatible with the Paris Agreement goal of limiting warming to well below 2 °C feature a high amount of emissions mitigated through CCS (Edenhofer, 2015; IPCC, 2018; Kriegler et al., 2014). However, the expansion of CCS has not met expectations so far (IEA, 2009; Reiner, 2016; Viebahn and Chappin, 2018), and the massive scale-up of CCS present in many scenarios is at odds with current CCS deployment levels (Minx et al., 2018; Rogelj et al., 2016).

This mismatch has produced debates regarding the technical, economic, social and political feasibility of a large-scale deployment of CCS in the energy sector (Anderson and Peters, 2016; Buck, 2016; Williamson, 2016). Research on this topic is rapidly expanding (Minx et al., 2018) and the technical literature has highlighted some factors hampering the scale-up of CCS, such as high costs, storage capacity issues, and injection rates constraints (Lane et al., 2021; Martínez Arranz, 2016; Viebahn et al., 2014, 2015). However, research on the social and political feasibility of CCS is relatively less developed, although at least as important (Viebahn and Chappin, 2018). This mirrors general patterns regarding the (mis-)allocation of climate research funding: according to a recent estimate, only 0.12% of all funding for climate change mitigation research is spent on social science research, with the natural and technical sciences receiving the bulk of research funding (Overland and Sovacool, 2020).

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Several papers (L'Orange Seigo et al., 2014; Tcvetkov et al., 2019; Viebahn and Chappin, 2018) comprehensively review studies of public perceptions of CCS. Most studies are based on stakeholder elicitation processes or focus groups (see for instance Lock et al., 2014; Upham and Roberts, 2011). The results of national surveys of CCS perceptions and their determinants have been published for China (Chen et al., 2015; Li et al., 2014), Germany (Arning et al., 2019), Canada (Boyd et al., 2017), and Japan (Saito et al., 2019). Data on CCS perceptions in the United States (US) are provided in Whitmarsh et al. (2019)'s multinational study of the impact of framing effects on CCS support. All these survey-based studies report very low awareness of CCS among the general population and find that low levels of CCS acceptance are related to perceptions of CCS as a risky technology. Other studies have highlighted the role of trust (Terwel et al., 2011; Yang et al., 2016), community compensation (ter Mors et al., 2012) and communication (Bruin et al., 2015; Vercelli et al., 2013) in increasing public acceptance of CCS.

This study contributes in two ways to the literature on the political feasibility of scaling up CCS. First, using data from a survey (N = 1520) fielded in the United States in 2018, we investigate awareness and perceptions of CCS. Most existing industrial-scale CCS projects are operating in the US (Global CCS Institute, 2019) and the country could be a leader in CCS deployment, which is why understanding awareness and perceptions of these technologies among the American public is particularly important (Tcvetkov et al., 2019). We focus on technologies that capture CO_2 produced by fossil fuel power plants, as they are the most widely employed CCS technologies (Global CCS Institute, 2019). Our study delivers an assessment of risk and benefit perceptions of CCS and investigates individual characteristics that explain heterogeneities in these perceptions. To foreshadow our results, we find that awareness of CCS is extremely low and that respondents with previous awareness of CCS perceive the benefits of the technology to be higher.

Second, drawing from political science investigations into the determinants of policy support (Bechtel and Scheve, 2013; Fesenfeld et al., 2020), we analyze data from a survey-embedded conjoint experiment to assess how support for policies to scale up CCS depends on specific policy design features. Investigating determinants of public support for policies to scale up CCS is crucial to understand the political feasibility of a large-scale deployment of these technologies, but this aspect has not received sufficient attention in the literature so far. CCS policies can take various forms, such as bans on the construction of new fossil fuel power plants without CCS, government subsidies for CCS development, or increases in taxes on unabated fossil fuel power generation. We find that bans are significantly more supported than subsidies and tax increases. As for the impact of other key policy design features, policy support linearly decreases with policy costs and increases with minimal distance requirements of CCS plants from residential areas. Moreover, policy implementation in 2020 or 2030 is preferred over later implementation.

2. Research design and method

Our study is based on an online survey which included a conjoint experiment. The survey was part of a longer questionnaire focused on public attitudes toward rapid decarbonization policies (see details in the Appendix). It was preregistered at the Open Science Framework and administered to a demographically representative sample of 1520 American residents between the 1st and 18th of October, 2018 (see Table A4 in the Appendix for a comparison of the distribution of key socio-demographic variables in our sample and the US population). We report a power analysis in Section 5 of the Appendix, showing that our study was highly powered.

Our first objective was to assess awareness and perceptions of CCS among the American population. We assessed respondents' awareness of CCS and, after providing information on CCS technologies, we measured their perceptions of risks and benefits of these technologies (details on relevant survey items are provided in Table A1 in the Appendix). Building on previous relevant studies, we assessed perceived environmental and safety impacts, perceived societal benefits, and perceptions of CCS technologies as a good climate solution. We present these results in Sections 3.1 and 3.2 below. A regression analysis then assessed the determinants of CCS perceptions (details on relevant survey items are provided in Table A2 in the Appendix).

Our second objective was to assess how public support for policies to scale up CCS is shaped by specific policy design features. In order to do this, we employed a conjoint experiment. Conjoint experiments have been used to examine policy preferences in different contexts, including energy and climate policy (Hainmueller et al., 2014; Bechtel and Scheve, 2013; Gampfer et al., 2014). They allow observing respondents' preferences over a series of multidimensional policy scenarios and estimating the impacts of different attributes on policy support (Hainmueller et al., 2014). Before participating in the experiment, respondents were informed that policy proposals to scale up CCS in their state may vary on a number of attributes and received information on five policy attributes and their levels. They then were shown eight consecutive pairs of state-level policy proposals, with each proposal defined on the five attributes. For each pair of proposals, respondents were required to choose the proposal they preferred (forced-choice outcome) and to rate on a scale from 0 to 10 their probability of voting for each proposal in a hypothetical direct democratic vote (rating outcome). Details on the conjoint experiment are provided in Section 3 of the Appendix, and Figure A1 shows an example of a choice screen.

The attribute levels were fully randomized within and across policy pairs, which guarantees the non-parametrical identification of the causal effects of the policy attributes (Bechtel and Scheve, 2013). To estimate the average marginal effect of each attribute level on policy support, we ran a regression with dummy variables for different attribute levels. For each attribute, we define one level as baseline against which we compute the marginal effect of the other levels. The model we estimate is therefore the following:

$$y_{ijk} = \beta X_{ijk} + \varepsilon_{ijk}$$

where y_{ijk} is the vote by respondent i for proposal k in task j and X_{ijk} is a vector of attribute levels of the policy proposal presented to i in k. Standard errors are clustered by respondent to account for within-respondent correlations in responses.

We selected five pertinent policy attributes based on a survey of the scientific and policy literature related to CSS, focusing on the following dimensions: policy instrument, policy cost, timing, space, and stakeholder endorsement. Table 1 displays the five policy attributes and their levels.

As public support for public policies has been shown to crucially depend on policy instruments, our first attribute of interest is the specific policy instrument employed to scale up CCS. We included three policy instruments that have either been discussed in the policy debate or implemented (Bäckstrand et al., 2011; von Stechow et al., 2011): (1) Bans on the construction of new unabated coal- and natural gas-fired power plants (i.e., without CCS); (2) Government subsidies for CCS; (3) Increase in taxes on unabated fossil fuel power generation. We have not assessed support for more ambitious policies to scale up CCS that are not currently being considered at the political level, such as an obligation to phase out existing unabated fossil fuel plants unless upgraded with CCS technology. Given that Americans are sensitive to the cost of energy solutions (Ansolabehere and Konisky, 2014), we included cost as a second attribute likely to shape preferences towards CCS policies. We selected four different policy cost levels ($4, $9, $14, $19) defined as monthly cost per household, in order to make these amounts tangible to respondents. The timing of policy implementation is a third key element of policy proposals. It is particularly relevant in the context of climate policies and CCS, as postponing mitigation action has fundamental implications for our ability to achieve rapid decarbonization. The timing attribute levels we selected include the beginning of policy

Table 1
Policy attributes and their levels.

Attributes	Policy instrument	Costs (monthly, per household)	Beginning of policy implementation	Required distance to residential areas	Policy endorsement by
Level 1	Ban on the construction of new fossil fuel power plants without CCS	$4	2020	2 miles	Carbon Capture Coalition
Level 2	Government subsidies for CCS	$9	2030	5 miles	Greenpeace
Level 3	Increase in taxes on fossil fuel power generation without CCS	$14	2040	10 miles	Democratic Party
Level 4	-	$19	2050	50 miles	Republican Party

implementation in 2020, 2030, 2040, and 2050. The fourth policy attribute is required distance of plants employing CCS from residential areas, and its levels are 2, 5, 10 and 50 miles. Building on studies of public opposition to energy technology developments near communities and homes, and on previous studies of CCS perceptions finding opposition to CCS developments close to residential areas (Saito et al., 2019; Tcvetkov et al., 2019), we hypothesized that place attachment might cause proximity of CCS plants to exert a significant negative influence on policy support (Devine-Wright, 2009). Finally, as endorsements by key political and social actors can influence citizens' policy preferences (Lupia, 1994), we selected policy endorsement as the fifth attribute. Its levels are policy endorsement by the Democratic party, by the Republican party, and by two organizations with official positions in favor of CCS (the Carbon Capture Coalition) and against CCS (Greenpeace).

3. CCS perceptions

3.1. Awareness of CCS

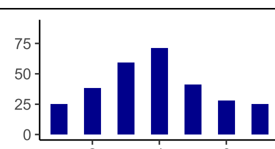
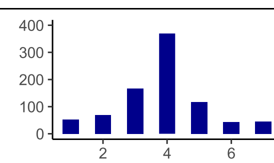
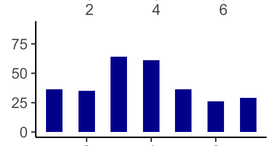
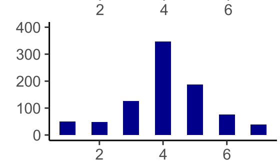
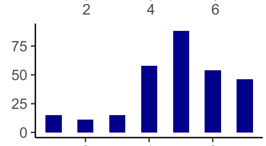
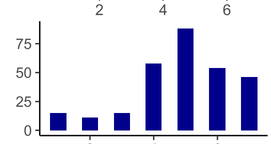
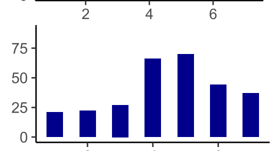
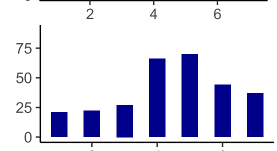
Consistent with results from other countries (Arning et al., 2019; Chen et al., 2015; Saito et al., 2019; Tcvetkov et al., 2019), we find very low awareness of CCS technologies among respondents in our sample. 57 percent of respondents declared that they had never heard about CCS before taking the survey, 24 percent were not sure and only 19 percent stated that they had heard about CCS before. These results suggest that the US population is not very familiar with CCS technologies. This is not surprising given the extremely low coverage of CCS in the mass media and in the national political debate (Dowd et al., 2012; Feldpausch-Parker et al., 2013).

3.2. Perceptions of CCS risks and benefits

As anticipated above, after providing information on CCS, we measured respondents' perceptions of risks and benefits associated with these technologies. Table 2 displays the survey items and the distribution of responses separately for the subsample of respondents that had never heard of CCS before taking the survey and for the subsample of respondents that had already heard of CCS before. Fig. 1 shows average perceptions of CCS for the same two subsamples.

Perceptions of the negative impacts or risks of CCS are similar for respondents with previous awareness of CCS and for respondents with no previous awareness. Perceptions of environmental risks (Q1) are moderate and equivalent for the two groups (mean value of 3.87 on a 7-point scale) and perceptions of safety risks (Q2) are also moderate and similar (mean values of 3.77 for the 'aware' and 3.86 for the 'non aware'). Perceptions of societal benefits of CCS (Q3) are higher among

Table 2
Survey items measuring perceptions of CCS technologies and distribution of responses for the subsamples of respondents with no previous awareness of CCS and with previous awareness of CCS. Responses based on a 7-point Likert scale from 1 = "Not at all" to 7 = "Very much". Respondents who were not sure they had heard of CCS before are not included here.

Survey Questions	Distribution of values for respondents with no previous CCS awareness	Distribution of values for respondents with previous CCS awareness
Q1. "To what extent do you think that CCS has a negative impact on the environment?"		
Q2. "To what extent do you think that CCS has a negative impact on your safety? "		
Q3. "To what extent do you think that CCS entails benefits for society? "		
Q4. "To what extent do you think that CCS is a good solution to the challenge of climate change? "		

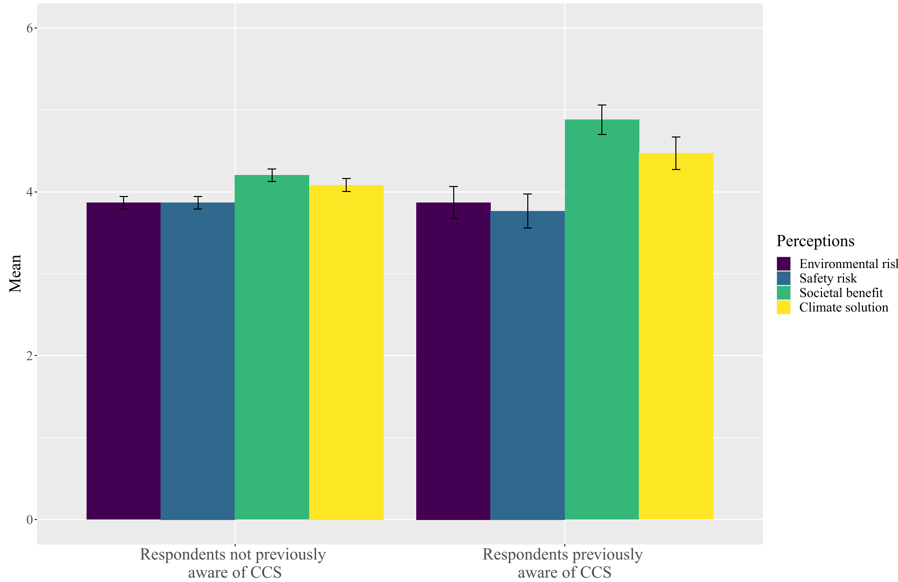


Fig. 1. Perceptions of risks and benefits associated with Carbon Capture and Storage technologies. Average values for the subsample of respondents with no previous awareness of CCS (n = 869) and for the subsample of respondents with previous awareness of CCS (n = 287). Respondents that declared they were not sure if they had heard of CCS before are excluded from this graph. Error bars represent 95% confidence intervals.

respondents with previous awareness of the technology compared to respondents with no previous awareness (mean values of 4.88 and 4.10 respectively), and perceptions of CCS as a 'good solution to climate change' (Q4) are also higher among the former (mean values of 4.47 for the 'aware' and 3.96 for the 'non aware'). The differences in perceptions of benefits among the two groups are statistically significant ($p < 0.001$). Overall, most likely due to the extremely limited debate on CCS in the public sphere and non-expert environments, perceptions of CCS are not extreme. However, respondents who are more familiar with CCS have more positive perceptions of this technology.

We then investigated the variation in perceptions of CCS by means of regression analysis. The dependent variable is an index composed of the four perception items. Higher values of the index indicate more positive perceptions of CCS (to construct the index we reversed the risk perception items). Our battery of independent variables comprises variables that have been found to influence support for climate policies in previous studies (Beiser-McGrath and Huber, 2018; Drews and Bergh, 2016). We include socio-demographic variables (age, gender, educational attainment, income, urban versus rural place of residence), political orientation, previous awareness of CCS, and psychological distance of climate change, which is an index measuring whether respondents perceived climate change to be close to themselves on several dimensions (details on the index and other variables are presented in Table A2 in the Appendix). The results of our linear regression analysis are displayed in Table 3. Consistent with our descriptive analyses above, respondents with previous awareness of CCS have more positive perceptions of CCS. Likewise, respondents perceiving climate change as closer to themselves have more positive views of CCS. Having a higher income and residing in urban areas is associated with more positive perceptions of CCS as well, while age and education are not significant predictors. Interestingly, Democrats have more positive perceptions of CCS than Republicans. The more positive perceptions of CCS among Democrats and among people with lower psychological distance to climate change might be in part due to the fact that CCS was explicitly presented as a climate change mitigation technology in our survey. This suggests that different ways of describing or framing CCS policies might have different impacts on policy support among different subgroups of citizens, in particular among Republicans or people with lower concern for climate change.

Table 3
Linear regression analysis of predictors of CCS perceptions. The outcome variable is an index constructed as the arithmetic sum of the four items measuring perceptions of risks and benefits of CCS presented in Table 2. Higher values of the outcome variable indicate more positive perceptions of CCS. Urban/Rural takes the values 1 = Urban; 2 = Suburban; 3 = Rural. Partisan orientation is a 7-point scale from 1 = Strong Democrat to 7 = Strong Republican. Psychological distance is a binary variable which is equal to 0 for respondents with higher psychological distance and to 1 for respondents with lower psychological distance to climate change. This variable is based on a dichotomization of an index combining different survey items measuring distance to climate change on different dimensions (see details in Table A2 in the Appendix). Previous CCS awareness is equal to 0 for respondents who had never heard of CCS before, 0.5 for respondents who said they maybe heard of CCS before, and 1 for respondents who had heard of CCS before. See details on survey items and descriptive statistics in Table A2 in the Appendix.

	CCS Perceptions
Age	−0.006
	(0.007)
Gender	0.378
	(0.224)
Education	−0.142
	(0.121)
Income	0.208**
	(0.063)
Urban/rural	−0.459**
	(0.162)
Partisan orientation	−0.155*
	(0.062)
Psychological distance	0.701**
	(0.241)
Previous CCS awareness	0.933**
	(0.292)
Constant	13.388***
	(0.805)
Observations	1511
R-squared	0.047

Robust standard errors in parentheses.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

4. Conjoint experiment results

Fig. 2 shows the results of the conjoint experiment, displaying marginal effects of attribute levels with the associated 95% confidence intervals. One level per attribute is selected as baseline category (shown without confidence intervals). We report here results based on the rating outcome. The corresponding regression table is presented in Table A5 in the Appendix. Inattentive individuals who failed an attention check were removed from the sample and from the analyses. Analyses were replicated on a sample that excluded 64 respondents who completed the survey in less than a third of median completion time with identical results (see Table A7 in the Appendix). Results based on logistic regression using the forced choice outcome variable are reported in Table A6 and Figure A2 and are qualitatively equivalent. Results based only on the first choice made by each respondent are also equivalent (see Figure A3 in the Appendix).

Fig. 2 shows that policies that ban the construction of new coal- and gas-fired power plants without CSS are more supported than subsidies for CCS and increases in taxes on unabated fossil fuel power generation. Subsidies find slightly more support than taxes, but the difference is not significant.

Policy support also depends on the timing of policy implementation. Policies implemented in 2020 and 2030 find higher support than policies implemented in 2040 and 2050 (note that the difference between 2030 and 2040 is not significant). These results are in line with studies by Rinscheid et al. (2020) and Rinscheid and Wüstenhagen (2019), who have shown that citizens in the US and Germany on average favor earlier implementation of decarbonization policies over later policy action.

As predicted, policy costs are another significant determinant of policy support, with support almost linearly decreasing with an increase in policy costs. Policy support also increases with stricter minimal distance requirements between plants employing CCS and residential areas. This is in line with findings of previous studies about CCS perceptions and perceptions of energy technologies in general.

Policy endorsement by key political and societal actors does not have a clear and sizable impact on average support on our full sample of respondents. These results are not surprising, as the impact of policy endorsements can reasonably be expected to have a differentiated impact depending on different respondents' perception of endorsers. When assessing heterogenous effects for respondents with different perceptions of these societal actors, we see that endorsement by the Republican (Democratic) party has a significant and sizable positive impact on policy support among Republicans (Democrats), and that endorsements by Greenpeace and the Carbon Capture Coalition significantly increase policy support among respondents with high levels of trust in these actors. The latter effects, however, are lower than those relating to political parties (see Figure A4 in the Appendix).

5. Support for illustrative policy scenarios

The conjoint design also allows simulating support for specific policy scenarios (Bechtel and Scheve, 2013). This can be done by rescaling the policy ratings provided by respondents on the [0, 100] set, estimating the effect of different attributes on the rescaled rating variable, and using the attributes' effects to compute predicted values for specific policy scenarios of interest. Fig. 3 displays support for a series of policy scenarios, showing how support varies with two key attributes: policy costs and distance from residential areas. Because partisan orientation is an important determinant of perceptions of CCS – average policy support across all our policy scenarios is 55 percent among Democrats and 38 percent among Republicans – we present policy support levels for the whole sample of respondents (purple in Fig. 3), but also separately for

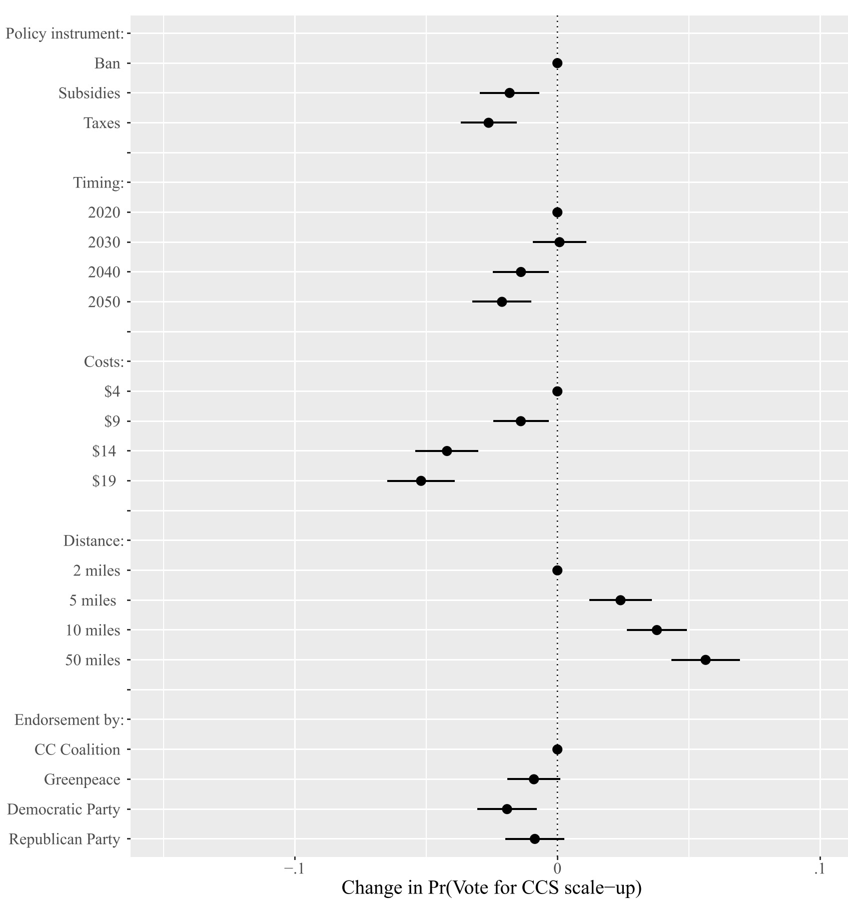


Fig. 2. Average effects of CCS policy attributes on policy support. Each dot represents the average marginal effect of an attribute level on the probability of voting for a policy proposal in relation to a proposal with the reference level for the same attribute. The horizontal bars represent the associated 95% confidence intervals. Dots without bars represent the reference level for each policy attribute. Calculations are based on linear regression analyses using policy rating as outcome variable. Standard errors are clustered for respondents. N = 24,320 policy proposals.

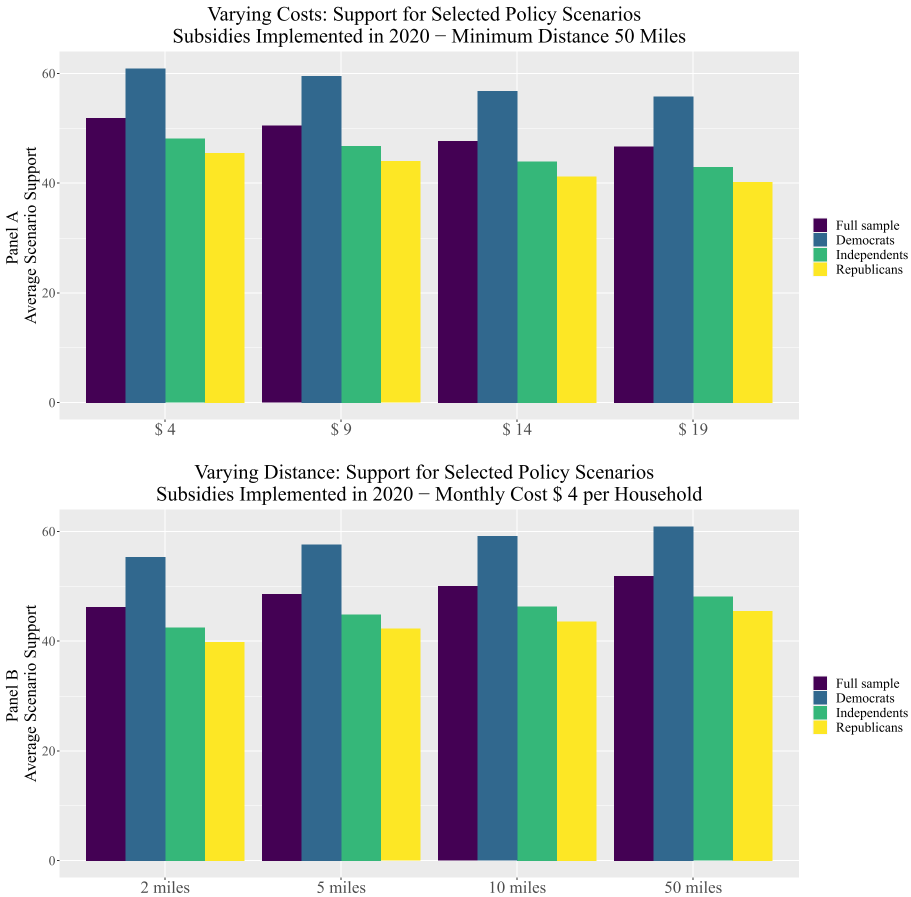


Fig. 3. Predicted levels of policy support for a selection of policy scenarios varying with respect to policy costs (Panel A) and distance from residential areas (Panel B). Predicted values of support based on estimated effects of attribute levels. Scenarios in panel A are based on CCS subsidies implemented in 2020 with minimal distance from residential areas of 50 miles. Scenarios in panel B are based on CCS subsidies implemented in 2020 with a cost of $4 per household per month. Results for the full sample of respondents are presented in purple, results for Democrats in blue, results for Independents in green and results for Republicans in yellow. Predicted values can be interpreted as the level of policy support within the respective population (full sample, Democrats, Independents, and Republicans). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Democrats (blue), Independents (green) and Republicans (yellow). These predicted values can be interpreted as the level of support a policy receives within the respective population (i.e., full sample, Democrats, Independents, and Republicans).

Panel A shows how policy support varies with policy costs. All scenarios in panel A are based on CCS subsidies that are implemented in 2020 and include a minimal distance from residential areas of 50 miles, averaged across the policy endorsement attribute levels. Policy support decreases with the increase of costs, and policies with a cost of $4 or $9 per household per month are supported by more than 50 percent of our sample. It is important to note that here support levels are relatively high because the distance attribute is fixed at 50 miles for all policy scenarios.

Panel B shows how policy support varies with distance requirements from residential areas. All scenarios in panel B are based on subsidies that are implemented in 2020 with a cost of $4 per household per month, averaged across the policy endorsement attribute levels. Policy support increases with the increase of distance requirement from residential areas. Policies with minimal distance requirements of 10 and 50 miles find support among 50 percent of our sample. Here, too, support levels are overall relatively high because the cost attribute is fixed at $4 for all policy scenarios.

Among Democrats, average support for all policies in Fig. 3 is higher than 50 percent, and sometimes higher than 60 percent, while among Republicans support is always lower than 50 percent. Support levels of Independents are between those of Republicans and those of Democrats for all policies. It is important to note that our study is based on a non-probability but demographically representative sample of American residents. While the support levels found in our study may not perfectly mirror support in the American population, the differences in support levels are a robust indication about the extent to which changes in policy attributes move citizens' support for CCS policies.

6. Conclusion and policy implications

Based on a survey and a conjoint experiment administered to a demographically representative sample of American residents, we investigated perceptions of CCS technologies and experimentally studied factors that influence public support for policies to scale up CCS. Our study documents that awareness of CCS technologies, which play a major role in many Integrated Assessment Model scenarios compatible with the Paris Agreement's goal of limiting global warming to well below 2°, is rather low. Individuals who are aware of CCS tend to perceive its societal and climate change-related benefits to be higher, and the same is true for individuals who perceive climate change to be closer to themselves on multiple dimensions. Our experimental results highlight the key role of several policy design features in shaping public support for policies to scale up CCS. In terms of policy instruments, state-level bans on the construction of new fossil fuel power plants without CCS found significantly higher support than other policies. The costs of scaling up CCS deployment, the timing of policy implementation as well as distance requirements were also shown to have an influence on policy support. Moreover, support for CCS policies varies with political orientation, with Democrats being more favorable than Independents and Republicans.

Our results have three key policy implications. First, support for policies to scale up CCS is sensitive to the choice of policy instruments. We found that bans on the construction of unabated fossil fuel plants are more supported than subsidies for CCS and taxes on unabated power generation. This is consistent with evidence of tax-aversion, in particular among Americans, present in the economics and behavioral literature (Hardisty et al., 2010; Kessler and Norton, 2016). Therefore, taking citizens' preferences into account, policymakers may wish to push legislation into this direction. Given the dim outlook for the construction of new coal-fired power plants in the US (Mendelevitch et al., 2019; Shearer et al., 2018), it would be crucial that such legislation explicitly includes also natural gas-fired power plants. Moreover, in order to effectively reduce emissions from coal- and gas-powered plants, such legislation would need to ratchet up rapidly, for instance by setting clear timelines for the phase-out of existing unabated plants unless upgraded with CCS technology. Second, required distance of CCS infrastructure from residential areas is a key attribute influencing policy support. This suggests that opposition to local CCS infrastructure might emerge during project development, mirroring opposition to other local energy infrastructure such as nuclear power plants, windmills or hydropower plants. CCS infrastructure will therefore have higher chances of political survival in less densely populated areas. Third, policy support considerably differs among individuals with different partisan orientation. The ideological polarization around climate change needs to be taken into due account when proposing, communicating and implementing policies to scale up CCS in the United States.

Future research may assess whether different framings of CCS policies have an impact on policy support among individuals with different partisan orientation. It might be tested whether support among Independents and Republicans increases when CCS deployment is framed predominantly in terms of jobs or energy security rather than climate change. Moreover, we cannot asses here whether the correlation between higher familiarity with CCS and more positive perceptions of these technologies is caused by the fact that available information on CCS is mostly produced by CCS promoters presenting CCS as a powerful climate mitigation option. Future studies might assess whether providing more information on CCS produces more positive perceptions and decreases wariness about these relatively unknown technologies.

Credit author statement

All authors contributed to conceptualization and writing of the paper. The design of the data collection and analyses were contributed to by all authors. Silvia Pianta and Adrian Rinscheid conducted the statistical analyses.

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

1. *Survey procedure*

The survey developed for this study was composed by four main sections: (1) a first set of general survey questions on demographic characteristics and environmental attitudes; (2) a second set of questions on *awareness* of CCS technologies (administered before providing information on CCS) and on *perceptions* of CCS technologies (administered after the provision of basic information on CCS); (3) the conjoint experiment; (4) a final set of "general" survey questions, including questions on attitudes toward government, trust in political elites, partisan orientation and education, that we placed at the end of the survey to prevent them from influencing our measurement of CCS perceptions and the conjoint experiment. Section 2 of the Appendix presents in Table A1 the survey items employed to measure CCS awareness and perceptions and in Table A2 the survey items not concerning CCS (administered in the first and last section of the survey). Section 3 provides details on the conjoint experiment, which aimed at assessing the role of policy design features in shaping support for CCS policies.

2. *Survey items*

Table A1
Survey items measuring CCS awareness and perceptions

Variable	Questions and Distribution
	CCS awareness - Measured before providing information on CCS.
Previous CCS awareness	*Have you ever heard of carbon capture and storage technologies (often abbreviated as "CCS")?* 1 = Yes (18.88%); 2 = I am not sure (23.95%); 3 = No (57.17%).
	CCS risks & benefits perceptions - Measured after providing information on CCS.
Perceived environmental impact	*To what extent do you think that CCS has a negative impact on the environment? Responses based on a 7-point Likert scale from "Not at all" to "Very much".*
Perceived safety impact	*To what extent do you think that CCS has a negative impact on your safety? Responses based on a 7-point Likert scale from "Not at all" to "Very much".*
Perceived societal benefits	*To what extent do you think that CCS entails benefits for society? Responses based on a 7-point Likert scale from "Not at all" to "Very much".*
Perceived climate solution	*To what extent do you think that CCS is a good solution to the challenge of climate change? Responses based on a 7-point Likert scale from "Not at all" to "Very much".*

Table A2
Survey items and descriptive statistics of demographic variables, partisan orientation and psychological distance of climate change.

Variable	Questions and Distribution
Section 1 of the survey	
Age	*Please indicate your year of birth.* Transformed to respondents' age.
Gender	*Please indicate your gender.* Male 44.7%, Female 55.3%
Income	*Please indicate an estimate of your annual family income (before taxes):* 1 = Less than \$20,000 (14.7%)/2 = \$20,000 - \$39,999 (20.2%)/3 = \$40,000 - \$59,999 (17.0%)/4 = \$60,000 - \$79,999 (13.4%)/5 = \$80,000 - \$99,999 (10.1%)/6 = \$100,000 - \$149,999 (15.3%)/7 = More than \$150,000 (8.6%)/8 = Don't know/Prefer not to answer (0.6%)
Urban-rural	*Which of the following best describes the area you live in?* 1 = Urban (24.6%); 2 = Suburban (52.4%); 3 = Rural (23.0%)
Psychological distance of climate change	Factor variable, based on 6 items (one omitted): My local area is likely to be affected by climate change. (psy1) 1 = strongly disagree (7.0%); 2 (7.6%); 3 (16.3%); 4 (25.0%); 5 (20.9%); 6 = strongly agree (23.2%) Climate change most likely affects areas that are far away from here. (psy2) 1 = strongly disagree (27.6%); 2 (18.5%); 3 (21.3%); 4 (14.7%); 5 (9.1%); 6 = strongly agree (8.7%) Climate change is likely to have a big impact on people like me. (psy3) 1 = strongly disagree (8.0%); 2 (8.2%); 3 (15.3%); 4 (22.4%); 5 (19.9%); 6 = strongly agree (26.3/%) I am certain that climate change is really happening. (psy4) 1 = strongly disagree (6.5%); 2 (6.1%); 3 (11.3%); 4 (17.2%); 5 (18.6%); 6 = strongly agree (40.3%) Most scientists agree that human activities are causing climate change. (psy5) 1 = strongly disagree (5.3%); 2 (4.2%); 3 (12.2%); 4 (21.2%); 5 (22.4%); 6 = strongly agree (34.8%) When, if at all, do you think America will start feeling the effects of human-caused climate change? (psy6) 1 = We are already feeling the effects (58.8%); 2 = within the next 10 years (12.2%); 3 = within the next 25 years (9.5%); 4 = within the next 50 years (3.6%); 5 = within the next 100 years (3.2%); 6 = beyond the next 100 years (3.7%); 7 = never (9.0%) Notes on index construction: First, an initial correlation analysis shows that psy2 does not correlate with the other 5 items: psy1 psy2 psy3 psy4 psy5 psy6 psy1 psy2 −.02 psy3 .77 .01 psy4 .73 .01 .77 psy5 .65 .03 .68 .71 psy6 −.61 .05 −.63 -.68 −.60 Next, we reverse-scored psy6 and used confirmatory factor analysis to check whether the remaining five items are valid representations of the underlying latent construct. All factor loadings are above .75, which supports the validity of the factor model: psy1 = .81/psy3 = .85/psy4 = .90/psy5 = .80/psy6 = .75 (all significant at $p < 0.001$). According to various fit indices, the model fits our data well (CFI = 1.000; RMSEA = 0.000; SRMR = 0.003). Scale reliability coefficient (Cronbach`s alpha): .909 To simplify the interpretation of results, in the regression analysis we employ a binary variable, which is simply a dichotomized version of the original Psychological Distance Index. Regression results are equivalent when employing the original index instead of its dichotomized version.
Section 4 of the survey	
Education	*What is the highest level of education you have completed?* 1 = Less than high school degree (1.78%); 2 = Graduated from high school (18.62%); 3 = Some college (30.92%); 4 = Four-year college degree (33.29%); 5 = Advanced degree (15.39%)
Partisan orientation	*Generally speaking, do you consider yourself a(n):* 1 = Strong Democrat (17.6%); 2 = Weak Democrat (8.9%); 3 = Lean Democrat (9.3%); 4 = Independent (32.6%); 5 = Lean Republican (11.2%); 6 = Weak Republican (6.2%); 7 = Strong Republican (14.2%)

3. Conjoint experiment

After answering the first set of survey questions measuring demographic characteristics, answering the question on CCS awareness, reading a short description of CCS technologies, and answering the questions on perceptions of CCS risks and benefits, respondents participated in the conjoint experiment aimed at assessing the role of policy design features in shaping support for CCS policies.

Respondents first read a short text with basic information on policy proposals regarding CCS. Second, all policy attributes were briefly explained and information on attribute levels was provided. Third, respondents were shown eight pairs of policy scenarios that differed randomly on five attributes (see the full list of attributes and their levels in Table A3 and an example of a choice screen in Figure A1). Respondents had to decide, for each pair of scenarios, which one they preferred (forced choice outcome), and indicate on an 11-point scale for each scenario their likelihood of supporting it if it were put to a referendum (rating outcome, in 10% increments from 0 to 100%).

	Scenario 1	Scenario 2
Policy types	Ban on new fossil fuel plants without CCS	Government subsidies for CCS
Beginning of policy implementation	2020	2030
Policy cost (per household, per month)	$4	$14
Distance from residential areas	2 miles	50 miles
Policy endorsement by	Democratic Party	Republican Party
Select one	○	○

If you had the possibility to vote for Scenario 1 in a direct democratic vote, how likely would you vote for it?
(0 is "would definitely NOT vote for" and 10 is "would definitely vote for")

Scenario 1	0	1	2	3	4	5	6	7	8	9	10

If you had the possibility to vote for Scenario 2 in a direct democratic vote, how likely would you vote for it?
(0 is "would definitely NOT vote for" and 10 is "would definitely vote for")

Scenario 2	0	1	2	3	4	5	6	7	8	9	10

Fig. A1. An example of a choice screen.

3.1. Information on CCS provided to participants

At the beginning of the conjoint experiment, participants were provided with the following introduction to the topic:

Carbon capture and storage (CCS) is a set of technologies aimed at capturing, transporting, and storing carbon dioxide (CO_2) emitted from industrial facilities and power plants that use fossil fuels like coal and natural gas. CO_2 emissions are one of the major contributors to climate change. The goal of CCS is to prevent CO_2 from reaching the atmosphere by injecting it in suitable underground geological formations - depleted oil and gas fields and deep saline formations - for permanent storage.

Some scientific studies promote CCS as a prospective solution to climate change, as it could significantly contribute to the reduction of CO_2 emissions, while other studies emphasize that CCS is a very costly technology and there is a need to investigate its potential risks in order to ensure that its deployment would not have an adverse impact on people and the environment. Political discussions currently focus on how to regulate and implement the use of CCS.

You may or may not agree with scaling up CCS, but if a scale-up were to be implemented in your state, you may still have different preferences as to specific scenarios. In the following, we will sketch out some scenarios for a scale-up of CCS. Please take a look at these scenarios and evaluate them.

3.2. Description of policy attributes and their levels

Participants were then provided with the following description of policy attributes and their levels:
Please read the following lines carefully!

Don't worry: it is not necessary that you remember every detail, but in going through the following aspects, you should get a feel for what matters in a potential scale-up of CCS technologies. You will not be allowed to proceed before having read the following lines on this page.
The below mentioned policy scenarios each consist of 5 aspects:

1. *Policy type: Which policies should be implemented to promote CCS?a) A ban on the construction of new fossil fuel power plants without CCS in your state: According to this policy, no new coal- or gas-fired power stations can be built in your state without including CCS. b) Government subsidies for CCS in your state: Your state government could subsidize CCS projects. This would make deployment of the technology more economically attractive. c) Increase in taxes on fossil fuel power generation without CCS in your state: Such a policy would make fossil fuel power generation with no CCS more expensive.*

2. *Policy costs: All policies to scale up CCS would produce some costs for American consumers. However, the exact amount depends on many factors, such as the concrete policy calibration, economic conditions, etc. Estimates for a scale-up policy currently range between costs of US$ 4 and 19 per household (per month).*
3. *Beginning of policy implementation: When should the policy be implemented? Various scenarios include implementation in 2020, 2030, 2040 or 2050.*
4. *Distance from residential areas: CCS facilities are currently planned in many American states. Some people fear that they could negatively affect buildings and the safety of communities. Different rules regarding the required distance of CCS facilities from residential areas are currently being discussed: 2 miles/5 miles/10 miles/50 miles*
5. *Policy endorsement: Various stakeholders (e.g., Greenpeace or the U.S.-based Carbon Capture Coalition) and political parties (Democrats, Republicans) have their own opinions on policy proposals to scale up CCS.*

Table A3
Policy attributes and attribute levels

Conjoint Attributes	Attribute levels
Policy type	•Ban on the construction of new fossil fuel power plants without CCS in your state. •Government subsidies for CCS in your state. •Increase in taxes on fossil fuel power generation without CCS in your state.
Policy costs (per household, per month)	•$4 •$9 •$14 •$19
Beginning of policy implementation	•2020 •2030 •2040 •2050
Required distance to residential areas	•2 miles •5 miles •10 miles •50 miles
Policy endorsement by	•Greenpeace •Carbon Capture Coalition •Democratic Party •Republican Party

4. *Sample of survey respondents*

To field the survey, we contracted with the survey company Lightspeed. Respondents were incentivized based on Lightspeed's standards.[1] Median survey completion time was 19 min and 43 s. To ensure high-quality data, several respondents were excluded based on a number of criteria. First, 560 inattentive respondents did not pass an attention check implemented a third of the way into the survey and were immediately excluded. Second, 34 speedsters with short completion time (<40% of median time) were excluded. Also excluded were 111 respondents who gave no consent and 17 respondents who did not match our restrictions in terms of age (minimum 18 years). The data of all these 722 individuals never show up in our analyses, as they are not included in our sample of 1520 American residents.

Table A4
Sample distribution of socio-demographic variables and comparison with US population.

Variable	Sample	US population
Age		(only pop. over 18)
18–29	18.3%	21.3%
30–39	19.0%	17.0%
40–49	16.3%	16.5%
50–59	19.3%	17.9%
60–69	17.0%	14.6%
70+	10.2%	12.7%
Gender		
♂	44.7%	49%
♀	55.3%	51%
Region		
Northeast	18.8%	17.3%
Midwest	22.8%	20.9%
South	39.5%	38.0%
West	18.9%	23.8%
Annual Family Income		
Less than $20,000	14.7%	16%
$20,000 - $39,999	20.2%	19%
$40,000 - $59,999	17.0%	16%
$60,000 - $74,999	13.4%	9%
$75,000 - $99,999	10.1%	12%

(*continued on next page*)

[1] Respondents recruited by lightspeed receive „LifePoints" (lightspeed's internal currency) for their participation in surveys. For our study, respondents received 100 LifePoints. Respondents can pay out their LifePoints via PayPal, exchange them for vouchers (e.g., Amazon), or donate the money to UNICEF.

Table A4 (*continued*)

Variable	Sample	US population
$100,000 - $149,999	15.3%	14%
More than $150,000	8.6%	14%
(Don't know/Prefer not to say)	0.6%	
Party Affiliation		
Democrat	35.8%	33%
Independent	32.6%	37%
Republican	31.5%	26%

Notes: Information on socio-demographic characteristics of the US population was obtained from the U.S. Census Bureau (for age and sex composition (2016) see https://www.census.gov/data/tables/2016/demo/age-and-sex/2016-age-sex-composition.html; for regions (2016) see https://www.census.gov/popclock/data_tables.php?component=growth, for income (2017) see https://www2.census.gov/programs-surveys/cps/tables/hinc-06/2017/hinc06.xls). Information on party affiliation is based on Pew Research Center surveys conducted in 2017 (http://www.people-press.org/wp-content/uploads/sites/4/2018/03/03-20-18-Party-Identification.pdf). The total percentage for Pew data does not add up to 100 as the remaining share belongs to the category "other."

Relative to US census figures, our sample slightly over-represents individuals between 30 and 69, and slightly under-represents individuals in the segments between 18 and 29 and over 70, but the differences are overall quite small. Our sample contains 44.7% males and under-represents the West, while the other three census regions are slightly over-represented. Income distributions are overall well matched, but our sample contains a lower share of high-income individuals. In terms of party identification, a comparison with the US population is not straightforward, but the distribution in our sample (roughly one third Democrats, Independents and Republicans, respectively) matches the numbers of recent Pew surveys, which can serve as a benchmark.

5. Power analysis

Standard parametric power analyses techniques are not directly applicable to conjoint experiments, given the complexity generated by multiple treatments, tasks, and paired designs. We therefore rely on the simulation-based tool developed by Stefanelli and Lukac (2020), who provide a framework for calculating power for conjoint experiments using simulation techniques. They provide an online tool, available at https://mblukac.shinyapps.io/conjoints-power-shiny/. Based on their framework, an experiment with 1500 participants, 8 tasks and 4 attribute levels has a 90% power to detect an effect of 0.03 and a 67% power to detect an effect of 0.02. In our experiment we indeed find significant effects of attribute levels as small as 0.014.

Applying a more standard power computation of our experiment, we can compute power as:

$$1-\beta = \Phi(z - z_{1-\alpha/2}) + \Phi(-z - z_{1-\alpha/2})$$

With:

$$z = \frac{\mu - \mu_0}{\sigma/\sqrt{n}}$$

where n is the sample size, σ is the standard deviation, Φ is the standard normal distribution function, and α is the confidence level. We find that, with our sample size of 1,520, a standard experimental setting would have a 97% power of detecting an effect of 0.02 with a standard deviation of 0.2, and a 78% power of detecting an effect of 0.014, which is the smallest significant coefficient that we find.

6. Conjoint analysis results: Regression Table

Table A5
Average marginal effects from conjoint experiment.
Notes: Coefficients from OLS regressions; robust standard errors (clustered by respondent) in parentheses. The results shown here refer to Fig. 2 in the paper.

	Policy Support
Policy type	
Baseline: Bans	
Subsidies	−0.0182**
	(0.00576)
Taxes	−0.0262***
	(0.00544)
Timing	
Baseline: 2020	

(*continued on next page*)

Table A5 (*continued*)

	Policy Support
2030	0.000805
	(0.00519)
2040	−0.0139*
	(0.00542)
2050	−0.0211***
	(0.00570)
Costs	
Baseline: $ 4	
$ 9	−0.0139**
	(0.00539)
$ 14	−0.0420***
	(0.00608)
$ 19	−0.0519***
	(0.00653)
Distance	
Baseline: 2 miles	
5 miles	0.0240***
	(0.00603)
10 miles	0.0379***
	(0.00580)
50 miles	0.0564***
	(0.00663)
Endorsement	
Baseline: CC Coalition	
Greenpeace	−0.00895
	(0.00513)
Democratic Party	−0.0192***
	(0.00575)
Republican Party	−0.00860 (0.00570)
Constant	0.490***
	(0.00913)
N	24320

Standard errors in parentheses.
*p < 0.05, **p < 0.01, ***p < 0.001.

7. *Robustness check: analysis of conjoint experiment using logistic regression and the forced choice outcome variable*

Table A6
Conjoint experiment results using logistic regression. Notes: Coefficients from logit regressions and transformed into average marginal effects; robust standard errors (clustered by respondent) in parentheses. Forced outcome policy support variable used as outcome variable. Results are identical to results of linear regression analysis.

	(1) Policy Support (Logit Coefficients)	(2) Policy Support (Marginal Effects)
Policy type		
Baseline: Bans		
Subsidies	−0.0619 (0.0376)	−0.0146 (0.00885)
Taxes	−0.289*** (0.0395)	−0.0681*** (0.00927)
Timing		
Baseline: 2020		
2030	−0.0591 (0.0375)	−0.0139 (0.00880)
2040	−0.271*** (0.0385)	−0.0640*** (0.00903)
2050	−0.361*** (0.0444)	−0.0850*** (0.0104)
Costs		
Baseline: $ 4		
$ 9	−0.314*** (0.0389)	−0.0742*** (0.00913)
$ 14	−0.631*** (0.0405)	−0.151*** (0.00954)
$ 19	−1.014*** (0.0458)	−0.241*** (0.0104)
Distance		
Baseline: 2 miles		
5 miles	0.338*** (0.0403)	0.0795*** (0.00941)
10 miles	0.599*** (0.0421)	0.142*** (0.00981)
50 miles	0.742*** (0.0487)	0.176*** (0.0113)
Endorsement		
Baseline: CC Coalition		
Greenpeace	−0.102* (0.0401)	−0.0240* (0.00941)
Democratic Party	−0.264*** (0.0435)	−0.0620*** (0.0102)
Republican Party	−0.117** (0.0420)	−0.0274** (0.00989)
Constant	0.479*** (0.0565)	
N	24,320	24,320

Standard errors in parentheses.
*p < 0.05, **p < 0.01, ***p < 0.001.

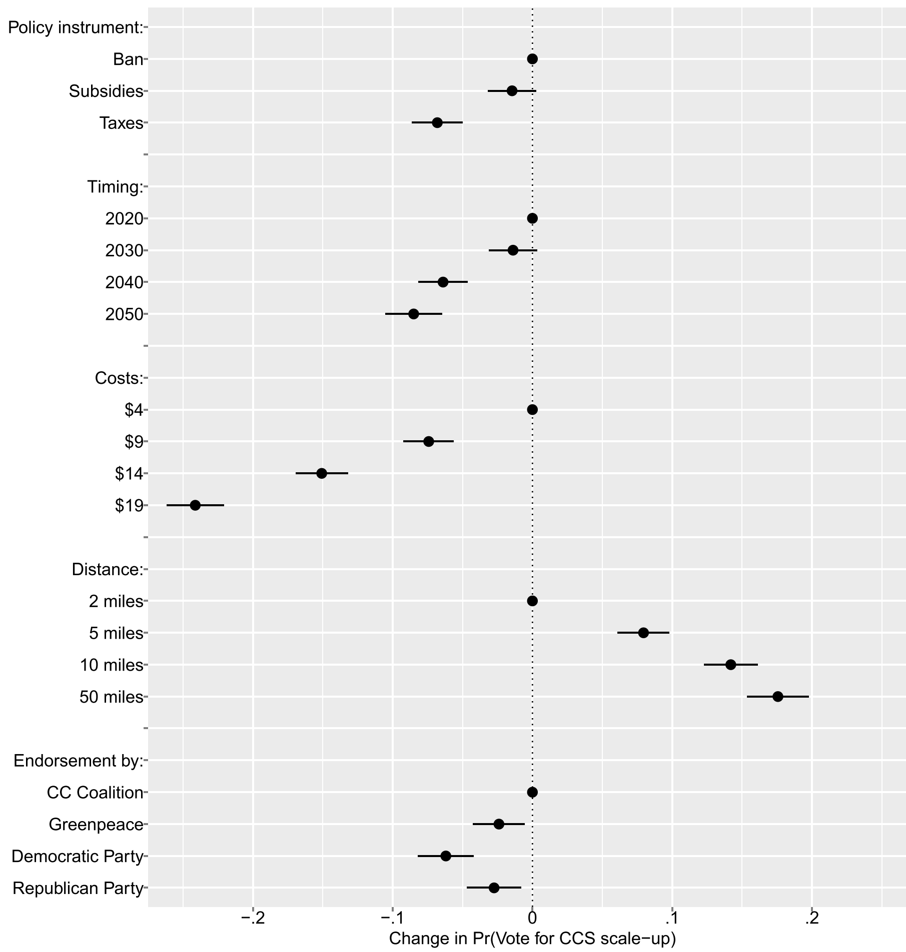

Fig. A2. Conjoint results based on the forced choice outcome variable.
Notes: Average effects of CCS policy attributes on policy support. Each dot represents an average marginal effect of an attribute level on the probability of voting for a policy proposal in relation to a proposal with the reference level for the same attribute. The horizontal bars represent the associated 95% confidence intervals. Dots without bars represent the reference level for each policy attribute. Calculations are based on logit regression analyses with the binary forced choice outcome variable and standard errors grouped at the level of the individual. N = 24,320 policy proposals.

8. *Conjoint plot based only on data on first choice by each respondent*

As a robustness check, we run the conjoint analysis only on the first choice made by each respondent (N = 1520). As shown in Figure A3, results are substantially equivalent to the results based on the full sample. As expected, confidence intervals are larger due to the smaller sample size.

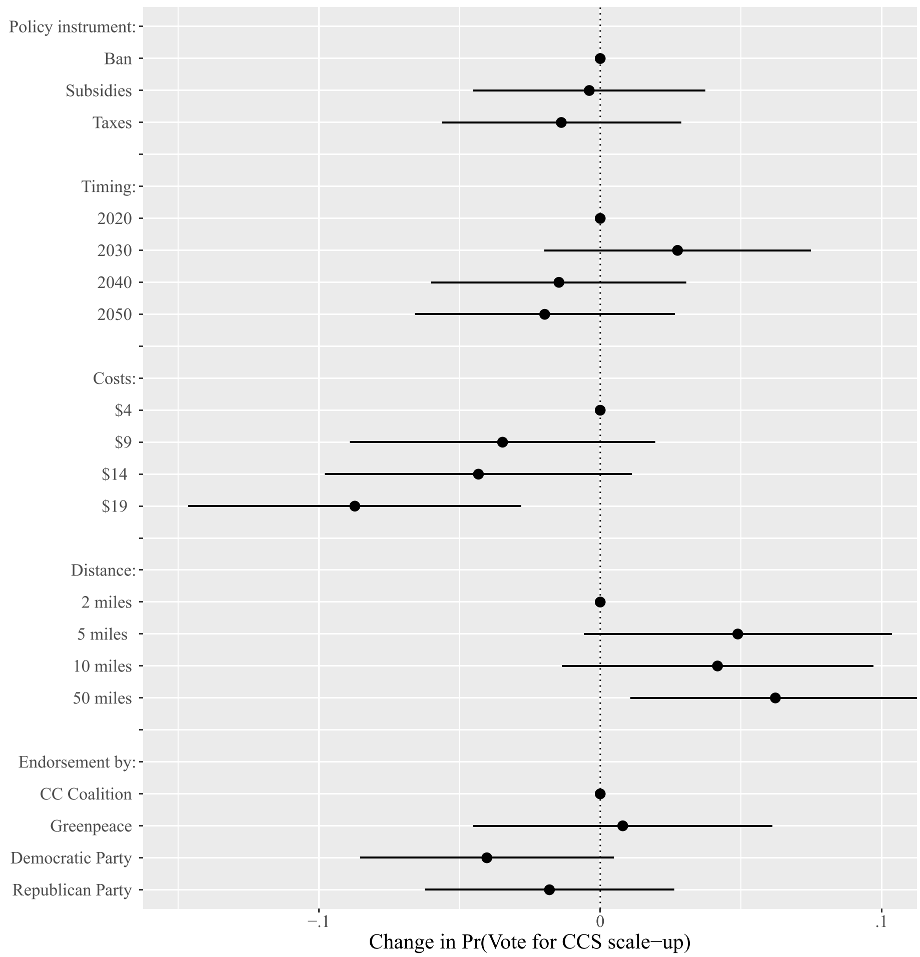

Fig. A3. Conjoint results based on the first choice made by each respondent. Notes: Average effects of CCS policy attributes on policy support. Each dot represents an average marginal effect of an attribute level on the probability of voting for a policy proposal in relation to a proposal with the reference level for the same attribute. The horizontal bars represent the associated 95% confidence intervals. Dots without bars represent the reference level for each policy attribute. Calculations are based on regression analyses with the rating outcome variable and standard errors grouped at the level of the individual. N = 1520 policy proposals.

9. *Comparing the results of the conjoint experiment on the full sample and on a sample excluding speedsters*

Table A7
Comparing results of the conjoint experiment on the full sample and on the sample excluding speedsters.
Notes: We report average marginal effects from the conjoint experiment - coefficients from OLS regressions - with robust standard errors (clustered by respondent) in parentheses. The results for the full sample shown in Model (1) here refer to Fig. 2 in the paper. We report in Model (2) the results of the same regression run on a sample excluding

respondents who took the conjoint experiment in less than 33.4% of median completion time (N = 23,376 policy proposals).

	(1) Policy Support (Full sample)	(2) Policy Support (No speedsters)
Policy type		
Baseline: Bans		
Subsidies	−0.0182** (0.00576)	−0.0184** (0.00589)
Taxes	−0.0262*** (0.00544)	−0.0279*** (0.00559)
Timing		
Baseline: 2020		
2030	0.000805 (0.00519)	0.000202 (0.00529)
2040	−0.0139* (0.00542)	−0.0146** (0.00548)
2050	−0.0211*** (0.00570)	−0.0209*** (0.00585)
Costs		
Baseline: $ 4		
$ 9	−0.0139** (0.00539)	−0.0151** (0.00550)
$ 14	−0.0420*** (0.00608)	−0.0466*** (0.00623)
$ 19	−0.0519*** (0.00653)	−0.0552*** (0.00669)
Distance		
Baseline: 2 miles		
5 miles	0.0240*** (0.00603)	0.0244*** (0.00613)
10 miles	0.0379*** (0.00580)	0.0380*** (0.00593)
50 miles	0.0564*** (0.00663)	0.0573*** (0.00678)
Endorsement		
Baseline: CC Coalition		
Greenpeace	−0.00895 (0.00513)	−0.00775 (0.00526)
Democratic Party	−0.0192*** (0.00575)	−0.0184** (0.00586)
Republican Party	−0.00860 (0.00570)	−0.00833 (0.00587)
Constant	0.490*** (0.00913)	0.488*** (0.00928)
N	24320	23296

Standard errors in parentheses.
*p < 0.05, **p < 0.01, ***p < 0.001.

10. *Trust in stakeholders as a moderator of endorsement effects*

The following graphs show average marginal effects of stakeholder endorsements on the probability to vote for a policy proposal in a referendum, conditional on trust in stakeholders. The calculations are based on regression analyses with rating outcomes (N = 24,320 policy proposals), the full set of attribute values as predictors, and clustered standard errors. The analysis is reiterated four times so as to visualize the effects conditional on trust in each stakeholder separately. E.g., panel (a) shows the effects of endorsement by different stakeholders (taking Democrats as baseline), conditional on different trust levels for Democrats.

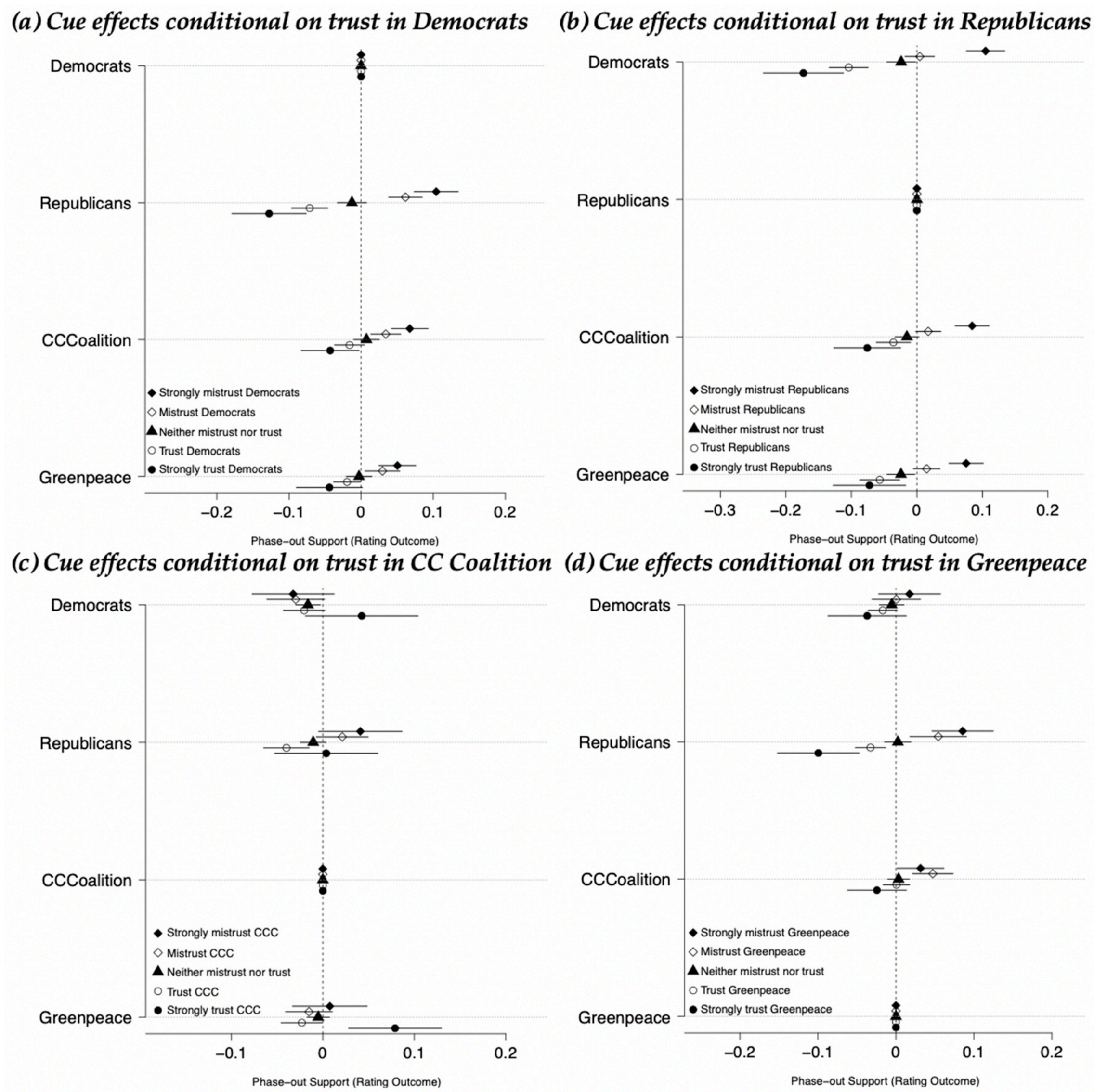

Fig. A4. Effects of stakeholder endorsements on CCS policy support, conditional on respondents' level of trust in these actors. Notes: Each dot represents an average marginal component effect (AMCE) of an attribute level (i.e., endorsement by stakeholders) on respondents' probability to choose a policy proposal in relation to a proposal with the reference level stakeholder attribute. Horizontal bars represent associated 95% confidence intervals. The calculations are based on regression analyses with rating outcomes, the full set of attribute levels included, and standard errors grouped at the level of the individual (clustered standard errors). n = 1520.

11. Independence of attribute effects from social norms interventions

The conjoint experiment was embedded in a broader survey on climate policy preferences which, in addition to the conjoint experiment, involved a randomized controlled experiment. Before completing the conjoint tasks, respondents were randomly assigned to an *endorsement norms* condition, a *non-endorsement norms* condition, or a *control* condition. In the two experimental conditions, respondents read a short text highlighting policy-relevant attitudes and behaviors of other people living in their state. In the endorsement norms condition, this included a statement about the increasing support for policies to scale up CCS among state citizens (highlighting a *relative* increase in support, in order not to make use of deception), while in the non-endorsement norms condition, it included a statement about the limited support for policies to scale up CCS (highlighting low absolute levels of support). For more detailed information, see the materials deposited on the OSF platform: https://osf.io/6w4h3/?view_only=b59087110dad4733b1dbc218c22a9eeb.

Here we document that the social norms manipulations did not have a systematic influence on respondents' policy preferences. As Figure A5 illustrates, information about descriptive social norms provided to study participants did not interact in statistically significant ways with any attribute used in the conjoint experiments. Even if some differences with regard to the size of effects can be detected in some cases (e.g., in particular, the cost attribute for respondents assigned to the endorsement norm condition had slightly different effect sizes with respect to the other treatment groups), the associated confidence intervals overlap in all these cases. As the effects of attribute levels on preferences do not depend on the experimental manipulations, the analyses shown in the paper are based on the pooled data obtained from the conjoint experiment.

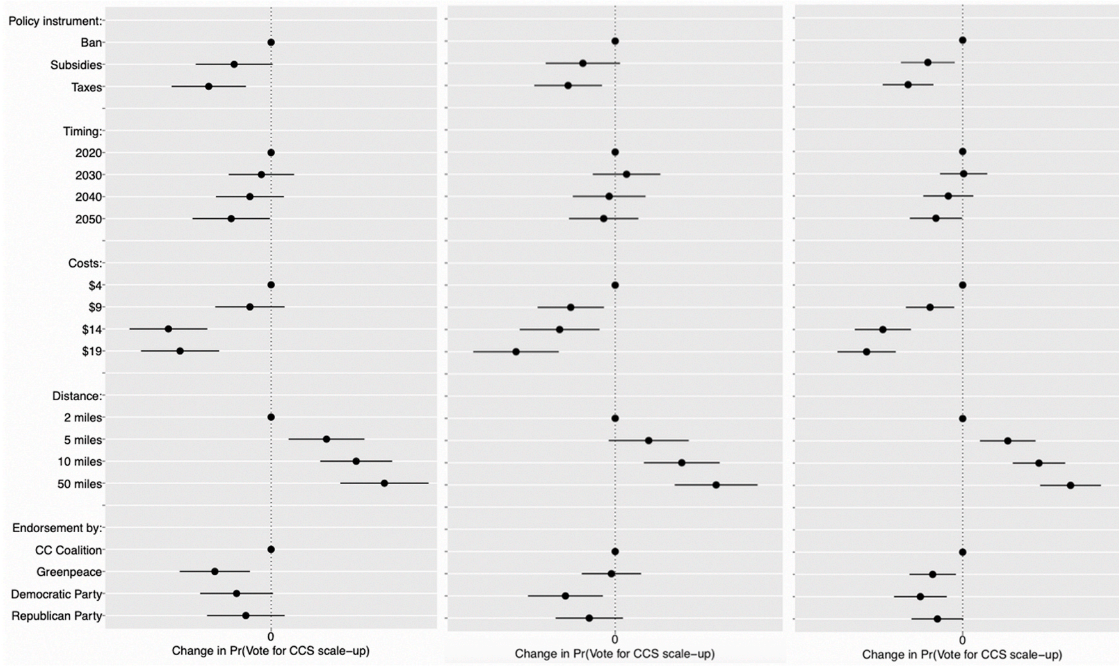

Fig. A5. The non-existing contingency of policy attribute effects on descriptive social norms. Notes: This is essentially a replication of Fig. 2 in the paper, but it shows the AMEs of individual attribute levels for the three norms treatment conditions separately. Calculations are based on regression analyses with rating outcomes and standard errors grouped at the level of the individual (clustered standard errors). N = 24,320 policy proposals.

References

Anderson, K., Peters, G., 2016. The trouble with negative emissions. Science 354 (6309), 182–183. https://doi.org/10.1126/science.aah4567.

Ansolabehere, S., Konisky, D.M., 2014. Cheap and Clean How Americans Think about Energy in the Age of Global Warming. The MIT Press. http://www.vlebooks.com/vleweb/product/openreader?id=none&isbn=9780262321075.

Arning, K., Offermann-van Heek, J., Linzenich, A., Kaetelhoen, A., Sternberg, A., Bardow, A., Ziefle, M., 2019. Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany. Energy Pol. 125, 235–249. https://doi.org/10.1016/j.enpol.2018.10.039.

Bäckstrand, K., Meadowcroft, J., Oppenheimer, M., 2011. The politics and policy of carbon capture and storage: framing an emergent technology. Global Environ. Change 21 (2), 275–281. https://doi.org/10.1016/j.gloenvcha.2011.03.008.

Bechtel, M.M., Scheve, K.F., 2013. Mass support for global climate agreements depends on institutional design. Proc. Natl. Acad. Sci. Unit. States Am. 110 (34), 13763–13768. https://doi.org/10.1073/pnas.1306374110.

Beiser-McGrath, L.F., Huber, R.A., 2018. Assessing the relative importance of psychological and demographic factors for predicting climate and environmental attitudes. Climatic Change 149 (3), 335–347. https://doi.org/10.1007/s10584-018-2260-9.

Boyd, A.D., Hmielowski, J.D., David, P., 2017. Public perceptions of carbon capture and storage in Canada: results of a national survey. Int. J. Greenh. Gas Contr. 67, 1–9. https://doi.org/10.1016/j.ijggc.2017.10.010.

Bruin, W. B. de, Mayer, L.A., Morgan, M.G., 2015. Developing communications about CCS: three lessons learned. J. Risk Res. 18 (6), 699–705. https://doi.org/10.1080/13669877.2014.983951.

Buck, H.J., 2016. Rapid scale-up of negative emissions technologies: social barriers and social implications. Climatic Change 139 (2), 155–167. https://doi.org/10.1007/s10584-016-1770-6.

Chen, Z.-A., Li, Q., Liu, L.-C., Zhang, X., Kuang, L., Jia, L., Liu, G., 2015. A large national survey of public perceptions of CCS technology in China. Appl. Energy 158, 366–377. https://doi.org/10.1016/j.apenergy.2015.08.046.

Devine-Wright, P., 2009. Rethinking NIMBYism: the role of place attachment and place identity in explaining place-protective action. J. Community Appl. Soc. Psychol. 19 (6), 426–441. https://doi.org/10.1002/casp.1004.

Dowd, A.-M., Ashworth, P., Rodriguez, M., Jeanneret, T., 2012. CCS in the media: an analysis of international coverage. Energy Environ. 23 (2–3), 283–298. https://doi.org/10.1260/0958–305X.23.2-3.283.

Drews, S., Bergh, J.C.J.M., den, van, 2016. What explains public support for climate policies? A review of empirical and experimental studies. Clim. Pol. 16 (7), 855–876. https://doi.org/10.1080/14693062.2015.1058240.

Edenhofer, O., 2015. Climate Change 2014: Mitigation of Climate Change, vol. 3. Cambridge University Press.

Feldpausch-Parker, A.M., Ragland, C.J., Melnick, L.L., Chaudhry, R., Hall, D.M., Peterson, T.R., Stephens, J.C., Wilson, E.J., 2013. Spreading the news on carbon capture and storage: a state-level comparison of US media. Environ. Commun. 7 (3), 336–354. https://doi.org/10.1080/17524032.2013.807859.

Fesenfeld, L.P., Wicki, M., Sun, Y., Bernauer, T., 2020. Policy packaging can make food system transformation feasible. Nat. Food 1 (3), 173–182. https://doi.org/10.1038/s43016-020-0047-4.

Gampfer, R., Bernauer, T., Kachi, A., 2014. Obtaining public support for North-South climate funding: evidence from conjoint experiments in donor countries. Global Environ. Change 29, 118–126. https://doi.org/10.1016/j.gloenvcha.2014.08.006.

Global CCS Institute, 2019. Global Status of CCS 2019 Report. https://www.globalccsinstitute.com/resources/global-status-report/.

Hainmueller, J., Hopkins, D.J., Yamamoto, T., 2014. Causal inference in conjoint analysis: understanding multidimensional choices via stated preference experiments. Polit. Anal. 22 (1), 1–30. https://doi.org/10.1093/pan/mpt024.

Hardisty, D.J., Johnson, E.J., Weber, E.U., 2010. A dirty word or a dirty world?: attribute framing, political affiliation, and query theory. Psychol. Sci. 21 (1), 86–92. https://doi.org/10.1177/0956797609355572.

IEA, 2009. Technology Roadmap: Carbon Capture and Storage. *Technology Roadmaps*. International Energy Agency, Paris, France, 2009. http://www. Iea. Org/Papers/2009/CCS_Roadmap. Pdf.

Ipcc, I. P. on C. C., 2018. Global warming of 1.5° C: an IPCC special report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways. In: The Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Intergovernmental Panel on Climate Change.

Kessler, J.B., Norton, M.I., 2016. Tax aversion in labor supply. J. Econ. Behav. Organ. 124, 15–28. https://doi.org/10.1016/j.jebo.2015.09.022.

Kriegler, E., Weyant, J.P., Blanford, G.J., Krey, V., Clarke, L., Edmonds, J., Fawcett, A., Luderer, G., Riahi, K., Richels, R., Rose, S.K., Tavoni, M., van Vuuren, D.P., 2014. The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies. Climatic Change 123 (3), 353–367. https://doi.org/10.1007/s10584-013-0953-7.

Lane, J.L., Greig, C., Garnett, 2021. The CCS conundrum – capacity, confidence and substitutes. Submitted for publication.

Li, Q., Liu, L.-C., Chen, Z.-A., Zhang, X., Jia, L., Liu, G., 2014. A survey of public perception of CCUS in China. Energy Procedia 63, 7019–7023. https://doi.org/10.1016/j.egypro.2014.11.735.

Lock, S.J., Smallman, M., Lee, M., Rydin, Y., 2014. "Nuclear energy sounded wonderful 40 years ago": UK citizen views on CCS. Energy Pol. 66, 428–435. https://doi.org/10.1016/j.enpol.2013.11.024.

L'Orange Seigo, S., Dohle, S., Siegrist, M., 2014. Public perception of carbon capture and storage (CCS): a review. Renew. Sustain. Energy Rev. 38, 848–863. https://doi.org/10.1016/j.rser.2014.07.017.

Lupia, A., 1994. Shortcuts versus encyclopedias: information and voting behavior in California insurance reform elections. Am. Polit. Sci. Rev. 88 (1), 63–76. https://doi.org/10.2307/2944882.

Martínez Arranz, A., 2016. Hype among low-carbon technologies: carbon capture and storage in comparison. Global Environ. Change 41, 124–141. https://doi.org/10.1016/j.gloenvcha.2016.09.001.

Mendelevitch, R., Hauenstein, C., Holz, F., 2019. The death spiral of coal in the US: will changes in US Policy turn the tide? Clim. Pol. 19 (10), 1310–1324.

Minx, J.C., Lamb, W.F., Callaghan, M.W., Fuss, S., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., Garcia, W. de O., Hartmann, J., Khanna, T., Lenzi, D., Luderer, G., Nemet, G.F., Rogelj, J., Smith, P., Vicente, J.L.V., Wilcox, J., Dominguez, M., del, M. Z., 2018. Negative emissions—Part 1: research landscape and synthesis. Environ. Res. Lett. 13 (6), 63001 https://doi.org/10.1088/1748-9326/aabf9b.

Overland, I., Sovacool, B.K., 2020. The misallocation of climate research funding. Energy Res. Soci. Sci. 62, 101349. https://doi.org/10.1016/j.erss.2019.101349.

Reiner, D.M., 2016. Learning through a portfolio of carbon capture and storage demonstration projects. Nat. Energy 1 (1), 1–7. https://doi.org/10.1038/nenergy.2015.11.

Rinscheid, A., Pianta, S., Weber, E.U., 2020. Fast track or Slo-Mo? Public support and temporal preferences for phasing out fossil fuel cars in the United States. Clim. Pol. 20 (1), 30–45. https://doi.org/10.1080/14693062.2019.1677550.

Rinscheid, A., Wüstenhagen, R., 2019. Germany's decision to phase out coal by 2038 lags behind citizens' timing preferences. Nat. Energy 4 (10), 856–863. https://doi.org/10.1038/s41560-019-0460-9.

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., Schellnhuber, H.J., 2017. A roadmap for rapid decarbonization. Science 355 (6331), 1269–1271. https://doi.org/10.1126/science.aah3443.

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K., Meinshausen, M., 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 534 (7609), 631–639. https://doi.org/10.1038/nature18307.

Saito, A., Itaoka, K., Akai, M., 2019. Those who care about CCS—results from a Japanese survey on public understanding of CCS-. Int. J. Greenh. Gas Contr. 84, 121–130. https://doi.org/10.1016/j.ijggc.2019.02.014.

Shearer, C., Ghio, N., Myllyvirta, L., Yu, A., Nace, T., 2018. Boom and Bust 2017: Tracking the Global Coal Plant Pipeline, 2017. http://Endcoal.Org/Wpcontent/Uploads/2017/03/BoomBust2017-English-Final. Pdf.

Stefanelli, A., Lukac, M., 2020. Subjects, trials, and levels: statistical power in conjoint experiments. SocArXiv. https://doi.org/10.31235/osf.io/spkcy.

Tcvetkov, P., Cherepovitsyn, A., Fedoseev, S., 2019. Public perception of carbon capture and storage: a state-of-the-art overview. Heliyon 5 (12), e02845. https://doi.org/10.1016/j.heliyon.2019.e02845.

ter Mors, E., Terwel, B.W., Daamen, D.D.L., 2012. The potential of host community compensation in facility siting. Int. J. Greenh. Gas Contr. 11, S130–S138. https://doi.org/10.1016/j.ijggc.2012.07.002.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2011. Going beyond the properties of CO2 capture and storage (CCS) technology: how trust in stakeholders affects public acceptance of CCS. Int. J. Greenh. Gas Contr. 5 (2), 181–188. https://doi.org/10.1016/j.ijggc.2010.10.001.

Upham, P., Roberts, T., 2011. Public perceptions of CCS: emergent themes in pan-European focus groups and implications for communications. International Journal of Greenhouse Gas Control.

Vercelli, S., Anderlucci, J., Memoli, R., Battisti, N., Mabon, L., Lombardi, S., 2013. Informing people about CCS: a review of social research studies. Energy Procedia 37, 7464–7473. https://doi.org/10.1016/j.egypro.2013.06.690.

Viebahn, P., Chappin, E.J.L., 2018. Scrutinising the gap between the expected and actual deployment of carbon capture and storage—a bibliometric analysis. Energies 11 (9), 2319. https://doi.org/10.3390/en11092319.

Viebahn, P., Vallentin, D., Höller, S., 2014. Prospects of carbon capture and storage (CCS) in India's power sector – an integrated assessment. Appl. Energy 117, 62–75. https://doi.org/10.1016/j.apenergy.2013.11.054.

Viebahn, P., Vallentin, D., Höller, S., 2015. Prospects of carbon capture and storage (CCS) in China's power sector – an integrated assessment. Appl. Energy 157, 229–244. https://doi.org/10.1016/j.apenergy.2015.07.023.

von Stechow, C., Watson, J., Praetorius, B., 2011. Policy incentives for carbon capture and storage technologies in Europe: a qualitative multi-criteria analysis. Global Environ. Change 21 (2), 346–357. https://doi.org/10.1016/j.gloenvcha.2011.01.011.

Whitmarsh, L., Xenias, D., Jones, C.R., 2019. Framing effects on public support for carbon capture and storage. Palgrave Commun. 5 (1), 1–10. https://doi.org/10.1057/s41599-019-0217-x.

Williamson, P., 2016. Emissions reduction: scrutinize CO_2 removal methods. Nat. News 530 (7589), 153. https://doi.org/10.1038/530153a.

Yang, L., Zhang, X., McAlinden, K.J., 2016. The effect of trust on people's acceptance of CCS (carbon capture and storage) technologies: evidence from a survey in the People's Republic of China. Energy 96, 69–79. https://doi.org/10.1016/j.energy.2015.12.044.