# Shared vision for a decarbonized future energy system in the United States

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**How do people envision the future energy system in the United States with respect to using fossil fuels, renewable energy, and nuclear energy? Are there shared policy pathways of achieving a decarbonized energy system? Here, we present results of an online survey ($n$ = 2,429) designed to understand public perceptions of the current and future energy mixes in the United States (i.e., energy sources used for electric power, transportation, industrial, commercial, and residential sectors). We investigate support for decarbonization policies and antidecarbonization policies and the relative importance of climate change as an issue. Surprisingly, we find bipartisan support for a decarbonized energy future. Although there is a shared vision for decarbonization, there are strong partisan differences regarding the policy pathways for getting there. On average, our participants think that climate change is not the most important problem facing the United States today, but they do view climate change as an important issue for the world today and for the United States and the world in the future.**

energy transitions | policy support | future thinking | political polarization | climate change

The United States is responsible for ∼15% of global carbon dioxide emissions, and 93% of carbon dioxide emissions in the United States in 2017 were attributed to fossil fuel combustion related to energy generation (1). Decarbonizing the energy system means replacing the fossil fuel energy sources currently being used (such as coal, oil/petroleum, and natural gas) with energy sources that emit far less carbon dioxide (such as wind, solar, and nuclear energy). Decarbonizing the energy system within the next few decades is necessary to prevent catastrophic climate change impacts (2). Historically, climate change has not been a salient voting issue (3). People's low willingness to take action today can be in part explained by the temporal, spatial, and social distance commonly associated with climate change, making the issue more abstract and less salient (4). More concretely connecting people with the future in general or their future selves specifically can reorient decisions made today toward long-term interests. For example, individuals who see an aged avatar of themselves form a stronger connection with their future selves and increase contributions to their retirement savings (5). In the context of the US energy mix and political support for decarbonization policies, what people imagine about the current and future energy system could potentially influence what actions they are willing to take or support today.

Inaction on climate change can in part also be explained by the widening partisan divide on the issue (6). In a 2019 survey in the United States, 67% of Democrats and only 21% of Republicans named climate change as a top priority for the federal government (7). To understand this partisan divide, research shows that stances on climate change exist partly due to in-group loyalty rather than a considered position based on scientific evidence (6, 8). It is important to note that the United States may be an outlier when it comes to the strong and troubling relationship between political ideology and political action on climate change in comparison with other countries (9).

One of the key approaches to mitigating climate change—increasing the penetration of renewable energy sources—does not seem to foster strong partisan division. Surveys of public opinion generally find support for low-carbon energy sources, specifically renewable energy sources like solar and wind (10, 11). This support cuts across partisan lines, although the motivations for support can vary with political affiliation (12). These findings suggest that pursuing a decarbonized energy system, one that relies primarily on low-carbon energy sources like renewables, may be less politically fraught than policies that are directly framed as climate policies.

Whether or not nuclear power has public, expert, and political support for being used to decarbonize the US energy system is far more complex, even though it is a low-carbon source. Arguments have been made for a nuclear-free energy transition that relies almost exclusively on wind, solar, and hydroelectric power (13). However, some see this plan as unfeasible, and instead argue that deep and rapid decarbonization of the energy system will require replacing most fossil fuel-based energy sources with varying mixes of renewable energy, such as wind, solar, geothermal, and hydropower; nuclear power; and fossil fuel generation with carbon capture and storage (14, 15).

In the context of this discourse, here we explore how members of the American public think about the current and future energy mix for each of these energy sources separately. Understanding perceptions and beliefs about the current and future energy mix can serve to identify how to engage the public on strategies to decarbonize the entire system, a crucial but challenging goal for mitigating climate change.

## Significance

**We explore public perceptions of the current and future energy mixes in the United States. Participants tend to underestimate contributions of oil and natural gas (although coal does not match this pattern) and overestimate contributions of solar and wind to the current national energy mix, problematically misperceiving that the current mix is more decarbonized than it really is. Both conservatives and liberals want a decarbonized future energy mix for 2050—a significant decrease in fossil fuel use and a significant increase in solar and wind energy. Although there is a shared vision of a decarbonized future energy mix, there are strong differences between liberal and conservative participants in their support for policies to achieve this future.**

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Data deposition: The data collected and analyzed for this study are available in the openICPSR repository, https://www.openicpsr.org/openicpsr/project/117262/version/V1/view.

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Prior research has found that perceptions of energy use are rife with systematic biases (16, 17), where participants underestimate high-energy use activities and overestimate low-energy use activities. To expand on this prior work and to better understand the nature of public support for decarbonization, here we investigate public perceptions of the current energy mix and what participants hope the future energy mix will be in 2050. We also assess how these perceptions relate to decarbonization policy support and antidecarbonization policy support. In this paper, we connect perceptions about the current and idealized future US energy mixes, the relative importance of climate change among several high-visibility policy issues, and the association of people's desired future energy mix with decarbonization policy support.

## Results

**Perceptions of the Energy Mix.** Average participant perceptions of the current energy mix and preferences for the future energy mix by political ideology are shown in Fig. 1. The actual percentage contribution values for all of the energy sources fall outside of the 95% CI range of participant's average estimates (*SI Appendix*, Table S6). The percentage prevalence rates of natural gas and oil are underestimated on average (−42.3 and −37.2%, respectively), while coal's contribution to the current energy mix is overestimated on average by +35.5%. Participants generally overestimate the contribution of nuclear energy to the national mix (+31.1%) and severely overestimate the contribution of renewable energy (geothermal: +2,052.1%, solar: +734.8%, hydroelectricity: +200.3%, wind: +159.6%), except for biomass, which is slightly underestimated on average (−16.8%).

To assess differences in responses between ideological groups, participants were assigned to one of three mutually exclusive categories: participants who self-identified as very liberal, liberal, or slightly liberal were grouped in "liberal"; participants who self-identified as slightly conservative, conservative, or very conservative were grouped into "conservative"; and the remainder of participants who self-identified as moderates were grouped into "moderate." One-way ANOVA revealed no significant differences between the three ideological groups for current energy estimates of eight of the nine energy sources. Oil is the only energy resource with a significant difference between ideological groups after using a Bonferroni correction of $0.05/9 = 0.0056$ ($F = 12.12$, $P < 0.001$). Liberal participants estimated the current contribution of oil at 24.2%, and conservative participants estimated 21.2%, both substantial underestimations of the actual value of 36.5%. Although this result is statistically significant, we do not read too much into this perceptual difference.

On average, participants want a decarbonized future energy system in 2050 as shown by the steep decline (i.e., future preference minus current estimate in terms of percentage points) in the use of fossil fuels in Fig. 1 (natural gas: −9.8%, coal: −14.4%, oil: −18.0%). In contrast, there is a preference for a steep increase in the use of solar (+21.1%) and wind (+12.6%) across all groups. Changes from current to future contributions of biomass (+2.0%), hydroelectricity (+4.2%), and geothermal (+4.1%) show a less steep increase. Finally, nuclear energy shows a very

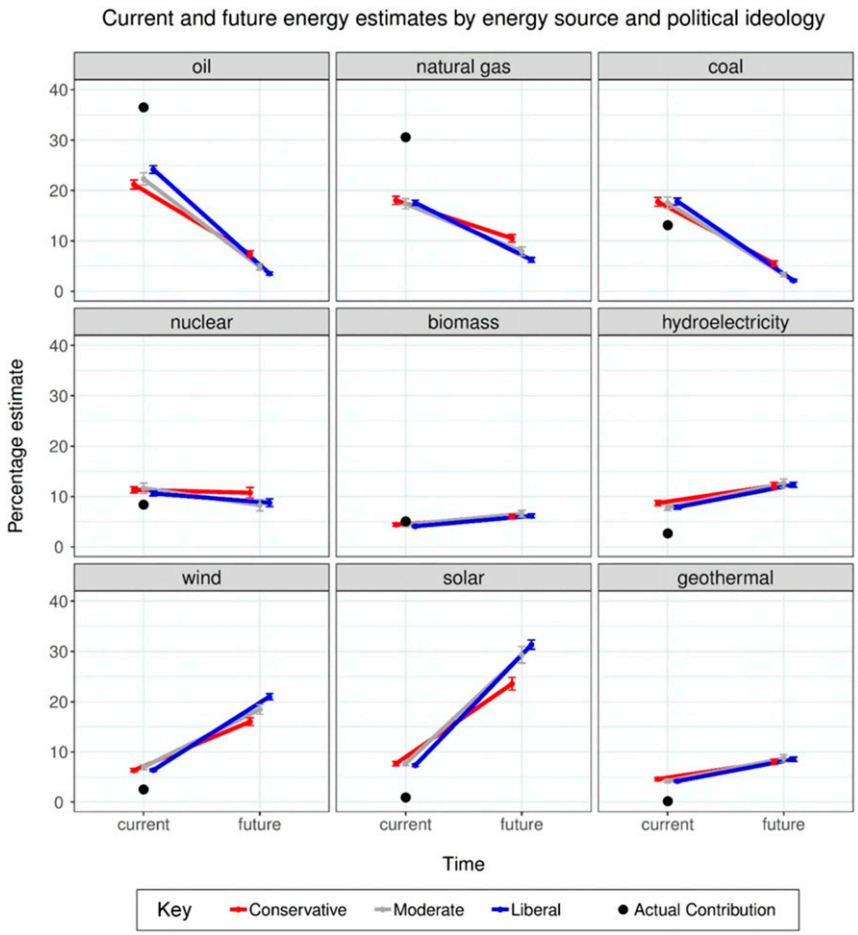


**Fig. 1.** Mean current (2019) and future (the year 2050) energy estimates by political ideological group. Solid black circles indicate the actual contributions of each energy source in the United States as of 2018 (1). Energy sources are ordered by actual percentage contribution to the current energy mix. Error bars indicate the 95% CI.

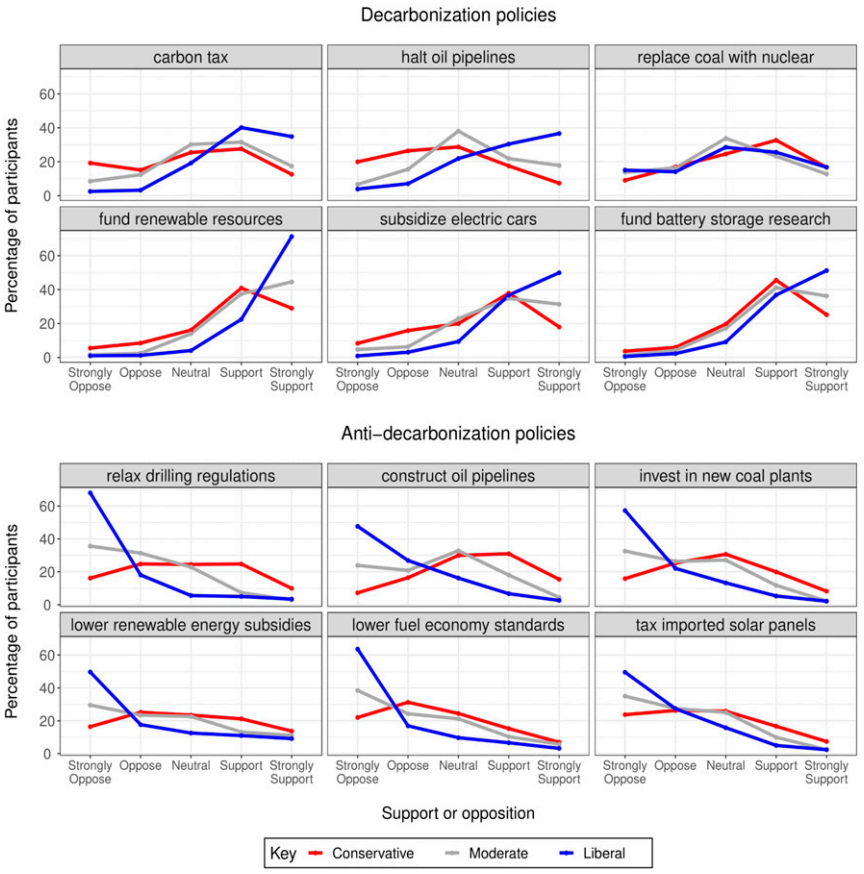


**Fig. 2.** Policy support responses by political ideology across six decarbonization and six antidecarbonization policies.

slight decrease from current estimates to future preference on average (−1.8%). In our sample, 35% of liberals, 29% of moderates, and 18% of conservatives express a preference for a fully decarbonized (fossil fuel-free) future energy mix. The general trend across participants indicates a desired future in which wind and solar are the primary sources of energy and fossil fuel resources contribute very little to the overall national energy mix.

While all three ideological groups prefer a predominantly decarbonized 2050 energy mix, there are subtle differences between the three groups in the direction that we would expect (analysis is in *SI Appendix*, section 2). Overall, liberal participants prefer a smaller contribution of fossil fuels to the 2050 mix as compared with moderates, and moderates prefer a smaller contribution compared with conservatives, although these differences between groups are less than five percentage points. After controlling for multiple comparisons (Bonferroni corrected alpha of $0.05/27 = 0.00185$), there is no significant difference between political ideological groups for their future nuclear energy preference (conservatives: 10.7%, moderates: 8.3%, and liberals: 8.8%). Liberals and moderates generally prefer more future reliance on solar and wind energy than conservatives. The finding is large for solar energy: liberals indicate a much larger contribution of solar energy than conservatives (31.3% vs. 23.6%, $t = 9.85$, $P < 0.001$) as do moderates (29.3% vs. 23.6%, $t = 5.47$, $P < 0.001$), and there is no significant difference between liberals and moderates (31.3% vs. 29.3%, $t = 2.12$, $P = 0.034$). The finding is somewhat smaller for wind energy, where liberals indicate a larger contribution of wind compared with conservatives (21% vs. 16%, $t = 9.90$, $P < 0.001$) as do moderates (18.5% vs. 16%, $t = 3.87$, $P < 0.001$) and liberals indicate a slightly larger contribution than moderates (21% vs. 18.5%, $t = 4.41$, $P < 0.001$). There is no significant difference between political ideological groups for biomass, geothermal, or hydroelectricity future preference. Note that, across the nine energy sources, some of the differences are statistically significant but that they are mostly small except for solar energy.

**Preferences for Policy Support.** Fig. 2 presents the levels of support for six decarbonization and six antidecarbonization policies for conservative, moderate, and liberal participants (*SI Appendix*, Fig. S1 shows mean responses by group). Decarbonization policies are positively associated with or promote decarbonization. Antidecarbonization policies are those that are negatively associated with or hinder decarbonization. An observable pattern emerges in which liberal participants show stronger support for decarbonization policies as compared with conservatives. In contrast, liberals show greater opposition for antidecarbonization policies than conservatives, and moderates generally tend to fall between liberals and conservatives. The policy assessing support for building new nuclear power plants to replace coal-fired power plants shows a similar pattern of responses for all three political groups.

To investigate political differences in policy support, two measures were created. A measure for support for decarbonization policies was created by averaging support across all six decarbonization policies (Cronbach's alpha = 0.71),* and a similar measure for antidecarbonization was created (Cronbach's alpha = 0.85). Across all participants, there is stronger support for decarbonization policies than antidecarbonization policies (means 3.8

*If the policy for nuclear energy is removed from the group, the Cronbach's alpha increases from 0.71 to 0.80.

vs. 2.2, $t = 65.33$, $P < 0.001$). There are significant differences between political ideological groups for decarbonization policy support ($F = 301.5$, $P < 0.001$) and antidecarbonization policy support ($F = 358.4$, $P < 0.001$). Liberals showed significantly greater support for decarbonization policies than both moderates (4.1 vs. 3.6 of 5, $t = 12.81$, $P < 0.001$) and conservatives (4.1 vs. 3.3, $t = 22.24$, $P < 0.001$), and moderates reported higher support compared with conservatives (3.6 vs. 3.3, $t = 7.40$, $P < 0.001$). Conversely, conservatives report significantly less opposition of antidecarbonization policy than moderates (2.8 vs. 2.3, $t = 10.95$, $P < 0.001$) and liberals (2.8 vs. 1.8, $t = 26.04$, $P < 0.001$), and moderates report significantly less opposition than liberals (2.3 vs. 1.8, $t = 11.71$, $P < 0.001$).

**Issue Importance.** When selecting among four issues, a plurality of participants (34.3%) reported that "access to quality health care" is the most important problem facing the United States today, 27.6% of participants selected "climate change," and 26.1% indicated "economy and jobs" as the most important issue (Fig. 3). Reponses change quite dramatically for the world in the future: climate change doubles to 60.7%, economy and jobs as well as health care drop to 21.5% and 13.0% of participants, respectively. "Immigration" is the least important issue across all four focal points. Our results suggest that climate change is not perceived as the most important issue facing the United States today but is anticipated to be the most important issue for the United States and the world in the future. As the spatial and temporal distance of the focal point increases, so too does the percentage of participants who indicate that climate change is or will become the most important issue. The opposing trend is observed for the remaining three issues: the percentages of participants who indicate access to quality health care, economy and jobs, and immigration all decrease as the spatial and temporal distance increases.

When asked to select the single most important issue for each focal point, a higher percentage of liberals select climate change compared with moderates and conservatives (Fig. 4). All three political ideological groups indicate that climate change will become a more important issue for the world in the future as compared with the United States today, a pattern not observed for the other three issues. This trend in the data suggests that climate change is potentially unique among salient voting issues in that it is perceived to be an issue that will be increasingly important for the United States and the world in the future.

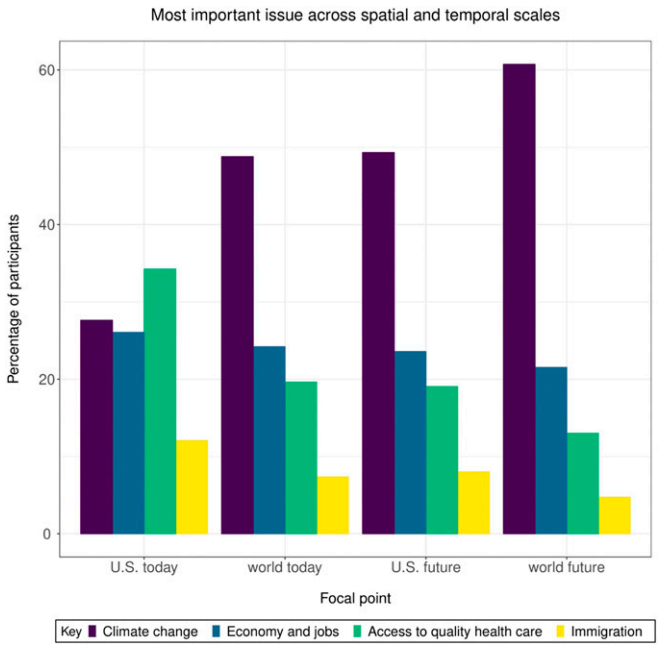


**Fig. 3.** Percentage of participants indicating the most important issue across four focal points: the United States today, the world today, the United States in the future, and the world in the future.

**Predicting Decarbonization Policy Support.** To understand and explore the factors that increase support for decarbonization, we created a measure of general support for decarbonization policies (reverse coding the antidecarbonization policies) to serve as our dependent measure. Values for the 12 policies were averaged to obtain a score from one to five, with higher values indicating greater policy support for decarbonization (Cronbach's alpha = 0.85). Below, we first describe the composite variables that we created and then discuss the results of the regression predicting support for decarbonization policies.

A "decarbonization score" was calculated by taking the sum of the preferred future energy mix for low-carbon sources (nuclear and all renewable energy sources) and subtracting the sum of the current energy mix estimates for low-carbon energy sources.[†] Values for the decarbonization score could potentially run from −100 to 100%, with high decarbonization scores indicating a desire for greater future expansion of low-carbon energy.

"Climate change belief" is a measure of belief and personal importance of climate change; participants' values for climate change belief and personal climate change importance were summed and divided by two (Cronbach's alpha = 0.83).

"Climate change relative importance" is a measure of how important climate change is for the United States today relative to other salient issues. This construct was calculated by subtracting the average of the importance ratings for the economy, health care, and immigration from the importance value reported for climate change. Positive values indicate that climate change is reported as more important on average than the other three issues.

Results of the linear regression predicting decarbonization policy support are shown in Table 1. The decarbonization score has a significant and positive relationship with decarbonization policy support, indicating that participants who want a more decarbonized future energy mix have stronger support for decarbonization policies. Political conservatism is negatively associated with policy support. Stronger belief in climate change is associated with greater support for decarbonization policies. Similarly, individuals who perceive climate change to be a more important issue relative to the economy, health care, and immigration have higher policy support. Males report stronger support for decarbonization policies as compared with females and those who preferred not to indicate gender. Income, age, and education are positively related to decarbonization policy support; however, only income and age yield a statistically significant result. When running regression models predicting support for each of the 12 policies separately, gender, income, and age were not consistent across models, but political ideology and decarbonization score were mostly consistent, replicating the findings in Table 1 (*SI Appendix*, Tables S12 and S13).

## Discussion

Our work highlights that there are surprisingly minor differences across ideological groups in their future preferences for energy sources for the United States, and in general, our participants want a heavily decarbonized energy system in 2050. On the other hand and less surprising is that there are ideological differences

[†]Many participants provided energy mix estimates that did not total to 100% (33.7% of participants for current mix and 27.0% of participants for future mix). To take this issue into account, energy estimates for each energy source were portionally scaled such that the sum of all nine energy sources for both the current and future energy mix equals 100 by participant.

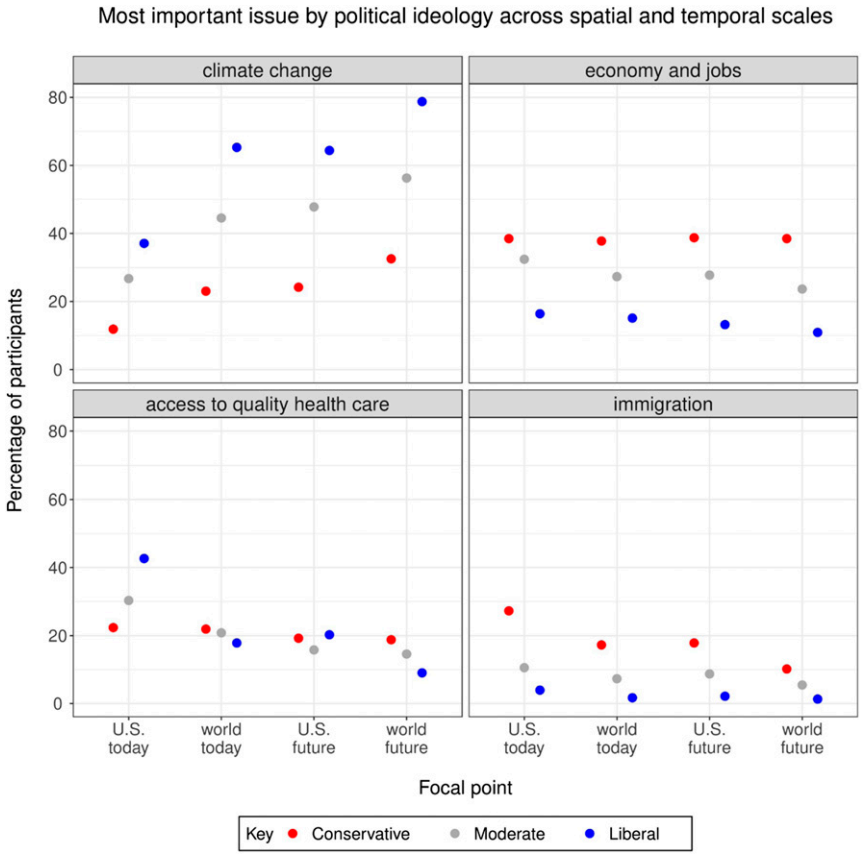


**Fig. 4.** Percentage of participants indicating the most important issue across four focal points: the United States today, the world today, the United States in the future, and the world in the future by political ideology.

about the policy pathways to get this decarbonized future. The shared common future is good news, especially while there is a growing number of studies showing how liberals and conservatives are different (6, 18). Our next step to achieving this desired decarbonized future will require identifying and testing ways to foster bipartisan policy support for decarbonization pathways. We will need to contend with the many challenges to accomplishing strong support from conservatives, such as their aversion to solutions that go against their party ideals (8, 19, 20). Another potential strategy to explore involves tethering liberals and conservatives to their shared common future mix and prompting them to backcast ways of getting there. Given that climate change is generally not viewed as a problem threatening the United States today, we need to broadly motivate the urgency for climate action for both liberals and conservatives (21). Other issues to consider include the need to address unique challenges posed by specific decarbonization policies [such as improving trust in institutions associated with the nuclear industry (22, 23)] and the need to target multiple levels of action through city, state, and private firms that may be more politically feasible to facilitate system-wide change immediately (24).

The general pattern of errors found in Fig. 1 for perceptions of current actual energy use by source—overestimating resources that contribute little to our energy mix and underestimating resources that contribute significantly to our energy mix—might be surprising, but this pattern has been heavily documented in other quantitative estimation tasks, such as the study of demographic proportions (25), lethal events (26), energy estimates (16), water estimates (27), and energy in food estimates (28). The challenge for a decarbonizing energy transition is the systematic way that low-carbon energy sources are overestimated and fossil fuel sources are underestimated for the current energy mix. This overall systematic bias means that people think our current energy system is more decarbonized than it actually is, which could reduce the perceived urgency for decarbonization policies. The outliers to this general pattern are coal, which is overestimated by participants [potentially due to participants being less aware of the somewhat recent decline in the coal industry (29)], and biomass, which is estimated somewhat accurately (potentially due to it being a lesser-known energy source).

There are many limitations to our work. First, even though we use a sample of convenience, which provided enough heterogeneity to investigate patterns in the data, this study should be replicated with other samples in the United States and abroad. Second, we test 12 fairly general policies, which are limited in scope. The policies exclude local-level issues and other means of addressing climate change, such as energy efficiency (30). Third, even though we find broad support for decarbonizing the future energy mix, we do not have much insight into the motivation for why the desired future mix is dominated by low-carbon sources. Fourth, our work focuses on the national mix, even though energy mixes are more locally determined. We do not know how perceptions of city- or state-level energy mixes would be different from our findings here. Future research could probe answers to these questions to help facilitate the decarbonized energy transition.

## Methods

**Participants.** Adults ($n$ = 2,528) were recruited online via Amazon's Mechanical Turk (Mturk) in February 2019 and were compensated $2.50 for their participation (31). Participation was limited to residents of the United States who were aged 18 y and older. As an attention check, participants were asked to describe what the survey was about, and all individuals who provided a response that broadly referenced energy, climate change, or

**Table 1. Linear regression for policy support for decarbonization**

| Variable | Scale of variable | Decarbonization policy support | |
|---|---|---|---|
| | | Estimate | SE |
| Intercept | | 2.707*** | 0.093 |
| Decarbonization score | −100 to +100% | 0.010*** | 0.000 |
| Political ideology | 1–7 (very liberal to very conservative) | −0.099*** | 0.007 |
| Male | 1 = male; 0 = female or other | 0.055** | 0.019 |
| Education | 1–6 scale | 0.009 | 0.009 |
| Age | 18–84 y | 0.003*** | 0.001 |
| Income | 0–1,000 (in thousands) | 0.0004* | 0.000 |
| Climate change belief | 1–4 scale | 0.237*** | 0.019 |
| Relative climate change importance | −3 to +3 scale | 0.161*** | 0.014 |

Adjusted $R^2 = 0.569$. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

politics passed the attention check (failed by 248 participants). Of the participants who failed the first attention check, a second open-ended response was read and coded for coherence. Individuals who did not pass the second check were removed from the sample, resulting in a total sample of $n$ = 2,429. We limit our analysis to this sample.

Three participants reported an age above 464; these three participants are only excluded from the descriptive analysis of age and regression analysis, resulting in a sample of $n$ = 2,426. One participant was eliminated from energy estimate and regression analyses due to responding zero to every energy estimate, which prevented standardization of their responses, resulting in a sample of 2,425 for regression analyses.

The median age across the sample was 34 y, slightly lower than the median age of 38.1 y in the United States in 2017 (32). The sample was 49.2% female (50.8% in the United States) and 50.5% male, and eight participants responded "other." The median household income was $50,000 ($60,226 in the United States). All except for nine participants held high school diplomas or General Education Development (GED) certificates, and 61.7% of participants held a college degree (34% in the United States). Fifty-one percent of participants self-identified as liberal, 20% self-identified as moderate, and 29% self-identified as conservative. Forty-six percent self-identified as Democrats, 31% self-identified as Independents, and 24% self-identified as Republicans. Although participants in Mturk samples tend to skew liberal and young with higher levels of education (33), Mturk samples can be used to recruit a diverse national sample (34), albeit not completely representative of the US population. Although our sample is not representative of the US population, our sample has more than sufficient heterogeneity to investigate and answer our research questions.

**Design.** Participants were first provided with brief descriptions for the nine primary energy sources used in the United States (e.g., coal, solar, geothermal, etc.). Participants were then asked to estimate the percentage contribution of each of these nine energy sources to the current energy mix of the United States using the following prompt: "What do you think is the current energy mix of the United States? In other words, what percent of the total energy consumption in the United States is supplied by each source today?"

Next, participants were asked to provide percentage estimates for their future energy mix using the following prompt: "Now we're going to ask about your hopes for the future energy mix of the United States. What do you think would be the absolute best possible energy mix for the United States by the year 2050? In other words, what percent of the total energy consumption in the United States do you hope is supplied by each source in the year 2050? If there are energy sources that you hope will be part of the energy mix by the year 2050 that are not on the list provided, there is a place to fill in other energy sources." Participants' estimates for both the current and future energy mix were not constrained to sum to 100%.

After providing their preferred future energy mix values, participants were randomly assigned to one of three conditions and asked questions that are part of an ongoing project on imagined futures (*SI Appendix*, section 11 has details). We do not analyze the responses here. We found no statistically significant differences across experimental conditions, indicating that responses could be pooled and analyzed in aggregate.

To evaluate policy preference, participants were asked to indicate their support or opposition to 12 energy policies using a five-point Likert scale from strongly support to strongly oppose. The policies were balanced such that six decarbonization policies were included (e.g., a carbon tax, funding renewable energy) and six antidecarbonization policies were included (e.g., investing in coal-fired power plants, decreasing subsidies for wind and solar energy sources). These 12 energy policies were selected through an iterative process to determine inclusion in this study. First, a list of policies was developed, which included policies from the news and previous surveys. Second, policies were divided into decarbonization and antidecarbonization categories. Policies were then selected to be balanced between decarbonization and antidecarbonization, address at least one energy source, and be general and clear enough to be understood and interpretable by participants after extensive pretesting.

As a measure of how climate change ranked in comparison with other salient voting issues, participants were asked to rate the importance of four issues (access to quality health care, economy and jobs, climate change, and immigration) on a four-point Likert scale from not at all important to extremely important. Importance for all four issues was rated for the United States today, the United States in the future, the world today, and the world in the future. After rating the importance of each issue, participants were asked to indicate which of the four issues they believed to be the most important. Next, to evaluate behavioral intention related to these four issue topics, participants were asked to indicate how likely they would be to volunteer their time to an organization, donate money, or contact their government representatives and urge them to take action. Participants provided a self-report on a five-point Likert scale from very unlikely to very likely for all four issues.

We asked participants about their climate change beliefs. The lead-in passage and items were similar to those used by Howe et al. (35), assessing climate change importance to the participant personally and whether the participant believed that climate change was happening.

The survey concluded with sociodemographic questions about gender, age, income, level of education, political ideology, political party affiliation, and zip code. The entire survey text is available in *SI Appendix*, section 12.

This research was approved by Indiana University's Internal Review Board at the Office of Research Administration, and informed consent was received from all participants.

**Data Availability.** All data collected and analyzed for this study are available online at https://www.openicpsr.org/openicpsr/project/117262/version/V1/view.

**Code Availability.** Code to generate results is available on request.

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