PLOS CLIMATE

RESEARCH ARTICLE

Economics, health, or environment: What motivates individual climate action?

Heidi E. Brown[1]*, **Erika Austhof**[1], **Paula M. Luz**[2], **Daniel B. Ferguson**[3]

1 Department of Epi and Biostats, College of Public Health, University of Arizona, Tucson, AZ, United States of America, **2** Evandro Chagas National Institute of Infectious Diseases, Oswaldo Cruz Foundation, Rio de Janeiro, RJ, Brazil, **3** Department of Environmental Science, University of Arizona, Tucson, AZ, United States of America

* heidibrown@arizona.edu

Citation: Brown HE, Austhof E, Luz PM, Ferguson DB (2023) Economics, health, or environment: What motivates individual climate action? PLOS Clim 2(8): e0000177. https://doi.org/10.1371/journal.pclm.0000177

Editor: Jamie Males, PLOS Climate, UNITED KINGDOM

Received: January 10, 2023

Accepted: June 30, 2023

Published: August 2, 2023

Data Availability Statement: All data can be found in the manuscript and supporting information files.

Funding: This research was funded in part by the US Centers for Disease Control and Prevention's Building Resilience Against Climate Effects: Enhancing Community Resilience by Implementing Health Adaptations Cooperative Agreement (Award # 6 NUE1EH001318–03–01; HEB) and by the National Oceanic and Atmospheric Administration's Regional Integrated Sciences and Assessments (RISA) program (Grant NA17OAR4310288; DF and HEB) with the Climate Assessment for the

Abstract

Climate change is a major threat to human health, however the role of health in climate change communication is understudied. The goal of this study was to understand how to support individuals' adoption of climate related mitigation and adaptation activities. We hypothesized the primary motivation for engaging in pro-environmental activities would be unequally distributed across health, economics, or environment motivations. We also hypothesized respondents who felt greater susceptibility and those with higher perceived self-efficacy would adopt more pro-environmental behaviors. In 2020, we conducted a cross-sectional study using Amazon's MTurk platform. Among the respondents, the most commonly reported activity was alternatives to private vehicles (30% already engaging), while more than two thirds of respondents reported wanting to install solar panels (70.1%) and converting to a high efficiency vehicle (63.2%). Depending on the action, respondents' reported motivation varied. Economics was common to those who used public transportation and who installed solar paneling; purchasing a high efficiency vehicle was split between environment and economic reasons. Health was the primary motivation for converting to a plant-based diet. The perceived immediacy of climate change impacts was associated with adoption of pro-climate activities as were beliefs around human capacity to mitigate climate change. Despite the growing literature supporting health as a motivation for climate action, economic motivation was more commonly selected among the activities we evaluated. These results could aid the development of more efficient evidence-based communication strategies that would reach various audiences in society.

1. Introduction

Climate change may well be the greatest health threat of the 21st century [1]. Across 94 systematic reviews where the most studied outcomes were infectious disease, mortality and respiratory/cardiovascular or neurologic outcomes, there was consensus that climate change will result in worse human health [2]. The 2015 Lancet Countdown report found that the health impacts continue to worsen [1] and these negative health effects are projected to continue to

Southwest program at the University of Arizona. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

increase with increasing global mean surface temperature [3]. Moreover the effects of climate change are disproportionate across populations intensifying health inequity globally [1, 4].

According to a September 2021 World Health Organization (WHO) Compendium, approximately 25% of deaths worldwide could be prevented through reductions of risk factors like air quality, climate change, unsafe infrastructure, and lack of safe water [5]. Of the 38 recommended actions to adapt or mitigate climate change cited in that document, actions for individuals or communities included lifestyle changes (e.g., diet, resource consumption, energy use, transportation), communication strategies (i.e., who and what to communicate about climate change), creation of functional landscapes, and increasing diversity in the foods grown and consumed. Identifying impacts and assessing vulnerabilities and actions is just the first step to building climate resilience.

While 92% of Americans were aware of global warming in 2006, the majority regarded it as a low national priority [6]. Closing the awareness-to-action gap has become the crux of climate change communication research since this publication [7]. Encouragingly, public awareness of and public opinion about actions one can take to mitigate and adapt to climate change reached an all-time high in 2020 [8]. One proposed theory for closing the awareness-to-action gap for climate change states that increasing personal awareness of the situation and of the associated risks, will motivate positive behaviors and changes [9]. The motivation to change can occur on a large scale, such as implementing larger industry changes, or on a personal level with individual actions.

Consumer behavior and lifestyle choices are some of the major drivers of climate change [10], However, knowledge (facts and information) and awareness (perceptions and feeling) about the effects of climate change can vary by region and personal attributes [11, 12]. Being knowledgeable and aware does not directly lead to pro-environmental action [13, 14]. In an intervention study around climate action through a risk management framework, personal impact and human efficacy, protecting current and future generations were associated with motivation for action [15]. A 2019 meta-analysis, showed that while knowledge and experience were only weakly associated with adaptive behavior they were well studied and norms, perceived self-efficacy, and efficacy of action, though more predictive of adaptive behavior, were understudied [14].

Public health often frames health promotion through the Health Belief Model where motivation is explained through susceptibility, severity, benefits, barriers, and self-efficacy [16]. Rather than focusing on awareness and environmental identity, the social needs highlighted in the BUCkEt of Belonging, Understanding, Controlling, self-Enhancing and Trusting theoretical model may also provide better targets to motivate individuals for pro-environmental action [17]. Controlling of the BUCkEt model dovetails with self-efficacy of the Health Belief Model, suggesting that perceived control to act or control over one's environment may support pro-environmental action. Related to control is an individual's perceived susceptibility to climate change as something distant and uncertain and thus not controllable versus something 'real,' immediate and controllable [18]. In the Controlling motive, removing barriers and supporting perceived ability are important in promoting sustainable pro-environmental action.

Perceptions of risk, which can be framed as health risks, can be a strong motivation for behavioral change [19]. Awareness programs which include adverse impacts of climate change, we argue health impacts, with individual initiative can support climate change resilience [20]. Lifestyle changes like walking/biking rather than using a car or eating less meat also benefit health and wellness [21]. Sauerborn et al. [22] list three reasons to consider health effects in climate policy, namely 1) the impacts are large, growing, and not equitably distributed, 2) health can motivate behavior and policy changes, and 3) when quantified, the health co-benefits of mitigation activities will be significant. While a health effects framing can capture new

audiences and alternate views [23], health framing of climate change may narrow the discussion to only direct health impacts of climate change [24]. Still, framing climate change as a public health issue can motivate personal action and, when co-benefits are made explicit, increase support for mitigation policies [25–28]. In a study comparing among health effects, environmental, or national security framing of the benefits of mitigation and adaptation actions, news articles framed with a health lens were the most likely to elicit positive, supportive emotions [29]. Though still used less often than science, economic, or environmental frames [30], health has been effectively adopted as an effective frame for climate change communication [31].

Here we add to the literature on the role of previewed susceptibility and self-efficacy in adopting climate actions through report on an online survey conducted on a sample of US adults with a goal of understanding how to support individuals' adoption of climate related mitigation and adaptation activities. We hypothesized that the primary motivation for individuals engaging in pro-environmental activities would not be equally distributed when asked to choose between health, economics, or environment. Next, we tested the hypotheses that respondents who perceived greater susceptibility and those with higher perceived self-efficacy would adopt more pro-environmental behaviors. Our goal is to aid in the development of more efficient evidence-based communication strategies to improve adoption of adaptation and mitigations actions.

2. Methods

2.1 Study instrument

The study instrument included 67 questions and was estimated to take 10–15 minutes to complete. In this manuscript, we use a subset of these 67 questions focusing on knowledge, intention, and motivations around climate change, climate-related behaviors individuals can adopt, as well as demographic questions (age, gender, race, ethnicity, neighborhood type, income, zip code, state). We formatted the survey flow to include attention check questions in each block as described in Smith et al. [32] to encourage data quality and completeness. Finally, the survey concluded with six questions adapted from a news article and a subsequent research article on ways to reduce personal carbon footprint in daily living as a way to assess knowledge of carbon-mitigating behaviors for individuals [33, 34]. The survey questions used are included as S1 Text.

2.2 Study population

The survey was distributed from July 14, 2020 to July 15, 2020 (n = 200) and from July 15 to August 14, 2020 (n = 300). Participants consented to participate in the survey and confirmed that they were at least 18 years of age and living in the US. Participants were paid $2 USD. Only MTurk masters (users with a strong track record for completion of prior tasks) were eligible to participate in the first 80% of total survey responses before it was opened to any MTurk user to assist with the enrollment target of 500 participants. Prior comparisons, including our own with these data, between masters and non-masters participants showed no significant demographic differences [35, 36].

MTurk is an on-demand crowdsourcing marketplace for remote workers to complete tasks. While some reviews indicate that MTurk is as reliable as other online survey platforms for convenience samples [37, 38], respondents are typically younger and more likely to have a college degree than national benchmarks [35]. Our MTurk respondents were younger, with higher education attainment, and lower income than other online crowdsourcing markets but with a similar distribution along a global warming audience segmentation tool [36].

2.3 Study variables

We focused on activities that individuals can choose to engage in on their own and grouped them into two general categories: *mitigation* activities (actions that can reduce or stabilize greenhouse gases [GHG]) and *adaptation* activities (actions to adapt to the changing climate). While some of these are both mitigation and adaptation activities, activities classified as mitigation included: converting to a plant-based diet, converting to a high efficiency car, installing solar paneling on residence, and traveling by public transport or biking rather than individual vehicle. Activities classified as adaptation included: harvesting water checking air quality before engaging in outdoor activities, wearing sun protection, reducing activity during the hottest part of the day, wearing mosquito and tick repellent when outdoors, and always bringing water on hikes and walks. For each of these activities, participants were asked to select whether they (a) already were doing, (b) wanted to in the next 6 months, (c) would in the future, or were (d) not interested. Then, only among those who indicated they already were doing the action, we queried their primary reason for engaging with the activity with response options (a) to save money, (b) to promote health, or (c) because of the environmental impacts. These options were selected because previous research has shown that framing climate change as a health issue motivates personal action [23, 29] but also that income is associated with individual environmental action [39]. Finally, to assess perceptions around need for adaptation activities (except water harvesting which was asked about primary reason to engage), we asked whether participants' need for that activity had changed because of a changing climate.

2.4 Data analysis

Individuals reporting they converted to a plant-based diet, converted to a high efficiency car, installed solar paneling on residence, traveled by public transport or biking rather than individual vehicle, or harvested water were asked to select a primary reason for doing so from economic, health, or environmental reasons. Chi square goodness of fit test was used to compare an even distribution to the observed distribution of motivations (i.e., economic, health, or environmental). Those reporting that they checked air quality before engaging in outdoor activities, wore sun protection, reduced activity during the hottest part of the day, wore mosquito and tick repellent when outdoors, and always brought water on hikes and walks were asked to assess whether the need had increased, stayed the same or decreased because of a changing climate. Chi square goodness of fit test was used to compare an even distribution to the reported change in need for action (i.e., increased, stayed the same, decreased, or not related to a changing climate).

Additionally, to explore individual's behaviors across all individual actions, for each of the activities we assigned a value for whether individuals were doing (4), would do in the next six months (3), wanted to do in the future (2) or didn't want to do (1). A "doing score" was then calculated as the average score for all individual activities with high scores indicating those engaging in more actions and low scores indicating less action or interest in engaging in action. Based on others finding an association between personal experience and climate change [40], we hypothesized that higher doing score would be associated with greater immediacy with respect to climate change effect. Accordingly, the "doing score" was compared across groups based on individuals' perceptions of when climate change will start to harm people in the United States ((a) now, (b) in 10 to 25 years or (c) 50–100 years or(d) Never) and whether humankind can stop it ((a) isn't happening, (b) can't reduce even if it is happening, (c) could reduce but aren't willing, (d) could reduce but unclear if will, or (e) can and will), using ANOVA adjusting for multiple comparison using Tukey's method and controlling for the MTurk covariates. Given prior research describing how MTurk samples systematically

differ from US probabilistic samples, we controlled for age, gender, race and ethnicity, income and education [41].

A graphical depiction of the analysis is provided as S1 Fig. All analyses were completed using Stata v 15 (StataCorp, College Station, Texas). Data are available as S1 Data.

2.5 Ethics approval and consent to participate

The University of Arizona Institutional Review Board reviewed this research (Protocol # 2001327261A001) and deemed it exempt for limited review under 45 CFR 46.109(a).

3. Results

Of the 508 participants who completed the survey, four respondents were excluded due to failure to answer the attention check questions for a total of 504 responses, with a median completion time of 12.7 minutes. Similar to US demographics, participants' gender was evenly split between males (49.6% compared to 49.2% US) and females (49.4% compared with 50.8% reported for the US; Table 1). Five individuals reported their gender as non-binary (n = 4, 0.8%) or self-described (n = 1, 0.2%). Respondents were primarily white (77.5% compared with 76.3% nationally). Most (69.0%) reported an associate or bachelor's degree or more. While 25% of respondents indicated affiliation with the republican party, similar to US national estimates, democratic party affiliation was most commonly selected among our respondents (47.8%) while independent party affiliation most common among national estimates (40%). Questionnaires were completed by individuals from 46 states and Washington, DC. Using the National Climate Assessment categorizations of states, most participants were from the Southeast (27.2%), Northeast (22.4%), Midwest (19.3%) and Southwest (18.7%). No individuals from Alaska, 3 individuals from Hawaii, and only 5 from the Northern Great Plains completed the questionnaire.

3.1 What people are doing?

Among the mitigation activities, the most commonly reported activity was using public transportation or biking, with 30% of respondents marking this as an activity they already engage in. Installing solar panels and converting to a high efficiency vehicle were the most common actions that individuals would like to do but were not yet doing (70.1% and 63.2% of respondents, respectively). While converting to a plant-based diet was not a commonly selected action (55.9% were not interested), it was the second most frequent activity that individuals reported adopting if they were interested (27% of those interested were already doing). Using public transportation was the most commonly adopted activity where 51.5% of those interested were already using public transportation. See Fig 1.

With respect to health actions for individuals to adapt to climate change, reducing activity during the hottest times of the day, using sun protection and bringing water on walks and hikes were the most commonly reported activities (78.2%, 75.0%, and 74.2%, respectively). These percentages jump to near 80% when considering only those with an interest in the action (84.0%, 81.3%, and 79.0%, respectively).

The reported motivation for those reporting doing an action was not evenly distributed across the three options: environment, health, or economic. Among individuals who reported already doing the mitigation activities described above, economics was provided by over 50% of participants as the reason among those using public transport or biking rather than an individual vehicle and by those who installed solar paneling on their residence (Table 2). The impact on the environment was a primary reason among those who were water harvesting. Interestingly, the primary reason given for converting to a high efficiency car was about evenly

Table 1. Summary of demographic information of those completing the online survey, July 14-August 14, 2020, N = 500.

Characteristics	n (%)	National Comparison [a]
Age, mean (SD); range	41.6 (11.3); Range 24–76	
Sex		
Male	250 (49.6%)	49.2%
Female	249 (49.4%)	50.8%
Non-Binary	4 (0.8%)	
Self-Describe	1 (0.2%)	
Race		
White and other	405 (80.4%)	
White alone	390 (77.5%)	76.3%
API and other	43 (8.5%)	
Black and other	42 (8.3%)	
Black alone	36 (7.2%)	13.4%
API alone	34 (6.8%)	6.1%
Hispanic & other	27 (5.4%)	18.5%
AIAN and other	3 (0.6%)	
Total Household Income (in 1000s)		
<$30	114 (22.6%)	~ 22.2%
$30–99	314 (62.3%)	~ 44.4
≥$100	76 (15.1%)	33.6%
Education Level		
Some College or Less	156 (31.0%)	88%
Associate/Bachelor or more	348 (69.0%)	32.1%
Party Affiliation		
Democrat	241 (47.8%)	31%
Independent	126 (25.0%)	40%
Republican	124 (24.6%)	25%
No preference	7 (1.4%)	
Other	6 (1.2%)	

Abbreviations: SD, standard deviation

[a] Household income estimated from Statistica (note that percentage 25-35K was divided by 2 for estimate) [42] and Gallup News' Historical trends for party affiliation, [43] and for all other, the US Census population estimates for 2019 [44]

https://doi.org/10.1371/journal.pclm.0000177.t001

split between environmental impact and economic reasons. Health was the most reported motivation only for converting to a plant-based diet.

Among adaptation activities, a need driven by climate change for checking air quality, using sun protection, and reducing activity when it is hot was reported (Table 3). While no change was reported for the need to bring water on hikes or to use insect repellent.

3.2 Are perceptions associated with action

We compared the overall "doing" score with respondents' beliefs about when climate change will start to harm people in the United States (Fig 2) and their views about whether climate change can be mitigated (Fig 3). Bartlett's test for equal variances indicated the ANOVA was not valid with 6 categories of when impacts will be observed, so responses were combined into three categories (Fig 2). Controlling for the MTurk sampling bias, respondents who report

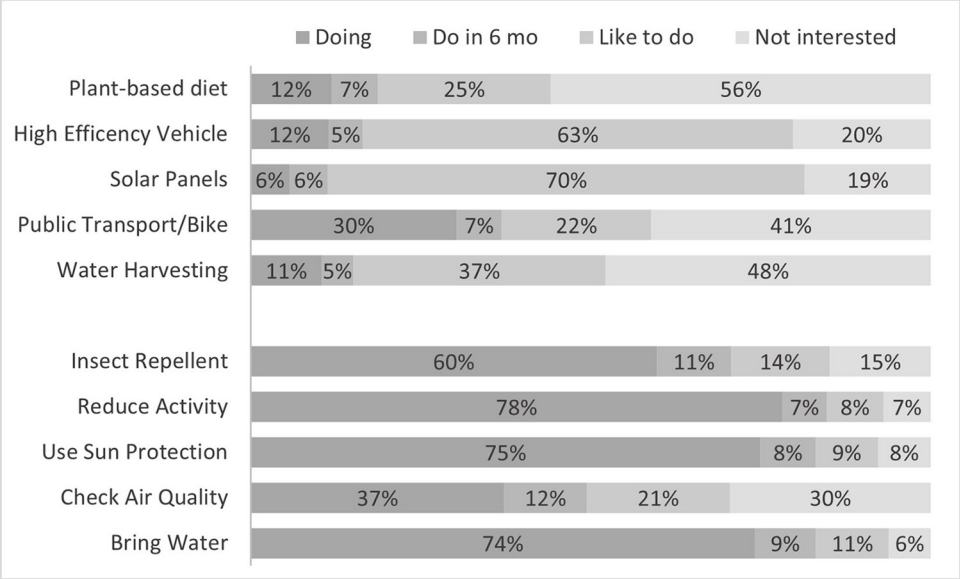

Fig 1. Responses to engagement with the ten adaptation and mitigation activities that individuals can personally carry out.

https://doi.org/10.1371/journal.pclm.0000177.g001

climate change is happening now or in their lifetime (10-25yrs), scored higher with respect to engagement with adaptation and mitigation activities than those who believe it will never happen or will happen to the next generation ($F(59,443) = 1.45$, $p = 0.02$, $\eta^2 = 0.162$).

Compared to people who think we cannot reduce global warming, those who believe that climate change can be addressed reported engaging in more activities ($F(61,441) = 1.42$, $p = 0.03$, $\eta^2 = 0.164$) after controlling for MTurk sampling bias. Specifically, compared to those who believed humans cannot reduce global warming, more activities were engaged in by those who believe humans could reduce global warming but are not willing (Tukey's $t = 4.54$, $p<0.001$), those who believe humans could but it is unclear if they will (Tukey's $t = 5.20$, $p<0.001$), and those who believe humans can and will do so successfully (Tukey's $t = 2.86$, $p< 0.035$).

4. Discussion

Using an online sample of US respondents, we sought to assess pro-environmental behaviors individuals can engage in and their motivations around those behaviors they adopt. We hypothesized that the primary motivation for individuals engaging in pro-environmental

Table 2. Motivations for engaging in activities.

	Environmental	Health	Economic	X^2	Cramer's V
Plant-based Diet	18 (30.0%)	**40 (66.7%)**	2 (3.3%)	36.4	0.551
High Efficiency Vehicle	**28 (48.3%)**	1 (1.7%)	**29 (50%)**	26.1	0.474
Solar Panel	11 (37.9%)	3 (10.3%)	**15 (51.7%)**	7.72	0.365
Public Transport/Bike	34 (22%)	42 (27%)	**76 (50%)**	19.63	0.254
Water Harvesting	**26 (49%)**	8 (15%)	19 (36%)	9.32	0.297

Chi Sq GOF compared to even distribution across response options. Bolded values indicate statistically significant values at $p<0.05$. Only those engaging in pro-climate actions reported their motivation.

https://doi.org/10.1371/journal.pclm.0000177.t002

Table 3. Perceptions around the need for climate related health actions.

	Increased	Same	Decreased	N/A	X^2	Cramer's V
Bring Water	131 (35%)	**207(55.5%)**	0	35 (9.4%)	119.5	0.327
Check Air Quality	**120 (63.8%)**	57 (30.3%)	3 (1.6%)	8 (4.3%)	189.1	0.580
Use Sun Protection	**202 (53.6%)**	147 (39.0%)	0	28 (7.4%)	125.9	0.334
Reduce Activity	**223 (56.6%)**	138 (35.0%)	11 (2.8%)	22 (5.6%)	310.4	0.512
Insect Repellent	96 (31.9%)	**164 (54.5%)**	2 (0.7%)	39 (13.0%)	199.2	0.470

Chi Sq GOF compared to even distribution across response options. Bolded values indicate statistically significant values at $p<0.05$. Only those engaging in pro-climate actions reported their perception of changes in need.

https://doi.org/10.1371/journal.pclm.0000177.t003

activities would be unequally distributed when asked to choose between health, economics, or environment. Further, we hypothesized that respondents who had greater perceptions of susceptibility to global warming and those who felt greater self-efficacy, measured as belief in global ability to act to control global warming, would be supportive of those individuals engaging or intending to engage in action. We found that travelling by public transport or biking rather than individual vehicles and converting to a plant-based diet were the most common activities individuals were already engaged with. We found support for our hypothesis that the motivations provided would not be evenly distributed across environment, health, and economics. Economics then health was the primary reason selected for adopting these behaviors. Furthermore, we found support for the hypothesis that higher perceived susceptibility, measured as recognition that climate change is happening now or that it will happen in their lifetime, was associated with higher scores for doing or wanting to do adaptation and mitigation activities. Finally, we found support for our hypothesis that perceived efficacy, global action to reduce climate change effects, was associated with engaging or wanting to engage in more activities compared with those who do not think global warming can be reduced.

A limitation to our survey is that it is a cross-sectional study using an online convenience sample. We did not collect robust open-ended questions to dive deeper into the motivations, rather we allowed participants to select between three prescribed options. The respondents in this cross-sectional convenience sample study are slightly younger and more educated than national samples [35, 36]. While we adjusted for this sampling bias when comparing action with perceived susceptibility and self-efficacy, the results should be interpreted with this in mind.

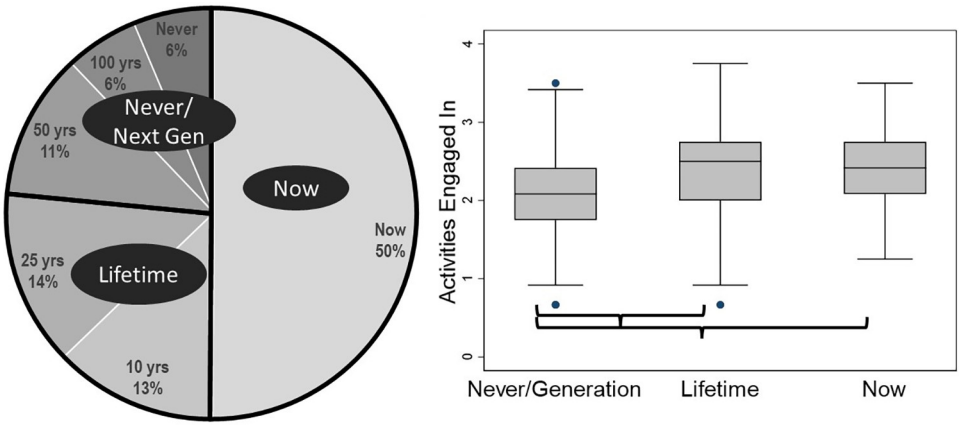

Fig 2. Association between activities engaged in and responses to the question "When do you think global warming will start to harm people in the United States. Points represent outliers.

https://doi.org/10.1371/journal.pclm.0000177.g002

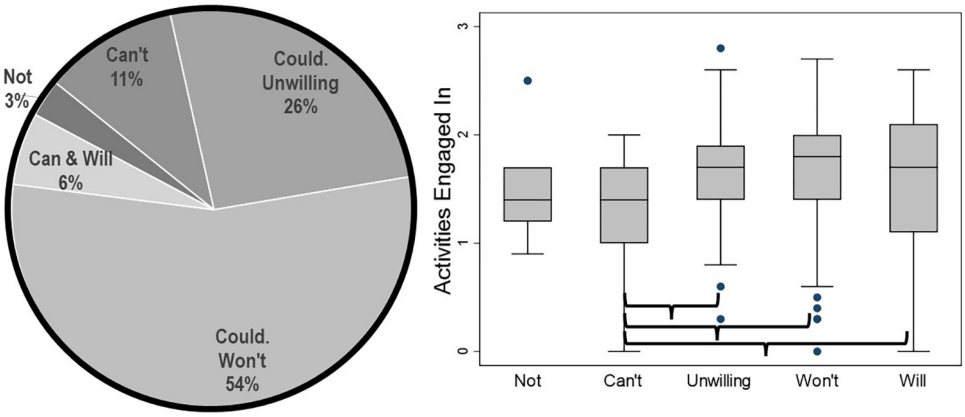

Fig 3. Association between activities engaged in and responses to the question "Is global warming happening and can we stop it?". Points represent outliers.

https://doi.org/10.1371/journal.pclm.0000177.g003

We restricted this analysis to actions that individuals can engage in. While recycling and changing to more efficient household light bulbs are commonly promoted as actions individuals can take, they have lower marginal effects, while being easier to modify through intervention [45]. In contrast, living car-free (2.4 tons of carbon dioxide equivalent (tCO2e) saved per year), avoiding air travel (1.6 tCO2e saved per roundtrip transatlantic flight) and eating a plant-based diet (0.8 tCO2e saved per year) are individual activities with a potential to substantially reduce annual personal emissions [46]. While we did not ask about air travel, of the two other high impact individual activities, only 11.9% of individuals in our survey had converted to a plant-based diet with a further 55.9% reporting they were not interested in doing so and only 11.5% reported driving a high efficiency car, though 63.2% were interested in doing so in the future.

4.1 Economic and health motivations for mitigation

The most common mitigation activity respondents engaged in was traveling by public transportation or biking rather than an individual vehicle (30%), and economics was the overwhelmingly most common motivation (50%), with the rest of responses split evenly between response options of environment and health. The question did not distinguish between whether the individual used public transport or biked. Surveys show more urban (21%) US adults regularly use public transport, compared to suburban (6%) or rural (3%) [47]. Insufficient service is cited for lower rates of public transportation use, and intercity coverage in rural areas is declining [48]. It is interesting that in our study economics was the most important motivation for adoption of public transportation/biking, as financial incentives have also been used as a motivation to encourage public transportation use with some success [49].

Moving towards a plant-based diet could reduce global mortality by 6–10% and reduce food-related GHG by 29–70% [50]. Even the lowest impact animal husbandry exceeds the impact of vegetable substitutes [51]. Among those individuals who had converted to a plant-based diet (n = 60 of 504 respondents), health was the most commonly reported reason (66.7%). Framing this activity with a health lens may promote engagement in converting fully to a plant-based diet or increasing the proportion of plants in a person's diet. While the mechanism may not be clearly delineated, there is evidence that a diet rich in plants reduces atherosclerosis and coronary artery disease [52], obesity [53], type-2 diabetes [54], and lower all-cause mortality [55]. Our finding of about 12% who had converted and 50% not contemplating is similar to an Australian study with more individuals engaged (28%) but a similar percentage not (58% in precontemplation) [56].

Like ours, health was listed as a reason to convert to a plant-based diet as was finances, but they also found convenience and knowledge were listed as barriers. Çoker and van der Linden found that attitude, norms and perceived control explained more than half of the variation in intention to reduce meat consumption [57]. While moving towards a more plant-based diet is a personal choice that not everyone may be able—or will want—to do, our results suggest that, instead of focusing on the impact on climate, framing this choice as a health-related decision may be the best motivating factor for encouraging individuals to take this action. Furthermore, as knowledge is a cited barrier to adopting plant-based diets, educational campaigns focusing on the health-related advantages of diet should be promoted.

In our survey, almost 70% wanted to install solar panels in the future and 63.2% wanted to convert to a high efficiency car, while only 5.8% and 11.5% had successfully done so. According to the US EPA, approximately 29% of US GHG emissions are from the transportation industry [58], and the use of solar panels can induce regional cooling (by 2˚C) [59]. Our results suggest that, if the right incentives were put in place, significant mitigation effects could be produced [58]. In the US, it will be interesting to assess the impact of the Biden Administration's recently signed Inflation Reduction Act, which, among other actions, includes tax incentives for electric vehicles. A high efficiency car, for example, is between $500-$10,000 more expensive than comparable conventional cars and due to the battery cost, may be unaffordable to many [60]. While this upfront cost is higher compared to conventional cars, the cost to run them is estimated to be lower [61].

Additionally, we found that among those who successfully engaged, the choice around high efficiency vehicles was split almost evenly between selecting the environmental (48.3%) and economic (50%) motivation options while the selected motivations around solar was slightly more economic (51.7%) than environmental (37.9%). A ZIP code level analysis of residential solar installation in the US found that economic factors were significant indicators of installation, among other factors [62]. However, despite rebates, credits and other incentives to support installation of solar panels cost remained a significant barrier to installation in the UK [63]. That over two-thirds of our respondents wanted to engage in these activities suggests the need for alternative and/or improved strategies to support adoption.

4.2 Supporting individual engagement

While our summary of the findings up to this point has focused on individual actions, individual actions alone cannot mitigate climate change. Lessons learned from implemented renewable energy policies reinforce the need for a clearly articulated rationale, cost containment strategies, and an assortment of policies to promote individual engagement in these activities with higher upfront costs [64, 65]. However, the necessary changes are not just in policies, but also as changes to social and cultural norms [18]. This change in norms is somewhat evident in the high adoption of the health adaptation behaviors that individuals can engage in in our study. For most of these activities, most of the respondents were already doing them (78% reduce activity during the hottest part of day; 75% use sun protection, 74% bring water on walks and hikes, 60% use insect repellent). These health-conscious behaviors have become norms. Only through encompassing, trans-sectoral change with policies that support individuals and remove barriers can the necessary cultural and lifestyle changes occur [9].

In addition to the finding that those with positive beliefs (humans can and will stop climate change) were engaging in climate-smart actions, we found that those who believed that humans could but are not willing or that humans could but will not do what is needed reported doing more of the activities we asked. This has been seen by others as well. Eco-anger —anger experienced in response to the climate crisis—was associated with greater engagement

in personal pro-climate behaviors among Australians in 2020 [66]. A nationally representative survey in the US also found that worry, interest, and hope were discrete emotions strongly associated with increased support for climate change policies [67]. Shifting the conversation toward control and self-efficacy [68], climate change communication that focuses on the gains with action rather than losses with no-action is associated with increased positive attitude toward climate change mitigation [69, 70]. Further, messaging the protective actions rather than risks, may be most important among vulnerable populations who already are more likely to identify themselves at higher risk for climate change impacts [71]. Related, our finding that those who perceive climate change as happening now or in their lifetime engage in more action supports the recommendation to emphases that climate change is present, local and personal [72].

There is no consensus on how to best support individual choice to engage in climate action. A comprehensive approach that includes both mitigation and adaptation actions is critical [73]. In a metanalysis of behavioral intervention to promote individual engagement in climate mitigation actions found behavioral interventions alone were insufficient to yield long term change, but might be useful in combination with other strategies [45]. When considering how to nudge individuals towards pro-climate behaviors, be it for themselves or for the environment, behavioral economics, a field which focuses on understanding individual decision making, has suggested that both the framing and the emotional content of the messages can be important [74]. Framing climate change within a public health focus has been suggested as a means to engage policy makers, namely to account for the co-benefits of GHG emission reductions [75]. However, reported motivations are not necessarily indicative of the true motivation for engagement. Noppers et al. [76] found instrumental values (e.g. the highly cited economic motivation in our study) were less important than symbolic or environmental reasons for adoption, though the significance of instrumental values are overestimated. Related, a public health framing rather than a national security framing has been shown to elicit more support toward mitigation and adaptation actions [29] and specifically, those with content that is less familiar (food-, water-, and vector-borne diseases) were most engaging [28]. Likely no one framing will be sufficient to instill long term behavioral change, but more work is necessary to establish the effects of interventions both in isolation and in combination [45].

5. Conclusion

In conclusion, our results show that the uptake of individual adaptive behaviors is already high, which aligns with and may result from the growing public awareness of actions one can take to mitigate and adapt to climate change [8]. The actions we included as adaption, though, have low barriers, being relatively inexpensive and easy. In contrast, the actions we included as mitigation actions are more cost prohibitive and harder to engage. We went beyond beliefs around climate change and asked about the motivations of those reporting engaging in pro-climate actions and found that health was the motivation listed only for converting to a plant-based diet. Great interest in high-efficiency vehicles and solar panels was reported and economics was the primary reason for those who had adopted these activities. Importantly, we found that those who did not believe climate change could be addressed were less likely to engage in activities. These results could aid the development of more efficient evidence-based communication strategies that would reach various audiences in society.

Supporting information

S1 Text. Survey questions. The questions used in the survey.
(DOCX)

S1 Fig. Study methodology.
(TIF)

S1 Data. Participant responses. Participant responses to questions used in the survey.
(XLSX)

Author Contributions

Conceptualization: Heidi E. Brown.

Data curation: Erika Austhof.

Formal analysis: Heidi E. Brown, Paula M. Luz.

Funding acquisition: Daniel B. Ferguson.

Methodology: Heidi E. Brown, Erika Austhof, Paula M. Luz.

Project administration: Heidi E. Brown, Erika Austhof.

Supervision: Heidi E. Brown.

Visualization: Heidi E. Brown.

Writing – original draft: Heidi E. Brown, Erika Austhof, Paula M. Luz.

Writing – review & editing: Heidi E. Brown, Erika Austhof, Paula M. Luz, Daniel B. Ferguson.

References

1. Watts N, Adger WN, Agnolucci P. Health and climate change: Policy responses to protect public health. Lancet. 2015 Nov 1; 386:1861–914. Available from: http://www.thelancet.com/article/S0140673615608546/fulltext https://doi.org/10.1016/S0140-6736(15)60854-6 PMID: 26111439
2. Rocque RJ, Beaudoin C, Ndjaboue R, Cameron L, Poirier-Bergeron L, Poulin-Rheault RA, et al. Health effects of climate change: an overview of systematic reviews. BMJ Open. 2021 Jun 1; 11(6):e046333. Available from: https://bmjopen.bmj.com/content/11/6/e046333 https://doi.org/10.1136/bmjopen-2020-046333 PMID: 34108165
3. Ebi KL, Boyer C, Ogden N, Paz S, Berry P, Campbell-Lendrum D, et al. Burning embers: synthesis of the health risks of climate change. Environ Res Lett. 2021 Mar 30; 16(4):044042. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/abeadd
4. Romanello M, McGushin A, Di Napoli C, Drummond P, Hughes N, Jamart L, et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet. 2021 Oct 30; 398(10311):1619–62. Available from: http://www.thelancet.com/article/S0140673621017876/fulltext
5. WHO. Compendium of WHO and other UN Guidance on Health and Environment. Geneva: WHO; 2021 Sep. Available from: https://www.who.int/publications/i/item/WHO-HEP-ECH-EHD-21.02
6. Leiserowitz A. Climate change risk perception and policy preferences: The role of affect, imagery, and values. Clim Change. 2006; 77:45–72.
7. Bushell S, Buisson GS, Workman M, Colley T. Strategic narratives in climate change: Towards a unifying narrative to address the action gap on climate change. Energy Res Soc Sci. 2017 Jun 1; 28:39–49.
8. Leiserowitz A, Maibach E, Rosenthal S, Kotcher J, Bergquist P, Ballew M, et al. Climate change in the American Mind: April 2020. New Haven, CT; 2020 Apr. Available from: https://doi.org/10.1007/s10584
9. Whitmarsh L, Seyfang G, O'Neill S. Public engagement with carbon and climate change: To what extent is the public 'carbon capable'? Glob Environ Chang. 2011 Feb 1; 21(1):56–65.
10. Roy J, Pal S. Lifestyles and climate change: link awaiting activation. Curr Opin Environ Sustain. 2009 Dec 1; 1(2):192–200.

11. Kearney GD, Bell RA. Perceptions of Global Warming among the Poorest Counties in the Southeastern United States. J Public Heal Manag Pract. 2019 Mar 1; 25(2):107–12. Available from: https://doi.org/10.1097/PHH.0000000000000720 PMID: 29521847

12. Howe PD, Marlon JR, Wang X, Leiserowitz A. Public perceptions of the health risks of extreme heat across US states, counties, and neighborhoods. Proc Natl Acad Sci U S A. 2019 Apr 2; 116(14):6743–8. Available from: https://www.pnas.org/content/116/14/6743 https://doi.org/10.1073/pnas.1813145116 PMID: 30862729

13. Kollmuss A, Agyeman J. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environ Educ Res. 2010; 8(3):239–60. Available from: https://www.tandfonline.com/doi/abs/ https://doi.org/10.1080/13504620220145401

14. van Valkengoed AM, Steg L. Meta-analyses of factors motivating climate change adaptation behaviour. Nat Clim Chang. 2019 Feb 1; 9(2):158–63.

15. Mullins-Jaime C, Wachter JK. Motivating Personal Climate Action through a Safety and Health Risk Management Framework. Public Health. 2023; 20(7).

16. Rosenstock IM, Strecher VJ, Becker MH. Social learning theory and the Health Belief Model. Health Educ Q. 1988; 15(2):175–83. Available from: https://pubmed.ncbi.nlm.nih.gov/3378902/ https://doi.org/10.1177/109019818801500203 PMID: 3378902

17. Brick C, Bosshard A, Whitmarsh L. Motivation and climate change: A review. Curr Opin Psychol. 2021 Dec 1; 42:82–8. https://doi.org/10.1016/j.copsyc.2021.04.001 PMID: 33992934

18. Lorenzoni I, Nicholson-Cole S, Whitmarsh L. Barriers perceived to engaging with climate change among the UK public and their policy implications. Glob Environ Chang. 2007 Aug 1; 17(3–4):445–59.

19. Petrovic N, Madrigano J, Zaval L. Motivating mitigation: when health matters more than climate change. Clim Change. 2014 Sep 1; 126(1–2):245–54. Available from: https://link.springer.com/article/10.1007/s10584-014-1192-2

20. Masud MM, Al-Amin AQ, Junsheng H, Ahmed F, Yahaya SR, Akhtar R, et al. Climate change issue and theory of planned behaviour: relationship by empirical evidence. J Clean Prod. 2016 Feb 1; 113:613–23.

21. Solomon CG, LaRocque RC. Climate Change—A Health Emergency. N Engl J Med. 2019 Jan 17; 380(3):209–11. Available from: https://www.nejm.org/doi/full/10.1056/NEJMp1817067 PMID: 30650319

22. Sauerborn R, Kjellstrom T, Nilsson M. Invited Editorial: Health as a crucial driver for climate policy. Glob Health Action. 2009; 2(1). Available from: /pmc/articles/PMC2799238/ https://doi.org/10.3402/gha.v2i0.2104 PMID: 20052423

23. Rossa-Roccor V, Giang A, Kershaw P. Framing climate change as a human health issue: enough to tip the scale in climate policy? Lancet Planet Heal. 2021 Aug 1; 5(8):e553–9. Available from: http://www.thelancet.com/article/S2542519621001133/fulltext https://doi.org/10.1016/S2542-5196(21)00113-3 PMID: 34390673

24. Ciesielski T. Climate Change and Public Health: A Small Frame Obscures the Picture. New Solut. 2017 Jan 31; 27(1):8–11. Available from: https://journals.sagepub.com/doi/10.1177/1048291117691075

25. Maibach EW, Nisbet M, Baldwin P, Akerlof K, Diao G. Reframing climate change as a public health issue: An exploratory study of public reactions. BMC Public Health. 2010 Dec 1; 10(1):299. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-10-299 PMID: 20515503

26. Amelung D, Fischer H, Herrmann A, Aall C, Louis VR, Becher H, et al. Human health as a motivator for climate change mitigation: results from four European high-income countries. Glob Environ Chang. 2019 Jul 1; 57:101918.

27. Semenza JC, Ploubidis GB, George LA. Climate change and climate variability: Personal motivation for adaptation and mitigation. Environ Heal A Glob Access Sci Source. 2011; 10(1). https://doi.org/10.1186/1476-069X-10-46 PMID: 21600004

28. Kotcher J, Feldman L, Luong KT, Wyatt J, Maibach E. Advocacy messages about climate and health are more effective when they include information about risks, solutions, and a normative appeal: Evidence from a conjoint experiment. J Clim Chang Heal. 2021 Aug 1; 3:100030.

29. Myers TA, Nisbet MC, Maibach EW, Leiserowitz AA. A public health frame arouses hopeful emotions about climate change: A Letter. Clim Change. 2012 Aug 28; 113(3–4):1105–12. Available from: https://link.springer.com/article/10.1007/s10584-012-0513-6

30. Badullovich N, Grant WJ, Colvin RM. Framing climate change for effective communication: a systematic map. Environ Res Lett. 2020 Nov 23; 15(12):123002. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/aba4c7

31. Weathers MR. Newspaper coverage of global warming and climate change (GWCC) as a public health issue. Appl Environ Educ Commun. 2013 Jan; 12(1):19–28. Available from: https://www.tandfonline.com/doi/abs/ https://doi.org/10.1080/1533015X.2013.795829

32. Smith SM, Roster CA, Golden LL, Albaum GS. A multi-group analysis of online survey respondent data quality: Comparing a regular USA consumer panel to MTurk samples. J Bus Res. 2016 Aug 1; 69 (8):3139–48.

33. Harrabin R. Climate change: Top 10 tips to reduce carbon footprint revealed—BBC News. BBC News. 2020. Available from: https://www.bbc.com/news/science-environment-52719662

34. Ivanova D, Barrett J, Wiedenhofer D, Macura B, Callaghan M, Creutzig F. Quantifying the potential for climate change mitigation of consumption options. Environ Res Lett. 2020 Aug 20; 15(9):093001. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/ab8589

35. Walters K, Christakis DA, Wright DR. Are Mechanical Turk worker samples representative of health status and health behaviors in the U.S.? PLoS One. 2018 Jun 1; 13(6):e0198835. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0198835 PMID: 29879207

36. Austhof E, Brown HE. Global Warming's Six MTurks: A Secondary Analysis of a US-Based Online Crowdsourcing Market. Int J Environ Res Public Health. 2022 Jul 7; 19(14):8320. Available from: https://www.mdpi.com/1660-4601/19/14/8320/htm https://doi.org/10.3390/ijerph19148320 PMID: 35886164

37. Buhrmester MD, Talaifar S, Gosling SD. An Evaluation of Amazon's Mechanical Turk, Its Rapid Rise, and Its Effective Use. Perspect Psychol Sci. 2018 Mar 1; 13(2):149–54. Available from: http://journals.sagepub.com/doi/10.1177/1745691617706516 PMID: 29928846

38. Coppock A, McClellan OA. Validating the demographic, political, psychological, and experimental results obtained from a new source of online survey respondents: Res Polit. 2019 Jan 28; 6(1). Available from: https://journals.sagepub.com/doi/10.1177/2053168018822174

39. Moser S, Kleinhückelkotten S. Good intents, but low impacts: Diverging importance of motivational and socioeconomic determinants explaining pro-environmental behavior, energy use, and carbon footprint. Environ Behav. 2018 Jul 1; 50(6):626–56. Available from: https://doi.org/10.1177/0013916517710685

40. McDonald RI, Chai HY, Newell BR. Personal experience and the 'psychological distance' of climate change: An integrative review. J Environ Psychol. 2015 Dec 1; 44:109–18.

41. Levay KE, Freese J, Druckman JN. The Demographic and Political Composition of Mechanical Turk Samples: SAGE Open. 2016 Mar 15; 6(1). Available from: https://journals.sagepub.com/doi/10.1177/2158244016636433

42. U.S. Income Distribution 2019 | Statistica. 2020. Available from: https://www.statista.com/statistics/203183/percentage-distribution-of-household-income-in-the-us/

43. Party Affiliation | Gallup Historical Trends. Gallup News. 2020. Available from: https://news.gallup.com/poll/15370/party-affiliation.aspx

44. U.S. Census Bureau QuickFacts: United States. Available from: https://www.census.gov/quickfacts/fact/table/US/PST045219

45. Nisa CF, Bélanger JJ, Schumpe BM, Faller DG. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. Nat Commun 2019 101. 2019 Oct 4; 10(1):1–13. Available from: https://www.nature.com/articles/s41467-019-12457-2

46. Wynes S, Nicholas KA. The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environ Res Lett. 2017 Jul 12; 12(7):074024. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/aa7541

47. Who relies on public transit in the U.S. | Pew Research Center. Available from: https://www.pewresearch.org/fact-tank/2016/04/07/who-relies-on-public-transit-in-the-u-s/

48. Firestine T. The U.S. Rural Population and Scheduled Intercity Transportation in 2010: A Five-Year Decline in Transportation Access. 2011. Available from: http://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=640&Link=0

49. Zeiske N, van der Werff E, Steg L. The effects of a financial incentive on motives and intentions to commute to work with public transport in the short and long term. J Environ Psychol. 2021 Dec 1; 78:101718. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0272494421001717

50. Springmann M, Godfray HCJ, Rayner M, Scarborough P. Analysis and valuation of the health and climate change cobenefits of dietary change. Proc Natl Acad Sci U S A. 2016 Apr 12; 113(15):4146–51. Available from: https://www.pnas.org/content/113/15/4146 https://doi.org/10.1073/pnas.1523119113 PMID: 27001851

51. Poore J, Nemecek T. Reducing food's environmental impacts through producers and consumers. Science (80-). 2018 Jun 1; 360(6392):987–92. Available from: https://www.science.org/doi/abs/10.1126/science.aaq0216 PMID: 29853680

52. Tuso P, Stoll SR, Li WW. A plant-based diet, atherogenesis, and coronary artery disease prevention. Perm J. 2015 Dec 1; 19(1):62. Available from: /pmc/articles/PMC4315380/ https://doi.org/10.7812/TPP/14-036 PMID: 25431999

53. Wang Y, Beydoun MA. Meat consumption is associated with obesity and central obesity among US adults. Int J Obes. 2009 Mar 24; 33(6):621–8. Available from: https://www.nature.com/articles/ijo200945 https://doi.org/10.1038/ijo.2009.45 PMID: 19308071

54. Tonstad S, Butler T, Yan R, Fraser GE. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. Diabetes Care. 2009 May 1; 32(5):791–6. Available from: https://care.diabetesjournals.org/content/32/5/791 https://doi.org/10.2337/dc08-1886 PMID: 19351712

55. Song M, Fung TT, Hu FB, Willett WC, Longo VD, Chan AT, et al. Association of animal and plant protein intake with all-cause and cause-specific mortality. JAMA Intern Med. 2016 Oct 1; 176(10):1453–63. Available from: https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2540540 https://doi.org/10.1001/jamainternmed.2016.4182 PMID: 27479196

56. Lea EJ, Crawford D, Worsley A. Consumers' readiness to eat a plant-based diet. Eur J Clin Nutr. 2005 Nov 9; 60(3):342–51. Available from: https://www.nature.com/articles/1602320

57. Naz Çoker E, Van Der Linden S. Fleshing out the theory of planned of behavior: Meat consumption as an environmentally significant behavior. Curr Psychol. 2022; 41:681–690. Available from: https://doi.org/10.1007/s12144-019-00593-3

58. EPA US. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020. 2022. Available from: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

59. Hu A, Levis S, Meehl GA, Han W, Washington WM, Oleson KW, et al. Impact of solar panels on global climate. Nat Clim Chang. 2015 Nov 2; 6(3):290–4. Available from: https://www.nature.com/articles/nclimate2843

60. Singh KV, Bansal HO, Singh D. A comprehensive review on hybrid electric vehicles: architectures and components. J Mod Transp. 2019 Mar 8; 27(2):77–107. Available from: https://link.springer.com/article/10.1007/s40534-019-0184-3

61. Milev G, Hastings A, Al-Habaibeh A. The environmental and financial implications of expanding the use of electric cars—A Case study of Scotland. Energy Built Environ. 2021 Apr 1; 2(2):204–13.

62. Kwan CL. Influence of local environmental, social, economic and political variables on the spatial distribution of residential solar PV arrays across the United States. Energy Policy. 2012 Aug 1; 47:332–44.

63. Balcombe P, Rigby D, Azapagic A. Motivations and barriers associated with adopting microgeneration energy technologies in the UK. Renew Sustain Energy Rev. 2013 Jun 1; 22:655–66.

64. Wiser R, Pickle S, Goldman C. Renewable energy policy and electricity restructuring: a California case study. Energy Policy. 1998 May 1; 26(6):465–75.

65. Hai MA. Rethinking the social acceptance of solar energy: Exploring "states of willingness" in Finland. Energy Res Soc Sci. 2019 May 1; 51:96–106.

66. Stanley SK, Hogg TL, Leviston Z, Walker I. From anger to action: Differential impacts of eco-anxiety, eco-depression, and eco-anger on climate action and wellbeing. J Clim Chang Heal. 2021 Mar 1; 1:100003.

67. Smith N, Leiserowitz A. The role of emotion in global warming policy support and opposition. Risk Anal. 2014; 34(5):937–48. https://doi.org/10.1111/risa.12140 PMID: 24219420

68. Koletsou A, Mancy R. Which efficacy constructs for large-scale social dilemma problems? Individual and collective forms of efficacy and outcome expectancies in the context of climate change mitigation. Risk Manag. 2011 Dec 28; 13(4):184–208. Available from: https://link.springer.com/article/10.1057/rm.2011.12

69. Spence A, Pidgeon N. Framing and communicating climate change: The effects of distance and outcome frame manipulations. Glob Environ Chang. 2010 Oct 1; 20(4):656–67.

70. Schneider CR, Zaval L, Markowitz EM. Positive emotions and climate change. Curr Opin Behav Sci. 2021 Dec 1; 42:114–20.

71. Akerlof KL, Delamater PL, Boules CR, Upperman CR, Mitchell CS. Vulnerable Populations Perceive Their Health as at Risk from Climate Change. Int J Environ Res Public Heal. 2015; 12:15419–33. Available from: www.mdpi.com/journal/ijerph https://doi.org/10.3390/ijerph121214994 PMID: 26690184

72. van der Linden S, Maibach E, Leiserowitz A. Improving public engagement with climate change: Five "best practice" insights from psychological science. Perspect Psychol Sci. 2015 Nov 1; 10(6):758–63. Available from: https://pubmed.ncbi.nlm.nih.gov/26581732/ https://doi.org/10.1177/1745691615598516 PMID: 26581732

73. Kyriakopoulos GL, Sebos I. Enhancing climate neutrality and resilience through coordinated climate action: Review of the synergies between mitigation and adaptation actions. Climate. 2023 May 10; 11(5):105. Available from: https://www.mdpi.com/2225-1154/11/5/105/htm

74. Kahneman D. Thinking, Fast and Slow. New York: Farrar, Straus and Giroux; 2013.

75. Gao J, Xu G, Ma W, Zhang Y, Woodward A, Vardoulakis S, et al. Perceptions of health co-benefits in relation to greenhouse gas emission reductions: A survey among urban residents in three chinese cities. Int J Environ Res Public Health. 2017 Mar 13; 14(3):298. Available from: https://www.mdpi.com/1660-4601/14/3/298/htm https://doi.org/10.3390/ijerph14030298 PMID: 28335404

76. Noppers EH, Keizer K, Bolderdijk JW, Steg L. The adoption of sustainable innovations: Driven by symbolic and environmental motives. Glob Environ Chang. 2014 Mar 1; 25(1):52–62.