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The role of climate change education

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on individual lifetime carbon emissions

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19   **Abstract:**

20   Strategies to mitigate climate change often center on clean technologies such as electric vehicles

21   and solar panels, while the mitigation potential of a quality educational experience is rarely

22   discussed. In this paper, we investigate the long-term impact that an intensive one-year

23   university course had on individual carbon emissions by surveying students at least five years

24   after having taken the course. A majority of course graduates reported pro-environmental

25   decisions (i.e., type of car to buy, food choices) that can be attributed to experiences gained in

26   the course. Furthermore, our carbon footprint analysis demonstrates that for the average course

27   graduate, these decisions reduced their individual carbon emissions by 2.86 tons of CO_2 per year.

28   Focus group interviews identify that course graduates have developed a strong personal

29   connection to climate change solutions, and this is realized in their daily behaviors and through

30   their professional careers. The paper discusses in more detail the specific components of the

31   course that are believed to be most impactful, and it shares preliminary outcomes from similar

32   curriculum designs that are being used with K-12 students. Our analysis also demonstrates that if

33   similar education programs were applied at scale, the potential reductions in carbon emissions

34   would be of similar magnitude to other large-scale mitigation strategies such as rooftop solar or

35   electric vehicles.

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1. Introduction

In 1992, the United Nations Framework Convention on Climate Change stated, "Education is an essential element for mounting an adequate global response to climate change" (UNFCCC 1992). Few would argue against the importance of education in providing an informed response to environmental problems. Solutions to climate change tend to focus on mitigation and adaptation measures, and successful implementation of either strategy requires an informed and educated citizenry. Yet despite the notion of education's importance in responding to climate change, education is rarely mentioned in discussions of today's major climate solution strategies. One reason that education programs do not often feature in discussions about climate change mitigation is that education programs typically have insufficient data to verify reductions in carbon emissions. This is in contrast to technologies such as renewable energy generation and the electrification of automobiles that can demonstrate reductions in carbon emissions using data. Should education be shown to be an effective tool to reducing emissions via changes in behavior and attitudes, it would seem likely that funding and interest in such methods would become more widespread and well supported.

Education has been found to be one method for promoting behavior change, but only under certain circumstances (e.g., Kollmuss and Agyeman 2002; Lyons et al. 2006). The environmental education literature offers some insight into the connections between education and behavior change, and it also provides guidance on how to encourage pro-environmental behavior (D'Amato and Krasny 2011; Craig and Allen 2015). The notion that knowledge leads to awareness and then to action has been countered with studies that document that knowledge and skills are not enough to change behavior (e.g., Bray and Cridge 2013). The literature suggests that more personal factors such as a deep connection to nature, personal relevance to the issue

63   and personal agency towards action are important factors that contribute to successful behavior

64   change programs (e.g., Hungerford and Volk 1992, Kollmuss and Agyeman 2002, Bamberg and

65   Möser 2007). Even among successful programs, the question of how long the intended behavior

66   is sustained can vary depending on the type of intervention, with longer and more sustained

67   engagements tending to have more long-lasting impacts (Orams 1997). This previous research

68   informs educational research programs towards designs that not only focus on information but

69   also promote the personal qualities that can support sustained action.

70   The purpose of this paper is to evaluate the impact of an intensive university climate change

71   course on individual long-term carbon emissions. The design of the course is described including

72   aspects of the course that were intended to help students develop a deep connection with climate

73   change and climate solutions. Five years of graduates from the course were surveyed at least five

74   years after they took the course. The results of both survey data and focus group interviews

75   provide an indication of the long-term impact of the course, and they contribute to our

76   understanding of the potential role that education can play in long-term behaviors and attitudes.

77   We then quantify the reductions in annual carbon emissions resulting from graduates' pro-

78   environmental behavior, and we compare the reductions achieved through this education

79   program with other climate change mitigation measures. A discussion of how this type of

80   educational approach may be used within the K-12 education system is also provided.

81   2. Methods

82   **2.1.   University Course and Students**

83   In fall 2007, a new course was offered at San José State University (SJSU) that satisfied all three

84   subject areas of the upper division general education (GE) requirements, plus the campus writing

85   requirement. The course, COMM/ENVS/GEOL/HUM/METR 168 & 168W: Global Climate

86   Change I & II (hereafter referred to as COMM 168), is taught over an academic year, with six

87   credit hours in the fall semester, and three credit hours in the following spring semester. The

88   course is taught in a standard lecture theatre and has about 100 students enrolled per year. The

89   course uses a number of design approaches to impact students in ways that maximize effects on

90   students' personal and professional lives. This course has been taught every year since 2007 and

91   continues to be popular with students.

92   The course evaluated in this research was taught by three faculty members from different

93   departments with expertise in the core themes of climate science, climate mitigation and

94   environmental communication. Although different professors taught the course during the five-

95   year study period, the syllabus was consistent through the period.

96   The subject population consists of approximately 500 matriculated students from COMM 168 in

97   the academic years between 2007 and 2012 and who received GE credit for the course (receiving

98   a grade of "C" or better). The subjects are all now SJSU graduates and at least five years have

99   passed since they took the COMM 168 course. Students were recruited through email via SJSU's

100   alumni database after campus Institutional Review Board approval was secured. The majority of

101   students enrolled came from colleges outside of the sciences as shown in Table 1.

College	% of students reporting
College of Social Sciences	46%
College of Business	18%
College of Humanities and the Arts	18%
College of Applied Sciences and Arts	11%

College of Science	7%

102 **Table 1. The distribution of colleges from the reported major for each of the participants.**

103 **2.2.   Survey and Focus Groups**

104   An 18-item survey instrument (provided in Appendix A was developed to study participants'

105   beliefs about climate change and whether their own personal actions to mitigate climate change

106   could be attributed to motivating factors associated with taking the COMM 168 course. Of the

107   more than 500 students who took the course, 104 students from the five different course

108   iterations between 2007 and 2012 completed the survey. The categories of questions focus on

109   participants' a) attitudes and beliefs about global warming and whether they perceive it to affect

110   them personally, and b) whether any of the participants' current pro-environmental behaviors can

111   be attributed to taking the COMM 168 course. A follow-up semi-structured focus group

112   interview was conducted with a small sample of participants to better understand survey

113   responses.

114   **2.3.   Estimating Carbon Emission Reductions**

115   Once responses to the survey questions were obtained, the potential carbon reductions from the

116   decisions made by participants can be estimated. Details of the procedure used are provided in

117   Appendix B, but we briefly describe the method here. We use an online personal carbon

118   footprint calculator ((http://coolclimate.berkeley.edu/calculator)) to estimate how a particular

119   action attributed to taking COMM 168 would impact individual annual carbon emissions. We

120   start by calculating the annual carbon emissions for an average person in California. Then, based

121   on the response to a particular question (e.g., participant attributed their current purchasing of

122   renewable energy from their utility to the COMM 168 class), we use the calculator to determine

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123   the reduction in annual carbon emissions due to that particular action (e.g., participant reduced

124   emissions by 1.38 tons/year by purchasing renewable energy from their utility). This procedure

125   is repeated for each of the actions identified in the survey.

126   ## 3. Results

127   **3.1. Survey**

128   The first part of the survey focused on participants' attitudes and beliefs about global warming.

129   A large majority of participants (83%) agreed with the statement, "Most scientists think global

130   warming is happening.", and most participants (84%) also felt that global warming would affect

131   their lives "a great deal" or "a moderate amount." This is notable since the general public often

132   discounts the impacts that global warming will have on them personally (Semenza et al. 2008;

133   Buys et al. 2012). Most participants (84%) also strongly agreed or agreed with the statement, "I

134   have personally experienced the effects of global warming.", and when asked about how global

135   warming will affect future generations, 91% said "a great deal."

136   The second group of questions asked about personal actions to reduce climate change and

137   whether the COMM 168 course had any effect on those actions. The general areas of climate

138   action included waste reduction, home energy conservation, transportation and food choices.

139   Each question asked participants to reflect on how participation in COMM 168 may have

140   affected their actions today in those areas.

141   A summary of the results for the different categories is provided in Figure 1. In the waste and

142   home energy conservation categories, a large percentage of participants described engaging in

143   some actions to reduce waste or reduce energy use in their home that they attribute to taking the

144   COMM 168 class. This included recycling more often (95%), giving away or donating products

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145   so they can be reused (75%), buying products that have less packaging (64%), changing to more

146   energy efficient light bulbs (86%) and purchasing energy saving appliances (59%). Fewer

147   participants reported actions such as composting food scraps (48%), purchasing renewable

148   energy from their utility (18%) and installing solar panels (4%).

149   In the transportation category, about 25% of participants reported some behavior to reduce

150   emissions that is attributed to the COMM 168 class. This included using public transportation

151   more (35%), using a bicycle for transportation (26%) and carpooling regularly (22%). And in the

152   food choices category, most participants (80%) reported that at least occasionally they made food

153   choices based on reducing carbon emissions.

154   **Figure 1. Survey results for questions related to how often participants make choices to reduce**
155   **carbon emissions as a result of the COMM 168 class. The blue bars represent the percentage of**
156   **students who agreed with the survey response, while the orange bars represent the relative impact**
157   **in carbon emissions in percent relative to the total reductions.**

158   The survey responses reported here suggest that participant behavior was influenced by the

159   COMM 168 course in ways that continue to impact daily life. The types of actions studied here

160   can be divided into two groups: one-time actions and recurring actions. For example, the

161   purchase of an energy efficient light bulb or automobile is a one-time action, and these decisions

162   will shape energy use for years into the future. In contrast, recurring actions such as recycling or

163   food choices are made every day, and thus require more consistent engagement or behavior

164   response. In reality, pro-environmental behavior includes both types of actions, and their impacts

165   on carbon emissions can vary depending on the type of action and whether recurring actions

166   become part of an individual's lifestyle. Given the number of years that elapsed between the

167   course and the survey, the survey provides a glimpse into behaviors that have likely become

168   habitual. In the waste and food categories, some recurring actions were noted by most

169   participants. Although recycling may be viewed as a fairly common action in many Californian

170   communities, food choices and the connection with carbon emissions is not as widely known by

171   the general public (e.g., Cordero et al. 2008; Wynes and Nicholas 2017). Given that 80% of

172   participants reported some changes to their food choices, it appears that the course did have an

173   impact on decision-making in this category even years after the class.

174   **3.2.   Estimated carbon emissions**

175   Using the survey responses about the actions that participants took, we then calculate the

176   reductions in carbon emissions for all participants. Figure 1 also shows the contribution of each

177   of the survey questions to the total reductions in carbon emissions. While changes to behavior

178   around reducing waste and energy conservation at home were the most common actions taken,

179   the largest reduction in participant-averaged carbon emissions came through transportation

180   decisions. For example, while only 31% of participants reported purchasing a more gas-efficient

181   car, this single action accounted for 18% of all carbon emission reductions observed. In contrast,

182   while over 90% of participants reported that they recycle more often, the combined reduction in

183   carbon emissions only accounted for 11% of the total reductions.

184   As shown in Figure 2, the average reduction in carbon emissions based on the participant survey

185   responses is 3.54 tons of CO_2/year, with most participants between 2 and 5 tons of CO_2/year.

186   About 5% of students reported almost no change (0-1 ton of CO_2/year), and about 10% reported

187   between 6 and 8 tons of CO_2/year. Of the four primary categories of carbon emission reductions,

188   changes in transportation were responsible for 40% of the total carbon emission reductions,

189   while waste reduction, food choices and home energy contributed respectively 33%, 13% and

190   12% of the achieved total carbon emission reductions.

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Figure 2. The distribution of carbon emission reductions (tons/year) for participants (n=104) as a result of the COMM 168 class.

3.3.   Understanding how personal relevance and carbon emissions are related

Given that one of the goals of the course is to help students develop a personal connection

between global warming and their lives, we explore the connections between participant beliefs

and total carbon emission reductions through analysis of grouped data. In Figure 3, we show the

relationship between individual carbon emission reductions with personal beliefs about how

global warming will influence them or future generations. We find that participants who believe

that global warming will harm them personally, or will harm future generations, have larger

reductions in carbon emissions compared to participants who don't believe there will be a strong

impact on them or future generations. Thus it appears that in most cases, participants were at

some level influenced by how they perceived the impact of global warming on their own well-

being, or the well-being of future generations, when making personal decisions related to the

environment.

Figure 3. The reductions in carbon emissions (in tons/year) for groups based on their responses to the two questions about how global warming will affect them personally or future generations. The percentage of the total responses for that question is also given above each bar.

Further, of the participants who agreed (strongly agreed or agreed) to the statement, "I have

personally experienced the effects of global warming," their reductions in carbon emissions were

3.7 tons of CO_2/year, while for the participants who didn't agree with that statement (disagreed,

strongly disagreed or neutral), their reductions were only 2.9 tons of CO_2/year (see Figure 4).

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214 **Figure 4. Relationship between statement response and total carbon emission reductions. For the**
215 **first two statements, agree means strongly agree + agree, while disagree means strongly disagree +**
216 **disagree + neutral.**

217 **3.4.   Focus Groups**

218 After evaluating the survey responses and noting themes in the utility of the course and personal

219 climate change mitigation strategies, we followed up with focus group interviews to gain more

220 in-depth understanding of the enduring influence of the course on students' personal and

221 professional lives. Including a qualitative approach such as focus group interviews can

222 complement the survey analysis and ultimately enhance the quality of the resulting analysis

223 (Wolff et al. 1993).

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225 Focus group participants were recruited from 100+ survey respondents. We conducted two focus

226 groups with a total of five participants. The focus groups were conducted in a classroom at San

227 José State University. Participants were asked a series of open-ended questions about the course

228 and its impact on their current lives. Responses from focus group participants converged around

229 two themes: the importance of daily decisions to mitigate their climate change impact and the

230 importance of engaging their community through climate change communication.

231 **3.4.1 Impact on Daily Decisions**

232 A hallmark of conversations with graduates from the course was the consideration of climate in

233 daily decisions. Fundamentally, focus group participants recognized the pervasiveness of climate

234 change. As Tara, a focus group participant, noted, "Almost every activity we choose can affect

235 [climate change] in some way. Whether we choose to take the bus or drive to work or whether

236 we choose to buy food that's grown on land that was cleared from rainforests…. Since it is in

237   every aspect of our life pretty much, that automatically makes it relevant to all those different

238   aspects." Other participants agreed and described daily actions that centered on transportation,

239   waste and food choices. Melissa noted, "I think about it all the time.... Definitely how I think

240   about and go about my days, making decisions, even just from using plastic." These responses

241   exemplify a common theme in the group—the knowledge of climate change gained in the course

242   prompted them to think about the impact of their actions.

243   The focus group participants noted that they go out of their way to take action because they feel

244   as if they are making a difference. Billy noted, "When everyone does something to mitigate

245   climate change, it will have a huge impact." Tara concurred, "Almost everything I do can affect

246   the climate somehow. If you start realizing how everything ties together, then pretty much

247   everything you do, every choice you make can affect it in some way." She continued, "I think

248   every small step does make a difference… One little step at a time, it all adds up. I'd like to think

249   we're making a difference. I feel like I am when I contribute a little bit." Participants suggested

250   that the interdisciplinary focus of the course allowed them to see the connections between their

251   actions and broader climate forcings.

252   Participant comments demonstrate that environmental actions are not just because of sacrifice

253   but that people feel good about taking action. Lolitta explained, "I feel good about how I'm

254   living my life, and I'm excited by all the changes that I'm making, and I will continue making

255   these changes because they make me feel great." Billy noted proudly that he acts because "it's

256   like a moral obligation." Ultimately, participants concurred that daily actions matter, and they

257   cited this belief as the reason they continue to take actions. Their comments suggest they are

258   empowered to act because they see themselves as part of the solution.

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259   **3.4.2 Community Engagement through Communication**

260   Overall, focus group participants noted that this course helped them develop experience

261   communicating with other people about their actions and why they are taking them. Participants

262   cited the community action class project as a key element in their understanding of the impact of

263   community engagement. Examples of community actions projects include developing

264   community gardens in a nearby apartment complex, giving presentations about climate solutions

265   to schools, and implementing composting programs in nearby businesses. Billy described the

266   lasting impact of "the hands-on approach" of the project: "Those experiences, I think for me, I

267   carry those longer than / more than being in the classroom…. Being with people, doing

268   something that's going to translate into what I have to do work-wise in the future, [the project

269   was a] translatable experience to the workforce." Melissa described the lasting impression of the

270   project as a crucial aspect to seeing the impact of action: "It actually bridged the gap between the

271   course and what the community itself is doing."

272   Participants noted the impact of the class on life beyond the home. One focus group participant,

273   Elaine, is a manager at Walmart, and she credited the course for her "awareness in an industry

274   with high consumption…. It's so interesting how much I've been able to use just from this

275   course." She noted her focus as a manager is how to "reduce your inventory, reduce the waste,

276   sell what you need to." Elaine views Walmart's waste issues as a management problem: "I see

277   the huge amounts that they're throwing away because they're not managing their business

278   correctly, because they're not managing their production versus what they need, what they don't.

279   So that's one of the things that I work on." Elaine's comments exemplify how many graduates of

280   COMM 168 viewed the importance of taking action.

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281   Billy noted the course explained how to make "big issues" like climate change "resonate with

282   your audience… That's what I do now." He explains that in his job at Pacific Gas and Electric,

283   one of his roles is communicating about water issues, "that's my biggest takeaway from this

284   class: messaging. [I now understand] the importance of communicating about climate change in

285   a way where people who don't have a background in that subject can understand." Other

286   participants concurred that the course made them experts in climate change, and they now have

287   to think about how to communicate with people who don't have such extensive knowledge.

288   Participants also noted the importance of communicating with others about the actions they take.

289   Tara noted: "It doesn't really help unless you try to bring it out there. If I only ever walk places,

290   no one will ever know unless I try to let them know why I walk places…. If you're going to make

291   a point by breaking the rules, you first have to know the rules because otherwise it doesn't mean

292   anything. If I want to rebel by not using a car, I first have to know that everyone thinks using a

293   car is a normal thing to do." Participants agreed that talking about their own actions helped in

294   discussing climate change issues with others.

295   The community action project was a key part of the course in giving students experience outside

296   of class in creating change. It also gave them some agency over this issue. Participants described

297   their attempts to make a difference, both in their personal and professional lives. Participants

298   noted the community action project allowed them to see the importance of communication in the

299   design of their projects. The focus group responses suggest that interdisciplinary education

300   including aspects of communication can give students the skills and experience necessary to

301   create change in their own communities.

302   **3.5.   Educational approach**

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303   We have identified a number of key design elements that stood out as critical to the success of

304   the education program we developed and that have sustained student engagement over many

305   years. These include a) connecting climate science to students' lives, b) providing students with

306   experience creating change in a community of their choice and c) creating a culture devoted to

307   stewardship and action. We found that these three key elements of the course helped students to

308   connect with the subject in ways that extended into their personal and professional lives, and

309   persisted over time to an extent that we have not seen in other similar classes. These elements

310   were not isolated from each other, or from other important elements of the class, including a

311   solid focus on climate science, climate mitigation and environmental communication. These

312   factors are in line with the models suggested by other researchers, including personal relevance

313   and empowerment (Bray and Cridge 2013). We now review each of these elements in more

314   detail to provide insights into how these ideas may be applied to other educational settings.

315   **3.5.1 Connecting science to students' lives**

316   There were various activities in the class designed to help connect climate change with students'

317   lives. One project asked students to reflect on how climate change would affect their personal

318   and professional lives. Another project had students track their personal energy use, and then

319   implement a plan to reduce their energy use in their home using data from their home smart

320   meters. These elements appeared to have some lasting impact, as various focus group

321   participants reflected on how the course materials affected their personal and professional lives.

322   In addition to the actions that were identified in the survey data, open-ended feedback also

323   revealed that the course affected other major decisions, such as where to live and how many

324   children to have. In fact, two of the participants mentioned their decisions to not have children or

325   to adopt a child were influenced by the course. This implies that at least for some of the students,

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326   the course content and the implications of climate change affected their personal lives deeply. It

327   appears that some of the high-impact actions identified by Wynes and Nicholas (2017) did

328   resonate with the COMM 168 students.

329   **3.5.2 Creating change in a community of their choice**

330   Another design element of the course was to provide students with real world experience

331   creating and implementing an action plan to reduce carbon emissions. The Community Action

332   Project (CAP) was the culminating experience during the second semester where student teams

333   competed to develop the most impactful community-based project. The groups presented their

334   results at the end of the semester, and were judged by an outside panel of experts. The goal of the

335   CAP was to give students real-world experience developing solutions to climate change. It was

336   our intention that through this experience, students would not only better understand some of the

337   challenges associated with creating change but also gain confidence that change can happen

338   through well-designed efforts. Ramsey (1993) found that using issue instruction and action

339   training was an effective way to promote pro-environmental behavior. And MacFall (2012)

340   found that students were deeply affected by their service-learning course even years after the

341   experience. The COMM 168 class was focused around the year-long CAP and feedback from the

342   focus groups shared how impactful the project was for some of the students, as a majority of the

343   focus group participants mentioned the CAP as the most memorable part of the course. It is our

344   conclusion that the CAP was an effective culminating experience, and today the class continues

345   to use this activity to help students take their learning into practice.

346   **3.5.3 Creating a culture devoted to stewardship and action**

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347   The third aspect of the class that we feel was important to creating impactful and lasting change

348   was the social norms that were established during the year-long class. Although we didn't create

349   any design elements at the start of the class to promote this, we do feel this was an important part

350   of the course success. Among the emerging theories of behavior change, community-based social

351   marketing (Mckenzie-Mohr, 2000; Heimlich and Ardoin 2008) and the strong impact of social

352   norms have been shown to be effective measures for stimulating behavior change.

353   Creating a culture for a class is not easy, but there are effective teaching strategies that can help

354   influence class culture, and we outline these here.

355   1) Group discussions with different students: We did a lot of group work in class. With 80-120

356   students per class, we took special efforts to mix students for their group work. This helps

357   students work with new students and not develop their own group that they work with

358   exclusively. We felt this helped students see multiple views across the class, and if an emerging

359   interest and dedication to climate change arose through the class, it could spread.

360   2) Committed faculty: The faculty who taught this course were all deeply committed to climate

361   change solutions, and they shared their own journey towards reducing carbon emissions.

362   Through this one-year class, students got to know their professors well, and each professor

363   engaged in some level of social action on their own. Role models are important in creating social

364   change, and we suggest that having professors committed to environmental solutions was also a

365   factor in creating social norms. For example, one of the focus group participants mentioned that

366   as a student she used to drive an SUV, but she now drives a Prius. One of the professors said, "I

367   didn't know you drove an SUV when you took this class," and she said, "I know you didn't

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368   know because I didn't want you to know." This is an example of the social norms that were

369   established in the class that may have extended to students' lives outside of school and over time.

4. Potential Role of Education on Carbon Emission Reductions

371   Given the reductions in carbon emissions calculated in Section 3.2 (and shown in Figure 2), we

372   now explore the potential role of education as a climate change mitigation strategy. We start by

373   estimating the participant reductions in carbon emissions compared to a control group. The

374   control group is created by using recent California's per capita carbon emissions data as

375   estimated by the California Air Resources Board (CARB 2017). Their data show that by 2014,

376   per capita carbon emissions for the average Californian declined by 0.68 tons/year compared to

377   2009, the midpoint when students had graduated from SJSU. By contrast, the participants in

378   COMM 168 reduced their per capita emissions by 3.54 tons/year. Thus, if we subtract the

379   emission reductions for the average Californian (0.68) from our participants (3.54), we find that

380   the net reduction above the average citizen is 2.86 tons/year (3.54-0.68 = 2.86).

381   We now use the net reduction in carbon emissions observed for graduates of COMM 168 to

382   compare the potential role of education as a climate change mitigation strategy with other

383   climate change mitigation strategies. For this comparison, we employ the methodology outlined

384   in Project Drawdown (http://www.drawdown.org), where 80 different technologies or strategies

385   are evaluated based on the potential to cumulatively reduce carbon emissions by 2050 (Hawken

386   2017).

387   The following procedure and set of assumptions is used to calculate carbon emission reductions

388   associated with climate change education, as shown in Figure 5. We first assume that a modest

389   investment in climate change education would allow students of secondary school age from

390   middle and high income countries (where their carbon emissions are highest) to receive a

391   specialized climate change education (i.e., using similar educational methodologies as we've

392   ourlined here), and that students who receive this education would each reduce their carbon

393   emissions by 2.86 tons of CO_2/year (i.e., as in the COMM 168 class), for that year, and for each

394   year following. Further, we assume that such a program would start small at 1 million students

395   and grow by 13% per year until 2050, when the program reaches over 38 million participants.

396   We use 2015 data from the United Nation Educational, Scientific and Cultural Organization

397   (UNESCO) (http://data.uis.unesco.org) to estimate the number of students of secondary school

398   age from high income and upper middle income as 298 million. This allows us to estimate the

399   percentage of students participating in this specialized climate change education program in 2020

400   and 2050, assuming the population of secondary students in these countries does not change.

401   In Figure 5, six of the solutions presented in Project Drawdown are compared with our own

402   estimate for using education as a climate change mitigation strategy. For the solution scenarios

403   developed by Project Drawdown, each of these represents ambitious and yet, also technically and

404   economically feasible plans for reducing carbon levels. Technical details and reference literature

405   for all these solutions are presented at www.drawdown.org. As examples, the Rooftop Solar

406   scenario grows the percentage of electricity generated by rooftop solar from 0.4% today to 7%

407   by 2050, while the Electric Vehicles scenario grows the percentage of passenger miles from

408   electric vehicles from less than 1% today to 16% by 2050. For the Climate Change Education

409   scenario we assume that a) each student reduces their carbon emissions by 2.86 tons of CO_2,

410   similar to the COMM 168 class and b) the adoption of this type of education grows from less

411   than 1% of all secondary students today to 16% of all secondary students by 2050 (note: the

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412   number of secondary students is restricted to only high income and upper-middle income

413   countries where residents have higher carbon emissions.)

414   **Figure 5. Comparison of various existing technologies that can be applied over a 30-year period**
415   **(2020-2050) to help reduce global carbon emissions. The potential role of climate change education**
416   **programs is calculated using the per student carbon reductions estimated from the COMM 168**
417   **class.**

418   The results of this comparison show that education, if designed appropriately, can potentially be

419   as effective as other established climate change mitigation techniques. Based on the scenario we

420   developed, the implementation of climate change education over a 30-year period (2020-2050)

421   could reduce emissions by 18.8 GT of CO_2 eq, an amount that would rank in the top quarter (15

422   out of 80) of the presented solutions in Project Drawdown. Although at scale, the use of

423   education as a climate change mitigation technique is still untested, our analysis suggests that if

424   the educational approach is sound, and if we take the effort to measure the impact of education,

425   we may realize the potential to reduce carbon emissions using education. We also acknowledge

426   that although some barriers to developing a successful large-scale climate change education

427   program exist, significant social and political challenges exist with most large-scale solutions to

428   climate change.

429   5. Discussion: Application to K-12 educational environments

430   The above results describe the impact of an educational design on college students and the

431   potential impact of scaling such a program across a large number of secondary school age

432   students. We now discuss some initial work by the authors to develop K-12 curriculum that uses

433   some of the design approaches identified in the COMM 168 class.

434   Within K-12 education, national and regional standards play an important role in guiding the

435   design of classroom learning experiences. In the U.S., the National Research Council of the

20

436   National Academy of Sciences helped develop an evidence-based framework for teaching

437   science that included contemporary research on the ways students learn science most effectively

438   (National Research Council 2012). As a result of the framework, the Next Generation Science

439   Standards (NGSS) were released in 2013 as a state-led set of science standards that would be

440   adopted at the state level. At present, 19 states have adopted the NGSS (representing 36% of

441   students) and another 19 states have used the NRC Framework for K-12 Science Education in

442   developing their own standards (representing 29% of students). These standards offer a new way

443   of teaching science that emphasizes integrative learning across science fields and applies

444   knowledge to real-world contexts. Given our experiences in the COMM 168 class and the

445   guidelines presented in the NGSS, we saw an opportunity to teach the required science subjects

446   (i.e., life science, physical science, earth science and engineering design) using climate change

447   and environmental solutions as an overarching theme. Other research suggests that using

448   environmental subjects can promote student learning and higher-order thinking (e.g., Ruiz-

449   Gallardo et al. 2013; Dresner et al. 2014).

450   Over the last three years, the authors have been working to apply an educational model similar to

451   that used in COMM 168 to a middle school science curriculum. In particular, the design of the

452   curriculum emphasizes a) establishing a personal connection to students' lives, b) providing

453   students with opportunities to create change in their own communities and c) helping students

454   develop empathy for nature and the environment. The results of this curriculum design include

455   the creation of a student-relatable storyline (i.e., collection of videos and games featuring a

456   climate action superhero) and the focus on learning experiences that help students build a

457   personal connection to climate change through participation in experiences where students

458   design climate solutions for their communities. Each unit of science instruction has a focus on

21

459   solutions to an environmental problem, and a continuity of learning across a middle school

460   sequence is designed to potentially provide students with a strong connection to environmental

461   stewardship. The middle school curriculum is currently being used in a number of school

462   districts in California and studies examining changes in student attitudes and behavior will be

463   reported in the future.

464   As an example of the type of educational experiences being designed, we share some insights

465   from an ongoing study to determine whether student motivation and agency around science and

466   environmental solutions can be enhanced through a storytelling and filmmaking experience.

467   During one of the five-week units of study, middle school students learn about the basics of

468   climate science and are guided through the process of storytelling and filmmaking as a method of

469   taking action on climate change. Students create their own short films about solutions to climate

470   change, and these films are screened to friends, family and submitted to a regional film festival.

471   Overwhelmingly, students, teachers and parents reported that this unit of study was a valuable

472   learning experience. Students enjoyed the filmmaking experience and the autonomy they had to

473   create their own type of climate solution. This is reflected in student interviews indicating that

474   their favorite part was that "we had no limitations at all" and "we got to put our storyboard and

475   the ideas that we had into action." Further, several students reported that they were either

476   interested in the opportunity to do more community action, or that they were now taking on

477   leadership roles towards further action. During an interview, one student responded, "Actually,

478   um, after this project I'm, like, really considerate of what I'm using…what my family and I

479   could do to, like, reduce global warming." Given that most students reported that they did not

480   know much about climate change prior to this unit, this feedback suggests that such measures

481   applied in K-12 environments may be valuable tools for inspiring social change.

6. Conclusions

The potential role of education on individual carbon emissions was studied using five years of data from students who completed an intensive university course on climate change. Students were surveyed at least five years after having taken the course, and their responses were used to provide both qualitative and quantitative measures of the impact of the course on their attitudes and behavior regarding solutions to climate change. The university course was designed to be impactful, including various elements to engage students around personal and social activism. In open-ended feedback and the focus group interviews, students recounted how the class has changed their lives, both personally and professionally. Examples of personal changes included the type of car they drive and the type of food they eat. Examples of professional changes included how they create environmental benefits through their job. The results from the survey data also showed that the course was impactful, even many years later. Student behavior related to waste decisions, home energy decisions, transportation and food choices all showed significant behavior change that was attributed to the COMM 168 course, and these changes were quantified using a reputable online carbon emissions calculator. The carbon emissions for an average California resident are 25.1 tons/year, while the estimated reductions in carbon emissions from the COMM 168 graduates are 3.54 tons/year. It was found that the participants who had personally experienced the effects of global warming, or felt that global warming will harm them personally, had the largest reductions in carbon emissions.

This study suggests that the COMM 168 class provided at least two of the crucial factors that Hungerford and Volk (1990) identify as contributing to pro-environmental behavior: ownership variables and empowerment variables. Surveys and focus group interviews demonstrated that students in this course established in-depth knowledge of climate change and demonstrated

505   knowledge of how to act in the service of climate change mitigation. Surveys and focus group

506   interviews also revealed that graduates of the course feel a lasting personal connection to the

507   issue and have confidence in the success of their actions. This strong sense of personal obligation

508   and the perceived individual agency to address climate change suggests that education with an

509   emphasis on community engagement may provide a public benefit.

510   The potential to use education as a climate change mitigation measure would be valuable and in

511   line with other mitigation measures if such reductions as achieved in the COMM 168 course

512   could be achieved in other classrooms. We demonstrate this through comparisons with other

513   climate change solutions and show that at scale, climate change education can be as effective in

514   reducing carbon emissions as other solutions such as rooftop solar or electric vehicles. The

515   notion that education is an important part of responding to climate change is not novel, and yet

516   rarely has it been quantified and measured. This paper sheds light on how such measurements

517   could be taken, and it offers a pedagogical insight for how to make education an effective

518   climate change mitigation strategy.

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578

579   Appendix A

580   Survey instrument used for the graduates of the COMM 168 class.

581

582   Intro: Thank you for agreeing to take our survey about the Global Climate Change Course
583   (COMM/ENVS/GEOL/HUM/METR 168—hereafter COMM 168). This is divided into two
584   sections: general information and post-course life.

585

586   General Questions:
587   1. What academic year did you enroll in COMM 168?
588   a. 2007-2008
589   b. 2008-2009
590   c. 2009-2010
591   d. 2010-2011
592   e. 2011-2012

593

594   2. What is/was your major?

595

596   3. When did you graduate from SJSU?
597   a. Spring 2008
598   b. Fall 2008
599   c. Spring 2009
600   d. Fall 2009
601   e. Spring 2010
602   f. Fall 2010
603   g. Spring 2011
604   h. Fall 2011
605   i. Spring 2012
606   j. Currently enrolled

607

608   4. How much do you think global warming will harm future generations?
609   a. Not at all
610   b. Only a little
611   c. A moderate amount
612   d. A great deal
613   e. Don't know

614

615   5. How much do you think global warming will harm you personally?

616

617   a. Not at all
618   b. Only a little
619   c. A moderate amount
620   d. A great deal

27

621   e.   Don't know

622

623   6.   Which of the following statements comes closest to your view?

624   a.   Global warming is not happening.

625   b.   Humans cannot reduce global warming, even if it is happening.

626   c.   Humans could reduce global warming, but people are not willing to change their

627   behavior, so we are not going to.

628   d.   Humans could reduce global warming, but it is unclear at this point, whether we

629   will do what is needed.

630   e.   Humans can reduce global warming, and we are going to do so successfully.

631

632   7.   Rate your opinion of the following statement: The actions of a single individual will not

633   make any difference in global warming.

634   a.   Strongly agree

635   b.   Somewhat agree

636   c.   Neutral

637   d.   Somewhat disagree

638   e.   Strongly disagree

639

640   8.   Rate your opinion of the following statement: New technologies can solve global

641   warming, without individuals having to make big changes in their lives.

642   a.   Strongly agree

643   b.   Somewhat agree

644   c.   Neutral

645   d.   Somewhat disagree

646   e.   Strongly disagree

647

648   9.   Which comes closer to your own view?

649   a.   Most scientists think global warming is happening.

650   b.   Most scientists think global warming is not happening.

651   c.   There is a lot of disagreement among scientists about whether or not global

652   warming is happening.

653   d.   Don't know enough to say.

654

655   10. How much do you agree or disagree with the following statement: "I have personally

656   experienced the effects of global warming."

657   a.   Strongly agree

658   b.   Somewhat agree

659   c.   Neutral

660   d.   Somewhat disagree

661   e.   Strongly disagree

662

663   11. How many of your friends share your views on global warming?

664   a.   None

28

665   b. A few

666

667   12. I personally recommended COMM 168 to other students

668   a. True

669   b. False

670   The following questions relate to your participation in COMM 168: Global Climate Change at

671   San José University, and if this course has affected any of your actions or decisions since

672   you took the course.

673   13. As a result of my participation in this course, I have taken the following actions to reduce

674   the amount of waste produced in my home. (Check all that apply):

675

676   ☐ Recycle more often

677   ☐ Buy products that have less packaging

678   ☐ Compost food scraps or food waste

679   ☐ Give away or donate products so that they can be reused

680   ☐ Other:

681   ☐ The course didn't have an influence on these actions

682

683   14. As a result of my participation in this course, I have taken the following actions to reduce

684   energy consumption at home (Check all that apply):

685

686   ☐ Purchased renewable energy from utilities

687   ☐ Purchased energy saving appliances

688   ☐ Installed solar P V

689   ☐ Installed solar hot water

690   ☐ Changed traditional light bulbs to energy-efficient light bulbs

691   ☐ Other:

692   ☐ The course had no influence on my home energy use

693

694   15. As a result of my participation in this course, over the course of a week, I make food

695   choices to reduce carbon emissions

696   a. All the time

697   b. Often

698   c. Sometimes

699   d. Occasionally

700   e. The course had no influence on my food choices

701

702   16. As a result of my participation in this course, I have made the following changes to my

703   transportation methods (Check all that apply):

704   ☐ Purchased a hybrid car

705   ☐ Carpool regularly

706   ☐ Purchased a more gas-efficient car

707   ☐ Used public transportation more often

708   ☐   Used a bicycle instead of a car as transportation method
709   ☐   The course didn't have an influence on my transportation methods
710
711   17. As a result of my participation in this course, I purchase carbon offsets when I fly.
712   a.   All the time
713   b.   Often
714   c.   Sometimes
715   d.   Occasionally
716   e.   Never
717   f.   The course had no influence on my purchase of carbon offsets
718
719   18. Was there any other situation when you remember how particular content of the class
720   influenced a decision(s) in your life? Explain.
721

722   Appendix B

723   Estimating reductions in carbon emissions from the survey responses.

724   The procedure used to estimate the impact of various behaviors on carbon emissions is described

725   here. In the survey, participants described particular actions they have taken as a result of taking

726   the COMM 168 class. We use an online carbon footprint calculator to estimate how those actions

727   change an individual's annual carbon emissions. The carbon footprint calculator we use was

728   developed by the CoolClimate Network: a partnership between government, business, NGOs and

729   universities including the University of California, Berkeley. This tool is supported and endorsed

730   by the California Air Resources Board (Jones and Kammen 2011).

731   The CoolClimate Calculator is publicly available (http://coolclimate.berkeley.edu/calculator) and

732   has been used in a number of studies (e.g., Shirley et al. 2012). The categories of questions to

733   estimate the household carbon emissions include travel, home, food, goods and services. As

734   shown in Figure B1, each of these categories includes subsections that include additional

735   questions that allow for more accurate estimates of carbon emissions for each category. The

736   calculator makes various assumptions based on user responses, but it also allows for more

737   detailed responses through an advanced section. For example, in the housing section, the

738   advanced section allows the user to enter detailed information about the building design (e.g.,

739   area and type of insulation including windows) and the type of appliances and heating/cooling

740   systems, versus the regular analysis that estimates carbon emissions based on how much energy

741   an average household uses.

742   **Figure B1 Screen shot from the CoolClimate calculator developed in part by the California Air**
743   **Resources Board (www.coolcalifornia.org).**

31

744   The following procedure is used to estimate the reductions in carbon emissions due to specific

745   actions. We start by selecting one person with an average annual household income for the state

746   of California. Given the internal assumptions based on the categories of travel, home, food,

747   goods and services, the annual carbon emissions are 25.1 tons of CO2/year for the individual.

748   We then select the 'Take Action' section, where changes in individual actions together with the

749   underlying assumptions can be made for a number of categories. We use this section to match

750   the responses from the COMM 168 participants with reductions of carbon emissions, using a set

751   of assumptions that are shown in Table A1. Each assumption comes from the CoolClimate

752   calculator and provides an estimate of how a particular action would reduce annual carbon

753   emissions. For example, one of the survey questions asks if the participant purchased renewable

754   energy from their utility. The CoolClimate calculator assumes the household uses 4,396 kWh of

755   electricity/year, which produces 1.36 tons of CO_2. We assume that participants who answer 'yes'

756   to the question about purchasing renewable energy from their utility would get 100% of their

757   electricity from clean energy and thus would save 1.36 tons of CO_2/year. In another example, for

758   the question about purchasing a more efficient vehicle, the calculator assumes that the individual

759   would trade in a 22 mpg vehicle for a 32 mpg vehicle, and after driving 13,100 miles/year, they

760   would save 2.08 tons of CO_2/year. Each of the question responses and associated assumptions

761   are given in Table B1.

| Question Response	CO_2 reduction (tons/year)	Assumptions used in CoolClimate calculator
Buy renewable energy	1.36	100% electricity from renewables
Buy energy star appliances	0.04	Energy star fridge or other products

Install solar panels	0.68	50% electricity from renewables
Install solar hot water	0.4	50% of heating of water from solar hot water
Change light bulbs	0.16	5 bulbs used 5 hours per day
Buy hybrid/electric car	4.22	average of hybrids (40 mpg*2/3) + electric vehicles (99 mpg*1/3)) = 59.67 mpg
Recycle more often, buy products with less packaging, compost food scraps, give away/donate products	0.42	Reduce waste by 25% for each action
Carpool regularly	0.85	3 times/week
Buy more fuel efficient vehicle	2.08	32 mpg vs. 22 mpg for 13,100 miles/yr.
Use public transit more	0.42	20 miles/week in bus instead of 22 mpg in car
Use bike for transportation	0.53	20 miles/week instead of 22 mpg in car
Make food choices to reduce emissions	0.69	Response of 'all the time' or 'often' is default setting for 'low carbon version of American diet' (0.69 tons/year). Response of 'sometimes' or 'occasionally' is a reduction of 0.46 tons/year through increase in meat consumption from 244 calories (default) to 353 calories.
Buy carbon offsets for flying	0.93	Response of 'all the time' or 'often' is 80% of flights purchased offsets (0.93 tons/yr.). Response of 'sometimes' or 'occasionally' is 40% of flights purchased offsets (0.46 tons/yr.).

762 **Table B1. Description of the assumptions and reductions in carbon emissions for each of**
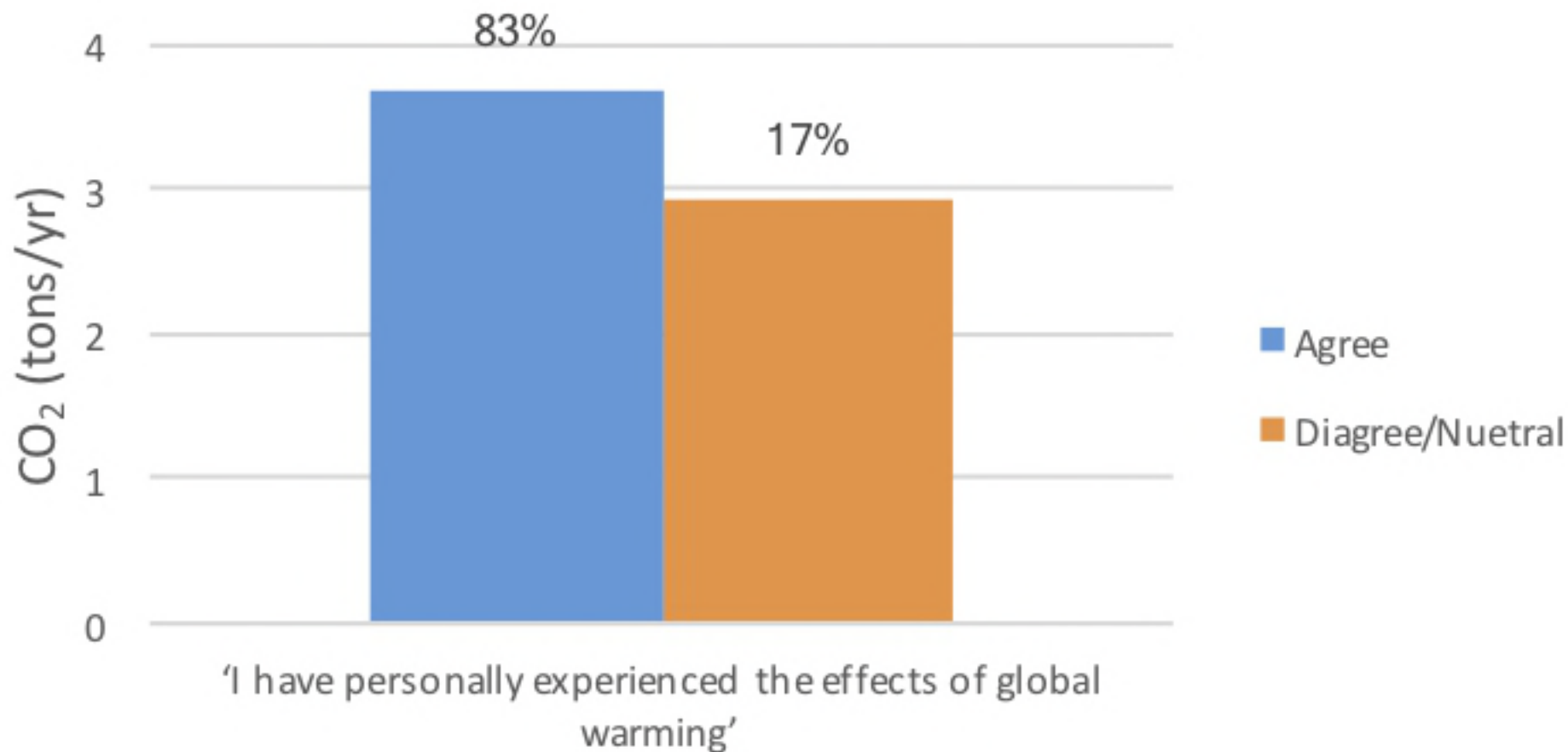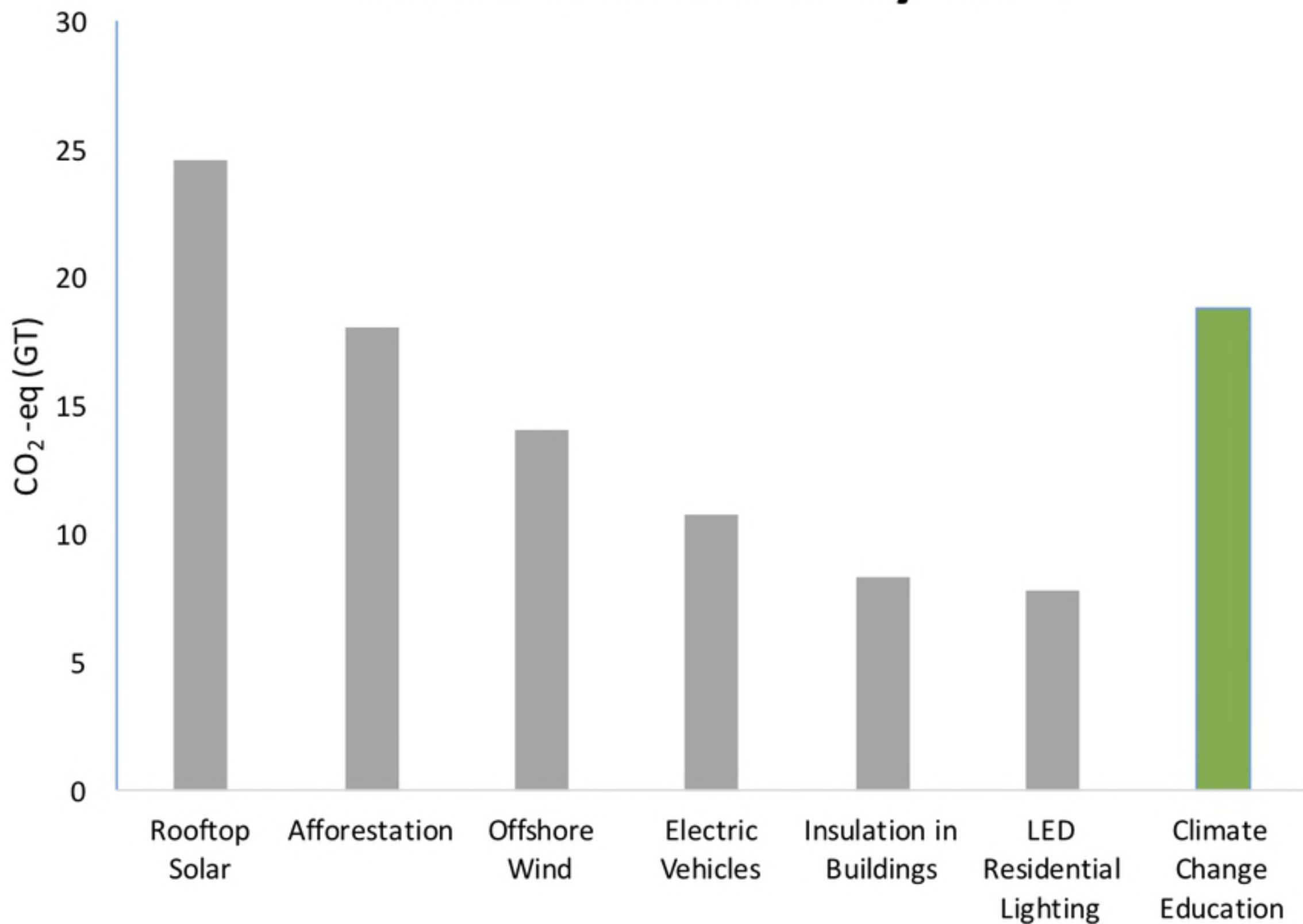763 **the survey responses.**

33
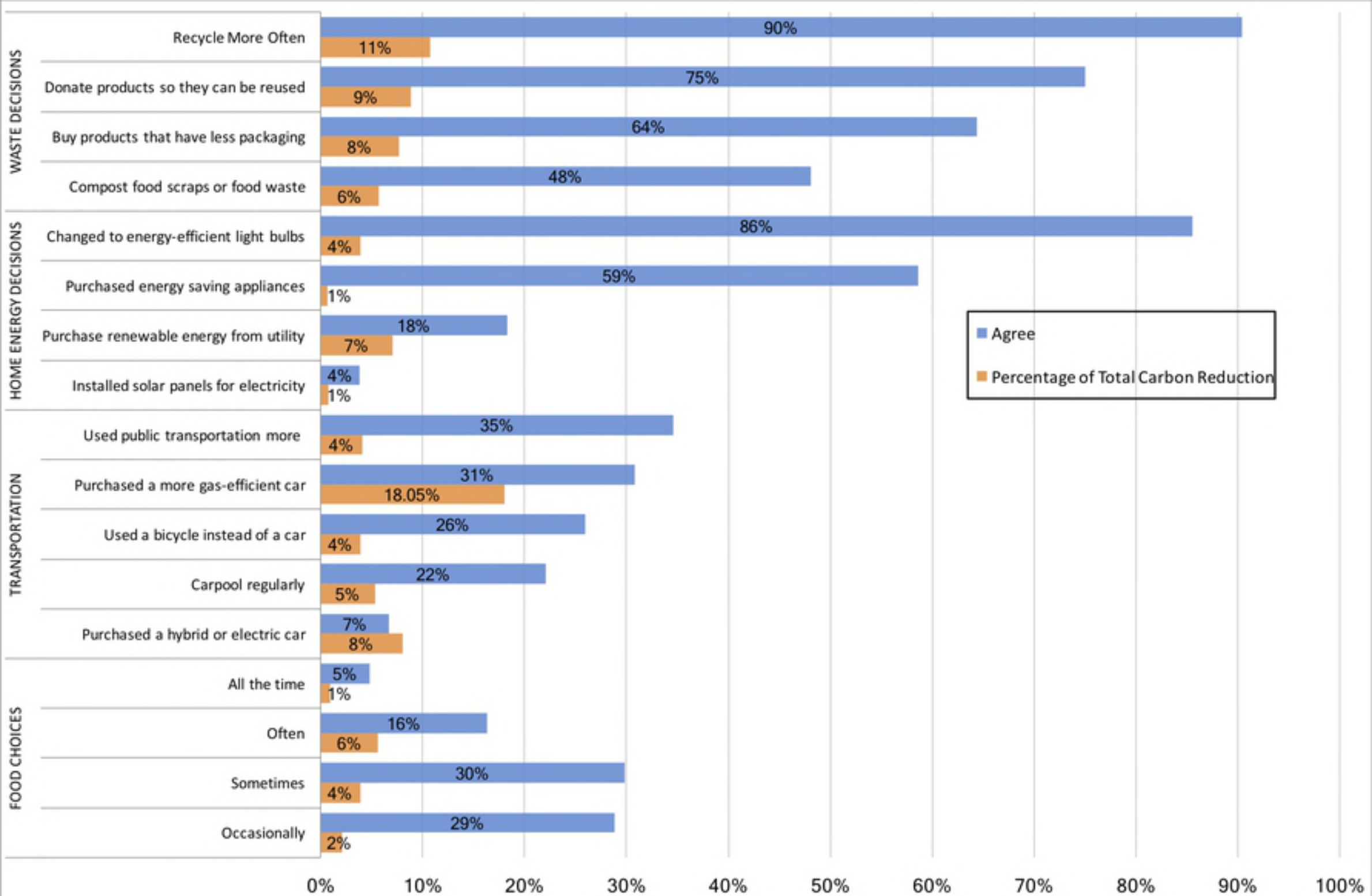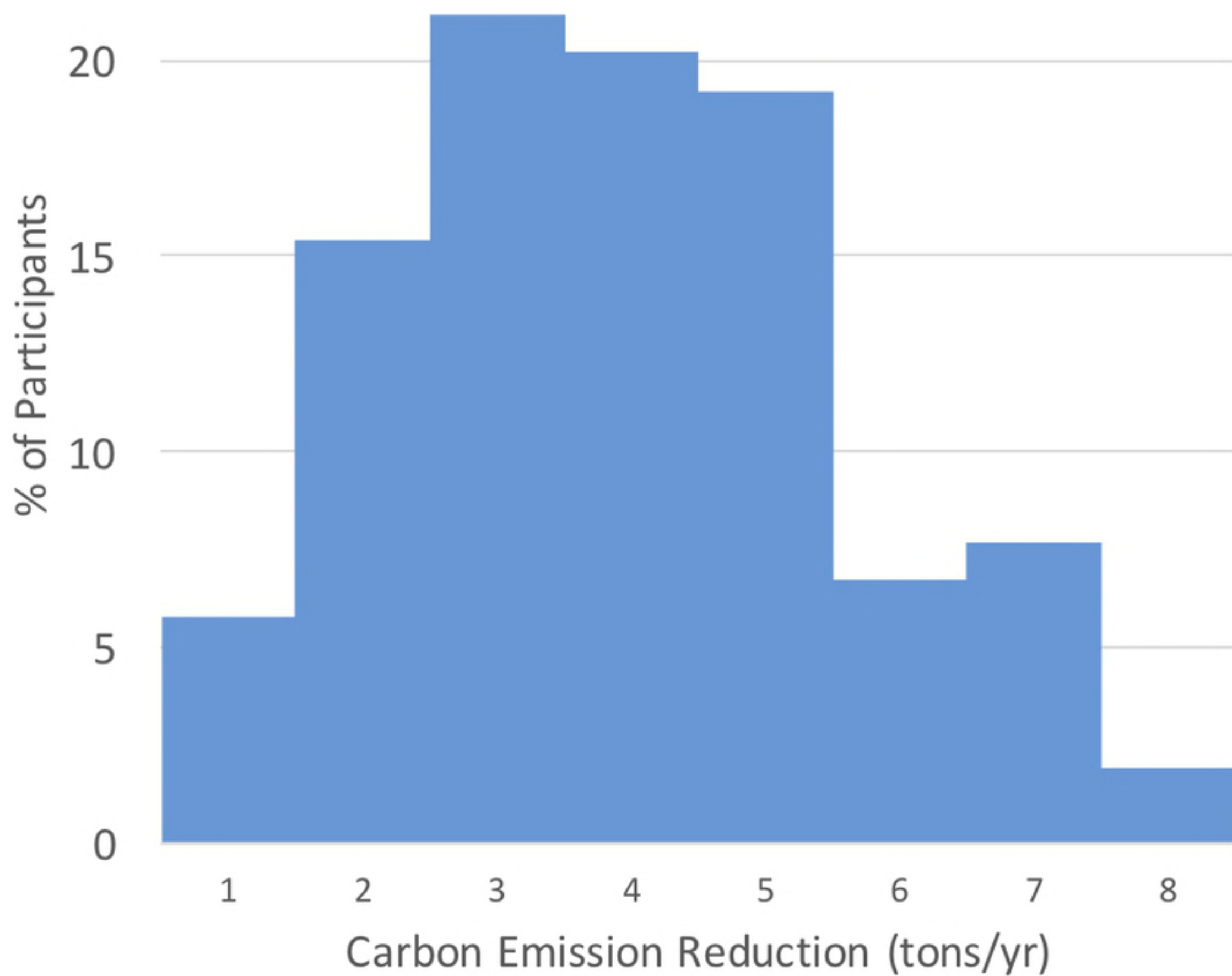
How much do you think global warming will harm...
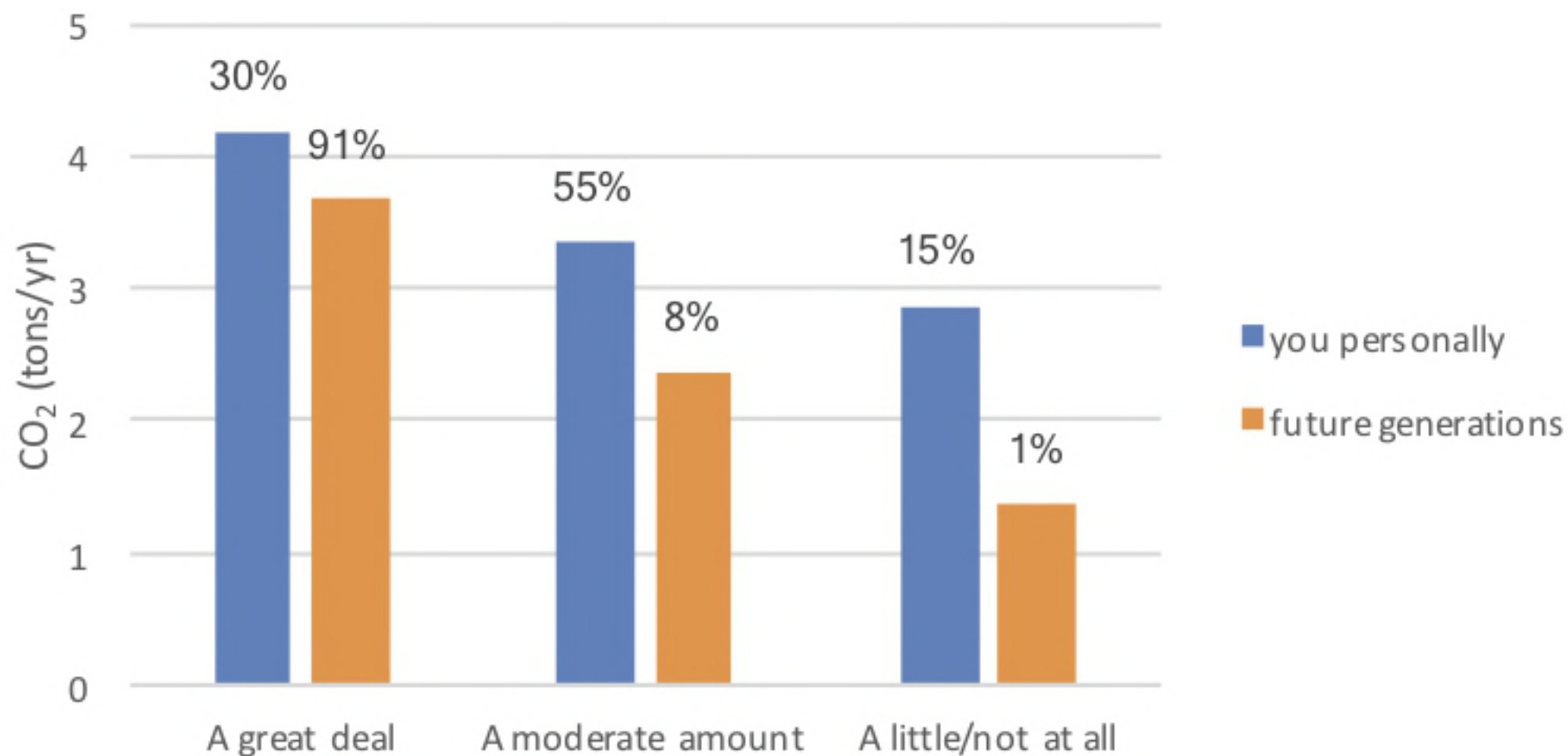
Reductions in Carbon Emissions

Carbon Reduction by 2050

Start with a quick carbon footprint estimate

Next

Zipcode | City | County | **State**

California (CA), United States

How Many people live in your household?
One

What is your gross annual household income?
Average

California

Total

25.1
tons CO_2/year

The footprint of the average household in California with one person and similar income.

Metric tons CO2/year

- Travel: Air Travel, Car Fuel
- Home: Construction, Natural Gas, Electricity
- Food: Meat
- Goods: Other Goods, Furniture, Clothing
- Services: Services

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