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16. Abstract

An online survey of driver opinion was conducted to determine how receptive drivers would be to in-vehicle technologies that reduce carbon emissions. In particular, the survey was designed to help understand whether drivers considered such technology attractive and, if so, what level of cost would be acceptable to adopt this technology. Cost was evaluated in three dimensions: initial monetary cost, reduction in fuel economy, and reduction in available cargo space. The analysis was based on 536 useable surveys.

Among the surveyed drivers, acceptability of carbon-capture technology depended on driver belief that human activity is associated with global warming. Drivers that reported agreement with such statements were found to be more accepting of in-vehicle carbon capture technology: they were generally willing to pay more for this technology or to trade storage space and fuel economy for such technology.

Overall, respondents appeared to be willing to pay about $100 for a 20% reduction in carbon dioxide emissions and $250 for an 80% reduction; they also appeared to accept about a 5% reduction in fuel economy for a 20% reduction in carbon dioxide emissions, and a 10% reduction in fuel economy for a 80% reduction; and finally, they appeared willing to accept about a 10% loss in trunk space for a 20% reduction in emissions, and a 16% loss in trunk space for an 80% reduction in emissions.

17. Key Words	18. Distribution Statement
Carbon capture, consumer opinion, in-vehicle carbon capture	Unlimited

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Introduction

In an effort to reduce greenhouse-gas emissions resulting from combustion, various methods are under development to capture and store these gases before they enter the atmosphere. While most of these efforts are directed at containing the carbon-dioxide emissions from large-scale stationary producers like coal-fired powerplants or other industrial sources (Forbes et al., 2008), there has also been some interest in considering the feasibility of carbon capture from small distributed power plants, like the gasoline-fueled internal-combustion engines ubiquitous in transportation (Damm & Fedorov, 2008).

In a previous report, some factors that might affect driver acceptance of in-vehicle carbon capture were discussed (Sullivan & Sivak, 2012). These factors included the added initial cost of the technology, the probable on-board storage required, possible impact on fuel economy, as well as changes in the routine tasks involved in vehicle upkeep. To obtain a better understanding of how the driving public views some of these issues, a survey was developed to directly probe drivers on several of these issues.

Survey Construction

The survey consisted of three parts. The first part was designed to obtain basic demographic information about drivers that might serve to explain answers to specific questions about new technologies used to mitigate vehicle emissions. Along with age, gender, and education level, drivers were also asked questions to characterize their broad driving situation. They were asked about the size of the vehicle they routinely drive, that vehicle's power source (full electric, hybrid, or internal-combustion engine), the miles of driving done in a week, and the number of times a trip of more than 500 miles is taken each year. The second part of the survey was used to appraise each respondent's understanding of the degree to which transportation contributes to the total carbon emissions in the United States. This involved asking the driver to estimate the percentage of carbon emissions that transportation contributes to all carbon emissions from human activity, as well as the degree to which the respondent believes that carbon-dioxide emissions may contribute to global warming. In the third part of the survey, respondents were first advised that after combustion, one pound of gasoline would produce about three pounds of carbon dioxide, based on EPA estimates (United States Environmental Protection Agency, 2011). This was followed up by four questions that requested drivers to estimate:

1. The maximum amount of money the driver would pay for in-vehicle carbon-capture capability.
2. The maximum acceptable reduction in fuel economy (in percent).
3. The maximum acceptable amount of available storage space (in percent) that could be reserved for carbon-dioxide storage.
4. Whether they would prefer a vehicle equipped with carbon capture over an electric or hybrid vehicle.

For these latter four questions, drivers were asked to make these judgments based on two hypothetical carbon-capture systems with two different performance capabilities: a carbon-capture system that could capture either 20% of CO_2 emissions or 80% of CO_2 emissions. A copy of the survey is provided in the Appendix.

Method

The survey instrument was constructed as an on-line series of forms presented through a web browser and hosted by the SurveyMonkey survey-hosting service (www.surveymonkey.com). Respondents were obtained through email-based solicitations selected from SurveyMonkey's estimated 30-million-person recruitment base. Prospective respondents were randomly selected and sent a web-based link to a survey through an email solicitation. In return for completing a survey, respondents were rewarded with charitable donations to selected organizations.

The present study aimed to collect about 500 completed surveys. The total number of completed surveys received was 574. From this sample, surveys were discarded in which the respondent made illogical responses, suggesting that the question was possibly misunderstood. This was primarily based on questions that asked subjects to determine the comparative value of a carbon-capture system that offered 20% carbon-dioxide capture versus 80% carbon-dioxide capture. If respondents valued the lesser-performing capture system greater than the better-performing capture system, the respondent's survey was removed from the sample. Similarly, this was also done for questions about acceptable loss in fuel economy and storage space—if a greater loss in fuel economy or greater loss in storage space was associated with the 20% capture system, compared with the 80% capture system, the respondent's survey was discarded. Thus vetted, there were 536 completed surveys remaining in the sample.

Results

The results are covered in three broad themes. First, the pool of respondents is characterized with regard to demographics and driving habits. Following this, respondents' opinions about global warming and transportation are reviewed and examined for demographic-related patterns. Finally, respondents' judgment of the value and acceptability of carbon-capture technologies are presented.

Driver Characteristics

Male respondents outnumbered female respondents (310 male; 226 female; Figure 1). The distribution by age group peaked in the 45-60 age group (171) while the other age groups seemed more evenly represented (18-29 years = 120; 30-44 years = 126; > 60 years = 115; see Figure 2). An exception to this was the four respondents reporting their age as below 18 years. In general, all respondents were expected to be the owner of the email account and over 18 years of age. However, it is clear that the identity of the respondent may not always be the actual owner of the email account, and could perhaps be other family members. Instead of relying on the demographic data associated with the email account, age, gender and education-level data presented in this report are based on responses to questions directly embedded in the survey.

As can be seen in the mosaic plot (see Figure 3), male respondents dominated the gender breakdown across age groups with the exception of the 30-44-year age range, in which female respondents dominated the sample. Level of education appeared to be more homogeneously distributed across male and female respondents, with more than half of each group reporting at least some college ($\chi^2 = 6.5$, $p = 0.25$; see Figure 4). Male and female respondents differed in the types of vehicles they tended to drive. Female respondents tended to drive more compact vehicles, while male drivers tended to drive more pickup trucks ($\chi^2 = 17.7$, $p = 0.006$; see Figure 5). Similarly, there was also variation in the vehicle distributions by age group, shown in Figure 6. Younger drivers tended to drive more compact vehicles, while middle-aged and older drivers tended to drive more SUVs ($\chi^2 = 34.6$, $p = 0.0105$).

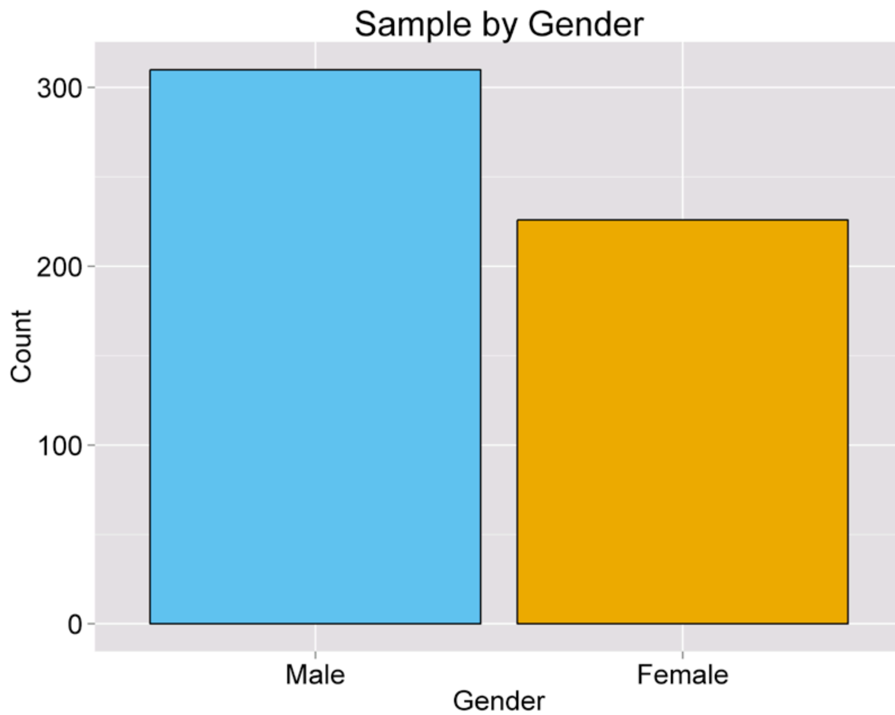

Figure 1. Number of respondents by gender.

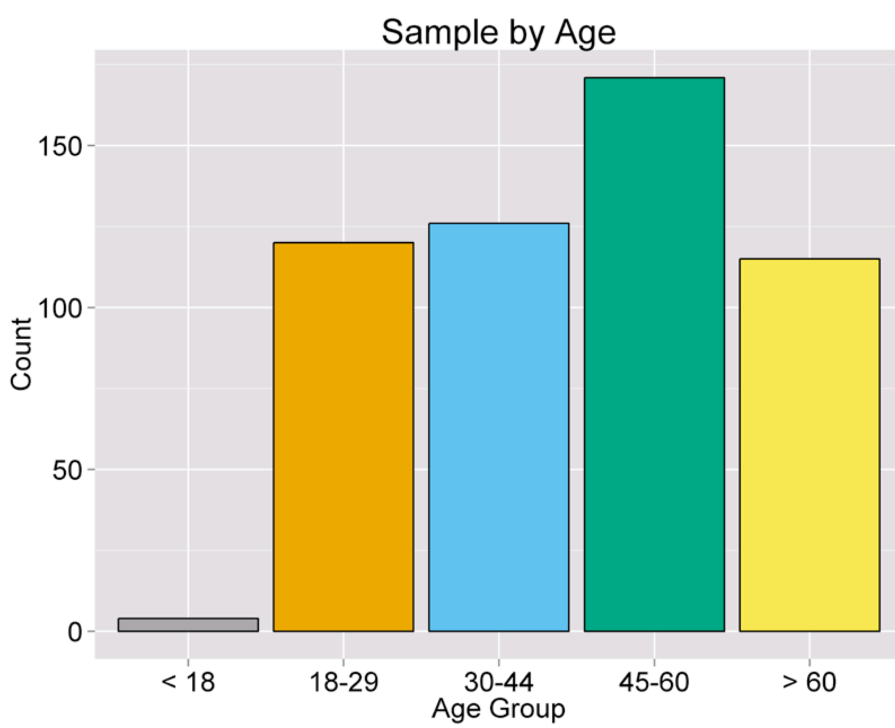

Figure 2. Number of respondents by age group.

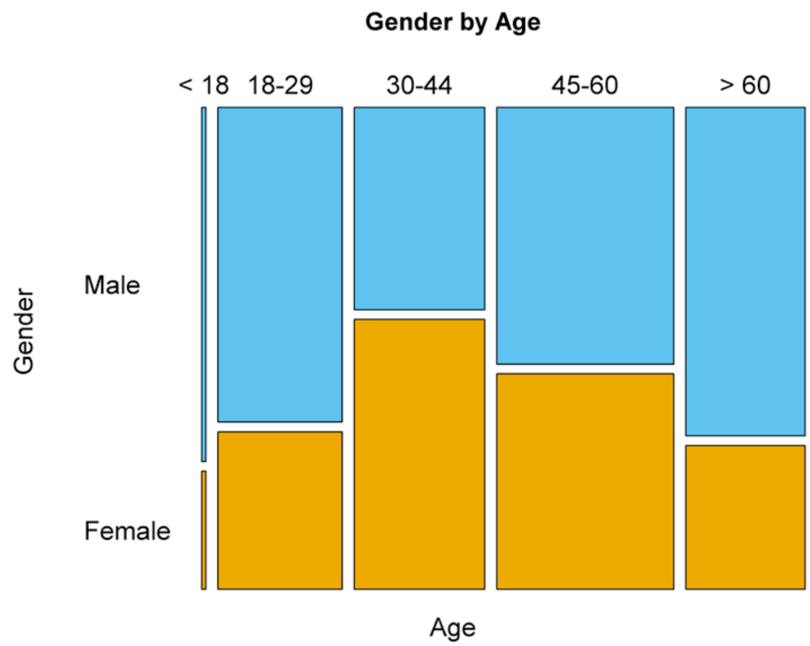

Figure 3. Distribution of gender among respondents across age groups.

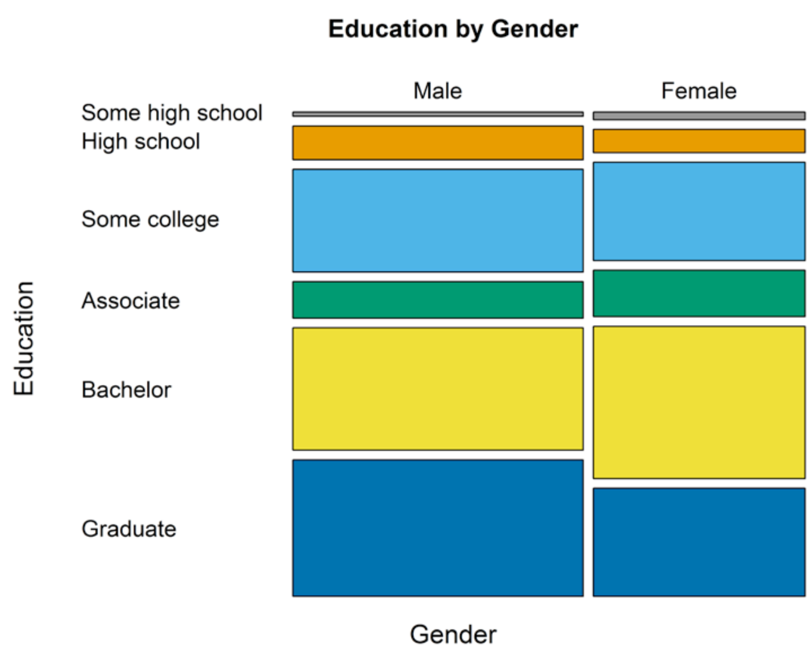

Figure 4. Distribution of education level among respondents across gender.

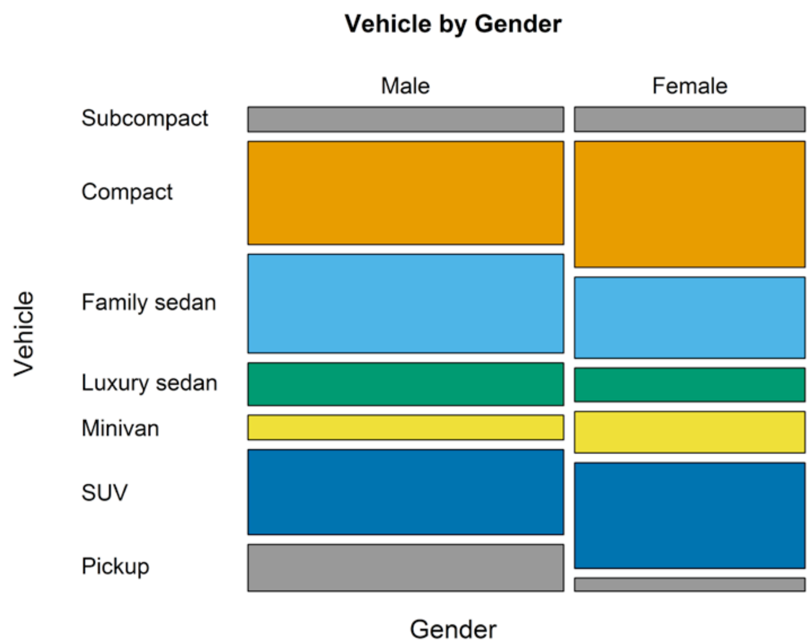

Figure 5. Distribution of vehicle type among male and female respondents.

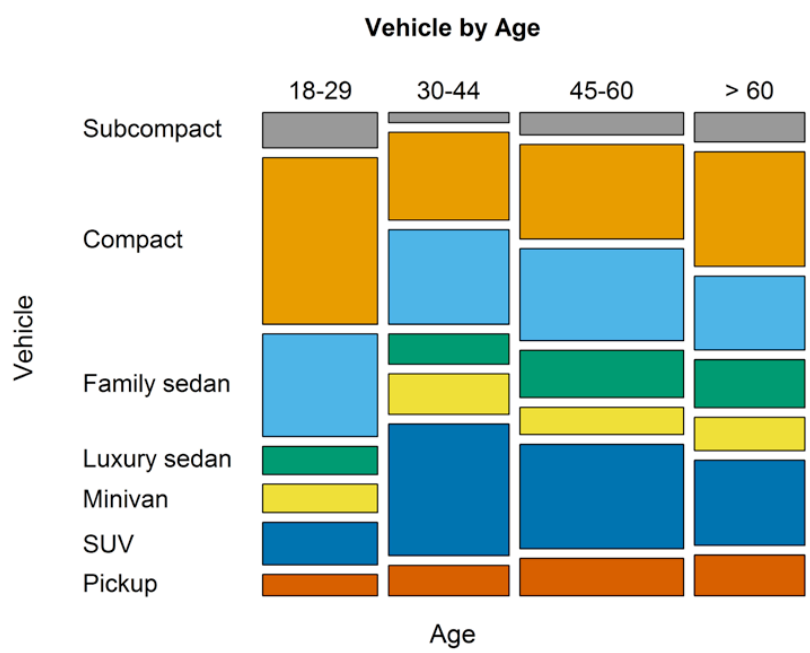

Figure 6. Distribution of vehicle types across respondents by age in the sample. (Respondents below 18 years are excluded from the plot.)

Driving Patterns

Self-reported weekly driving among respondents is shown in Figure 7. It was of some interest to determine whether respondents' attitudes about the value of carbon dioxide might be related to their weekly travel mileage. (For example, are drivers who drive fewer miles per week more or less receptive to the use of carbon-capture technology?) Most drivers' weekly mileage was between 20 and 250 miles. Driving mileage was further broken down by driver age to determine whether the distribution of mileage systematically differed among drivers by age. Overall, the variation in the mileage distributions is not large enough to suggest that distribution of miles driven differed across age groups ($\chi^2 = 6.5$, $p = 0.09$).

Long-trip driving habits were also investigated by asking drivers how often per year they took trips greater than 500 miles in length. The rationale for this question was to identify a segment of the respondents for whom vehicle storage might be an important consideration. It is expected that on lengthy trips, drivers are more likely to require storage for luggage than they are on shorter trips and possibly place a greater value on storage than drivers who mostly take short trips. The distribution of the annual frequency of 500-mile trips is shown in Figure 8. Further disaggregation of this distribution found no systematic differences by driver age group ($\chi^2 = 14.7$, $p = 0.25$), or driver gender ($\chi^2 = 22.5$, $p = 0.15$).

Drivers were also asked how their principal vehicle was powered. Among the respondents, 94% (505) of drivers reported driving internal-combustion-engine vehicles, while 4% (22) reported driving hybrid electric vehicles, and 1.7% (9) reported driving fully electric vehicles.

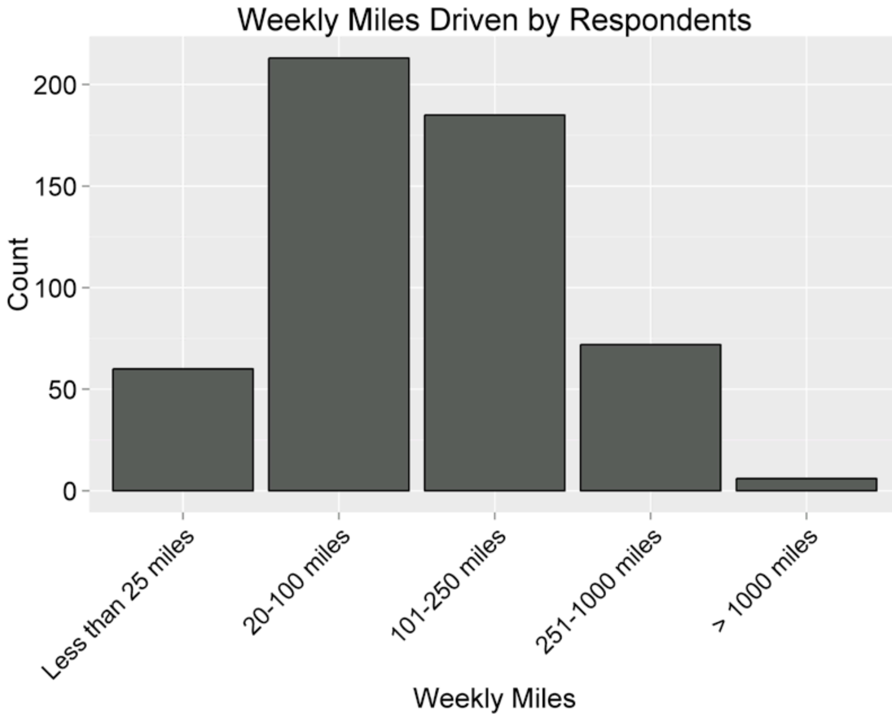

Figure 7. Distribution of driving miles among respondents.

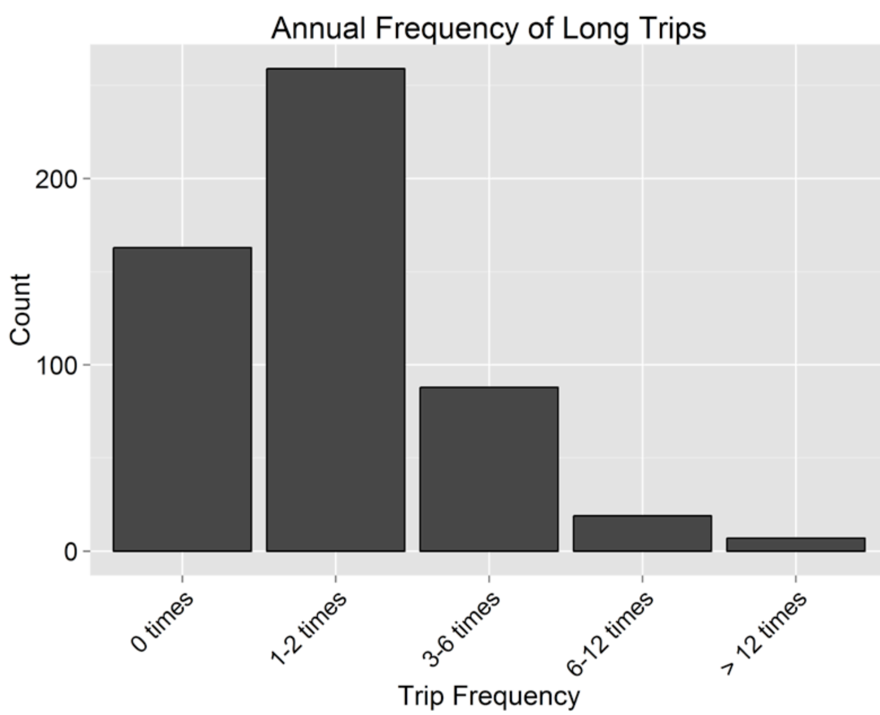

Figure 8. Distribution of trip frequency among respondents.

Respondents Views on Transportation and Carbon Emissions

Respondents were asked two questions about carbon emissions in the survey. The first question was intended to gauge their basic understanding about the role transportation plays in contributing to greenhouse-gas emissions. In general, few respondents appeared to know the approximate answer to the question (which is about 28%). Instead, they appeared to use a strategy of selecting numbers offset from the 50% point (see Figure 9).

Judgments of the veracity of the statement linking CO2 emissions from human activity to global warming showed that 67% of respondents believed the statement was either definitely true or probably true, while 18% respondents thought the statement was probably or definitely not true (shown in Figure 10). If the respondent's estimate of the contribution of transportation to overall carbon-dioxide emissions is disaggregated from the sample by belief, it is clear that beliefs about global warming appear to influence estimates about transportation's contribution (see Figure 11). There is a systematic trend for an increasing estimate with increasing belief that carbon dioxide from human active is related to global warning.

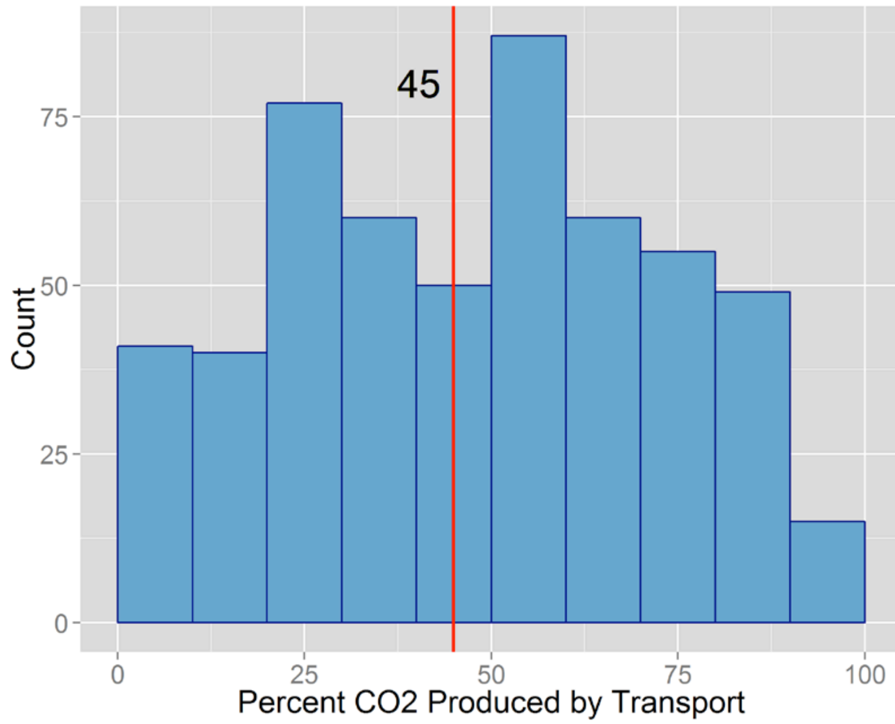

Figure 9. Distribution of respondents estimates of the percentage of CO2 produced by transportation. The red line identifies the mean of the distribution.

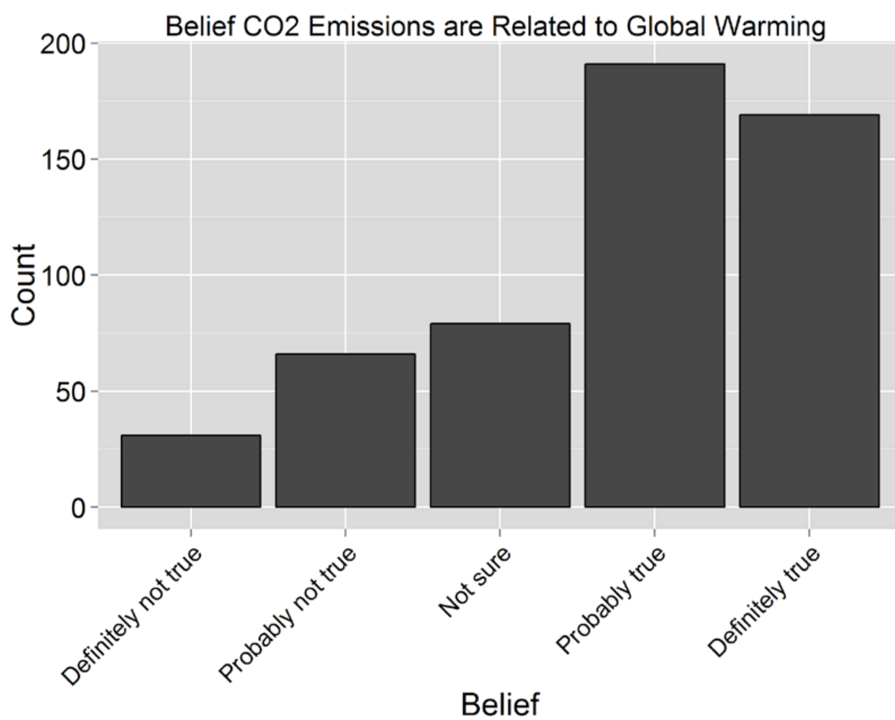

Figure 10. Respondents' opinions about the truthfulness of the statement that CO2 emissions from human activity are related to global warming.

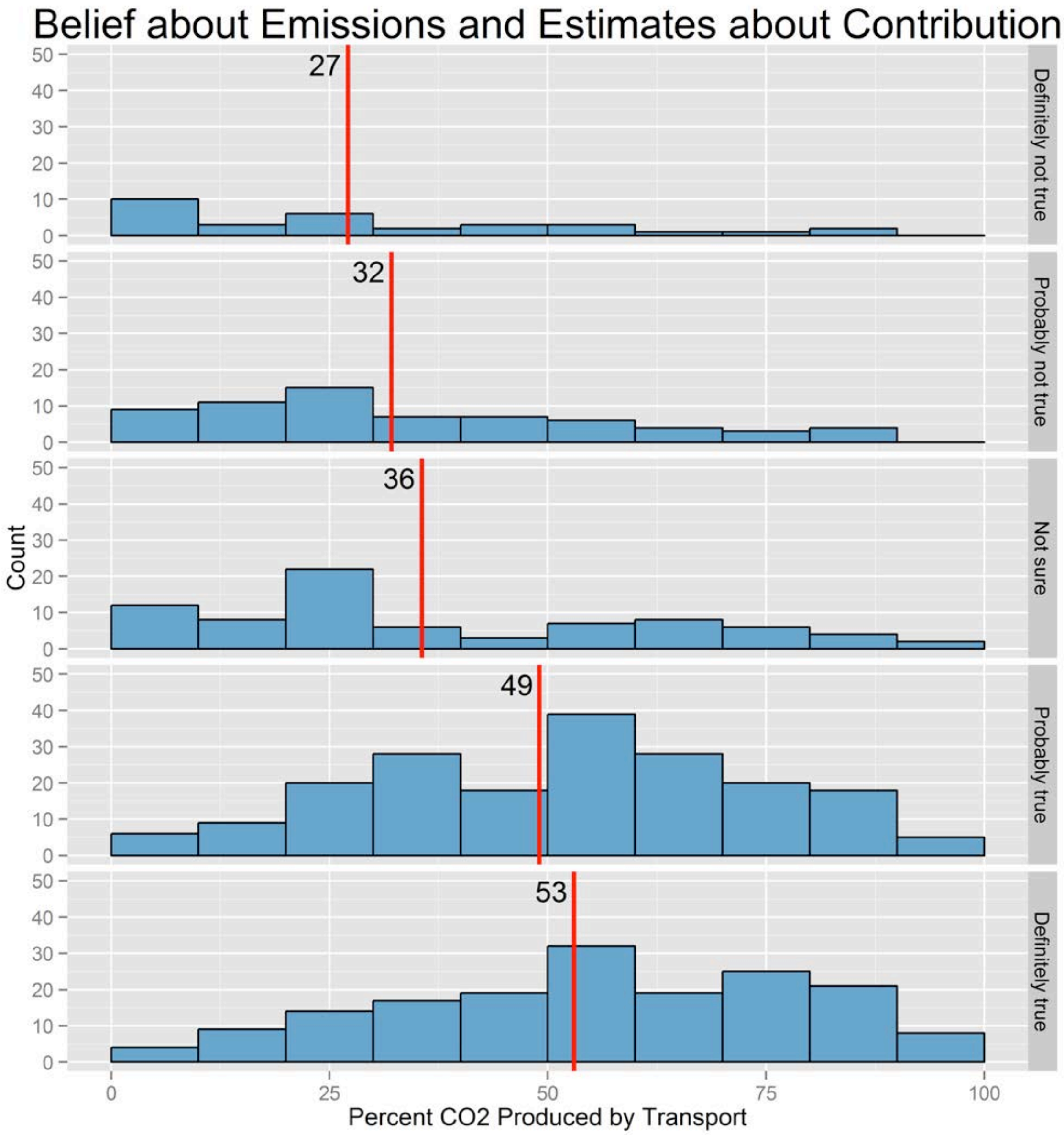

Figure 11. Judged contribution from transportation to the overall CO2 emissions by degree of belief in the association of CO2 emissions from human activity and global warming. The red lines identify the mean of the distribution.

Driver Valuation of In-Vehicle Carbon Capture

The next series of analyses review respondents' answers to questions about the amount of money, and amount of loss in fuel economy and storage space that would be acceptable for vehicles equipped with two different hypothetical carbon-capture systems—one that is capable of capturing 20% of all carbon emissions, and another that is capable of capturing 80% of all carbon emissions. We note that a segment of the respondents were dubious about the need for such a capture system and were not inclined to offer any concessions in exchange for such a system. Consequently, we provide two summaries of the valuation data: one that includes all data and another that includes only data where a non-zero answer was given to the question about the amount of money a respondent would pay for carbon-capture capability. These data will be presented in boxplots which depict the median (center horizontal bar), the 25^{th}-75^{th} percentile range (the filled areas above and below the median bar), and a whisker that stretches to the lowest and highest datum within 1.5 times the interquartile range. Where there is no overlap between the notches along the sides of two boxplots, the two medians differ significantly from each other.

Monetary value of CO2 capture capability

In this question, respondents were asked to estimate the maximum amount of money that they would pay for a carbon-capture system in their vehicle. The response distributions to the question exhibited long tails and are best reported as medians. These distributions are shown in Figure 12. The boxplots on the left include all data; those on the right include only the nonzero response data. Within each of the groups, responses for systems that provide 20% and 80% capture are shown. Respondents were willing to pay about $100 for a system that captured 20% of carbon dioxide emissions, and $250 for one that captured 80%. (This summary and the summaries to follow are based on all data.) Detailed breakdowns of estimates by respondent subgroups are provided in Table 1. Based on these breakdowns, the most systematic variation can be seen for the data based on belief about global warming.

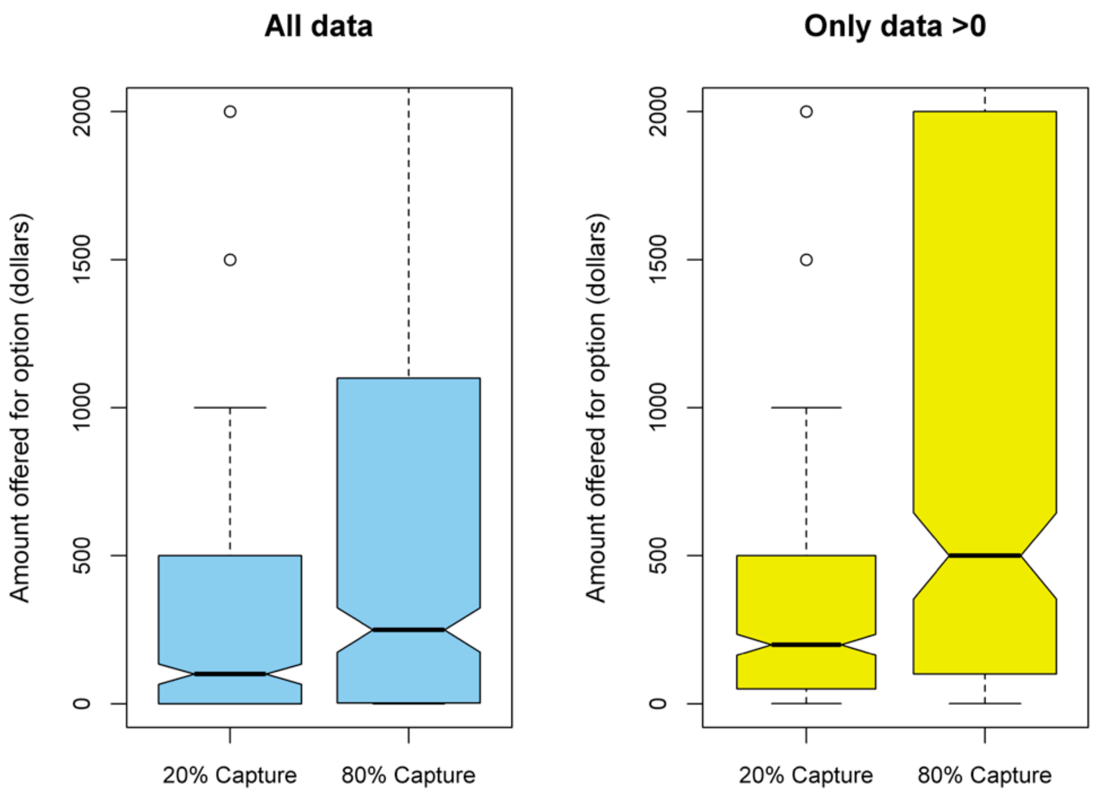

Figure 12. Boxplots showing approximate distribution of respondents' estimate of an acceptable maximum amount to pay for in-vehicle carbon capture.

Table 1.
Dollars respondents are willing to pay to capture CO2 emissions.
All respondents and respondents disaggregated by group.
(The entries in parentheses are based on cases with nonzero responses only.)

	Respondents and grouping (N)	20% reduction of CO2		80% reduction of CO2	
		50th percentile	75th percentile	50th percentile	75th percentile
	ALL (536)	100 (200)	500 (500)	250 (500)	1150 (2000)
Vehicle Type	subcompact (31)	200 (500)	500 (1000)	750 (1000)	2000 (2000)
	compact (144)	100 (100)	462 (500)	200 (500)	1000 (2000)
	family sedan (117)	100 (200)	500 (500)	500 (500)	2000 (2000)
	luxury sedan (50)	18 (100)	312 (750)	78 (500)	1000 (2000)
	SUV (122)	100 (200)	500 (1000)	225 (500)	1500 (2000)
	minivan (42)	100 (200)	500 (500)	450 (500)	1125 (1750)
	pickup (44)	35 (200)	200 (500)	100 (500)	500 (1000)
Power Type	internal combustion (505)	100 (175)	500 (500)	200 (500)	1000 (2000)
	hybrids (22)	300 (500)	625 (1000)	875 (1000)	3000 (3000)
	fully electric (9)	20 (275)	- -	80 (1000)	- -
Weekly Miles	<25 miles per week (60)	30 (100)	475 (500)	100 (500)	1375 (2000)
	25-100 miles per week (213)	100 (200)	500 (1000)	300 (500)	1500 (2000)
	101-250 miles per week (185)	100 (150)	500 (625)	200 (500)	1000 (2000)
	251-1,000 miles per week (72)	100 (350)	500 (1000)	500 (750)	1425 (2000)
	>1,000 miles per week (6)	150 (200)	- -	500 (500)	- -
Annual Trips	0 trips >500 miles (163)	100 (100)	500 (500)	200 (500)	1000 (2000)
	1-2 trips >500 miles (259)	100 (200)	500 (875)	250 (500)	1000 (2000)
	3-6 trips >500 miles (88)	100 (200)	500 (500)	300 (500)	1150 (2000)
	7-12 trips >500 miles (19)	50 (400)	1000 (1500)	500 (900)	3000 (6000)
	≥13 trips >500 miles (7)	20 (175)	- -	80 (300)	- -
Sex	male (310)	50 (150)	500 (500)	200 (500)	1000 (2000)
	female (226)	100 (200)	500 (1000)	375 (500)	2000 (2000)
Age Group	<30 years (124)	60 (100)	500 (1000)	200 (500)	2000 (3000)
	30-44 years (126)	100 (200)	500 (1000)	325 (800)	1500 (2250)
	45-60 years (171)	100 (200)	500 (500)	350 (500)	1000 (2000)
	>60 years (115)	50 (150)	250 (500)	200 (500)	1000 (2000)
Education	some high school (7)	5 (20)	- -	20 (80)	- -
	high school graduate (36)	30 (100)	450 (1000)	100 (300)	937 (6000)
	some college (124)	100 (100)	288 (500)	125 (500)	1000 (2000)
	associate degree (50)	100 (200)	500 (500)	375 (500)	1000 (1500)
	bachelor degree (166)	100 (150)	500 (500)	300 (500)	1500 (2000)
	graduate degree (153)	100 (250)	500 (1000)	500 (625)	1500 (2000)
Transport Emissions	0% (10)	0 (50)	- -	0 (50)	- -
	1-25% (146)	10 (150)	500 (1000)	100 (500)	1000 (2000)
	26-50% (186)	100 (200)	500 (500)	500 (500)	1500 (1875)
	51-75% (121)	100 (100)	500 (500)	350 (500)	2000 (2000)
	76-100% (73)	100 (100)	500 (500)	300 (500)	1500 (2000)
Global Warming	definitely not true (31)	1 (28)	30 (425)	1 (62)	75 (475)
	likely not true (66)	0 (200)	200 (625)	5 (500)	500 (1500)
	not sure (79)	25 (100)	200 (500)	50 (200)	500 (1000)
	likely true (191)	100 (100)	500 (500)	400 (500)	1500 (2000)
	definitely true (169)	150 (300)	1000 (1000)	500 (1000)	2000 (2000)

Acceptable reduction in fuel economy

For this question, respondents were asked what the maximum acceptable loss in fuel economy would be for each type of in-vehicle carbon-capture system. The response distribution to the question about reduction also exhibited long tails as before, and are best reported as medians. These distributions are shown in Figure 13. The boxplots on the left include all data; those on the right include only the nonzero response data. Within each of the groups, responses for systems that provide 20% and 80% capture are also shown. Respondents were willing to accept about a 5% reduction in fuel economy for a system that captured 20% of carbon dioxide emissions and 10% reduction for one that captured 80% of carbon dioxide emissions. Detailed breakdowns of estimates by respondent subgroups are provided in Table 2.

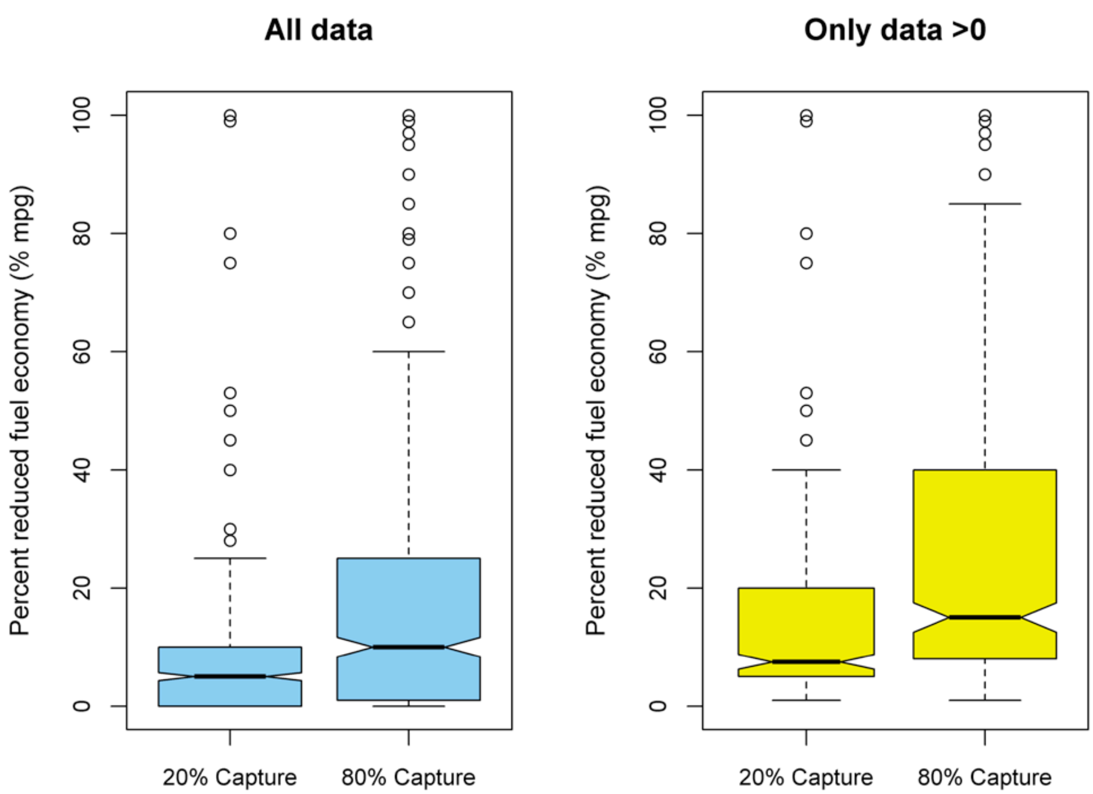

Figure 13. Boxplots showing approximate distribution of respondents' estimate of an acceptable reduction in fuel economy for in-vehicle carbon-capture capability.

Table 2.
Acceptable fuel economy reduction (percentage) to capture CO2 emissions.
All respondents and respondents disaggregated by group.
(The entries in parentheses are based on cases with nonzero responses only.)

	Respondents (N)	20% reduction of CO2				80% reduction of CO2			
		50th percentile		75th percentile		50th percentile		75th percentile	
	ALL (536)	5	(8)	10	(20)	10	(15)	25	(40)
Vehicle Type	subcompact (31)	5	(5)	20	(20)	10	(15)	30	(40)
	compact (144)	5	(5)	10	(20)	10	(20)	29	(40)
	family sedan (117)	5	(10)	10	(10)	10	(20)	25	(30)
	luxury sedan (50)	3	(5)	10	(20)	8	(10)	20	(40)
	SUV (122)	2	(10)	10	(20)	10	(15)	25	(30)
	minivan (42)	10	(10)	20	(24)	14	(20)	42	(70)
	pickup (44)	1	(5)	5	(10)	5	(10)	15	(30)
Power Type	internal combustion (505)	5	(6)	10	(20)	10	(15)	25	(40)
	hybrids (22)	4	(5)	10	(10)	10	(10)	20	(20)
	fully electric (9)	5	(20)	-	-	20	(20)	-	-
Weekly Miles	<25 miles per week (60)	5	(10)	20	(25)	10	(20)	55	(79)
	25-100 miles per week (213)	5	(10)	10	(20)	10	(20)	30	(40)
	101-250 miles per week (185)	2	(5)	10	(10)	10	(10)	2	(25)
	251-1,000 miles per week (72)	2	(10)	10	(15)	10	(20)	25	(36)
	>1,000 miles per week (6)	11	(20)	-	-	29	(50)	-	-
Annual Trips	0 trips >500 miles (163)	5	(10)	10	(20)	10	(15)	30	(40)
	1-2 trips >500 miles (259)	5	(5)	10	(20)	10	(15)	25	(40)
	3-6 trips >500 miles (88)	5	(10)	10	(20)	10	(15)	25	(30)
	7-12 trips >500 miles (19)	1	(5)	10	(10)	4	(10)	20	(20)
	≥13 trips >500 miles (7)	10	(20)	-	-	18	(45)	-	-
Sex	male (310)	3	(5)	10	(15)	10	(15)	20	(30)
	female (226)	5	(10)	10	(20)	10	(20)	30	(40)
Age Group	<30 years (124)	5	(5)	10	(20)	10	(20)	30	(40)
	30-44 years (126)	5	(10)	12	(20)	10	(20)	30	(40)
	45-60 years (171)	5	(5)	10	(14)	10	(15)	20	(30)
	>60 years (115)	2	(10)	10	(20)	7	(12)	25	(36)
Education	some high school (7)	1	(12)	-	-	10	(12)	-	-
	high school graduate (36)	5	(10)	14	(20)	12	(10)	29	(40)
	some college (124)	3	(10)	10	(20)	10	(20)	30	(40)
	associate degree (50)	5	(5)	12	(20)	10	(10)	40	(50)
	bachelor degree (166)	5	(5)	10	(20)	10	(15)	25	(40)
	graduate degree (153)	5	(5)	10	(15)	10	(15)	20	(29)
Transport Emissions	0% (10)	1	(10)	-	-	1	(20)	-	-
	1-25% (146)	1	(5)	5	(10)	4	(10)	16	(25)
	26-50% (186)	5	(5)	10	(10)	10	(15)	21	(30)
	51-75% (121)	5	(10)	20	(20)	20	(20)	40	(50)
	76-100% (73)	5	(10)	20	(20)	10	(15)	35	(50)
Global Warming	definitely not true (31)	0	(2)	1	(9)	0	(7)	5	(35)
	likely not true (66)	0	(5)	5	(19)	2	(10)	10	(32)
	not sure (79)	2	(10)	12	(20)	5	(20)	30	(45)
	likely true (191)	5	(5)	10	(20)	10	(20)	25	(40)
	definitely true (169)	5	(10)	10	(20)	10	(15)	30	(30)

Acceptable reduction in trunk space to support in-vehicle carbon capture

For this question, respondents were asked to estimate the percentage of available trunk storage space they were willing to reserve for carbon-dioxide storage. As in the previous two questions, the response distribution also exhibited long tails and are reported as medians. These distributions are shown in Figure 14. The boxplots on the left include all data; those on the right include only the nonzero response data. Within each of the groups, responses for systems that provide 20% and 80% capture are also shown. Respondents were willing to accept about a 10% reduction in trunk space for a system that captured 20% of carbon dioxide emissions and a 16% reduction for one that captured 80% of carbon-dioxide emissions. Detailed breakdowns of estimates by respondent subgroups are provided in Table 3.

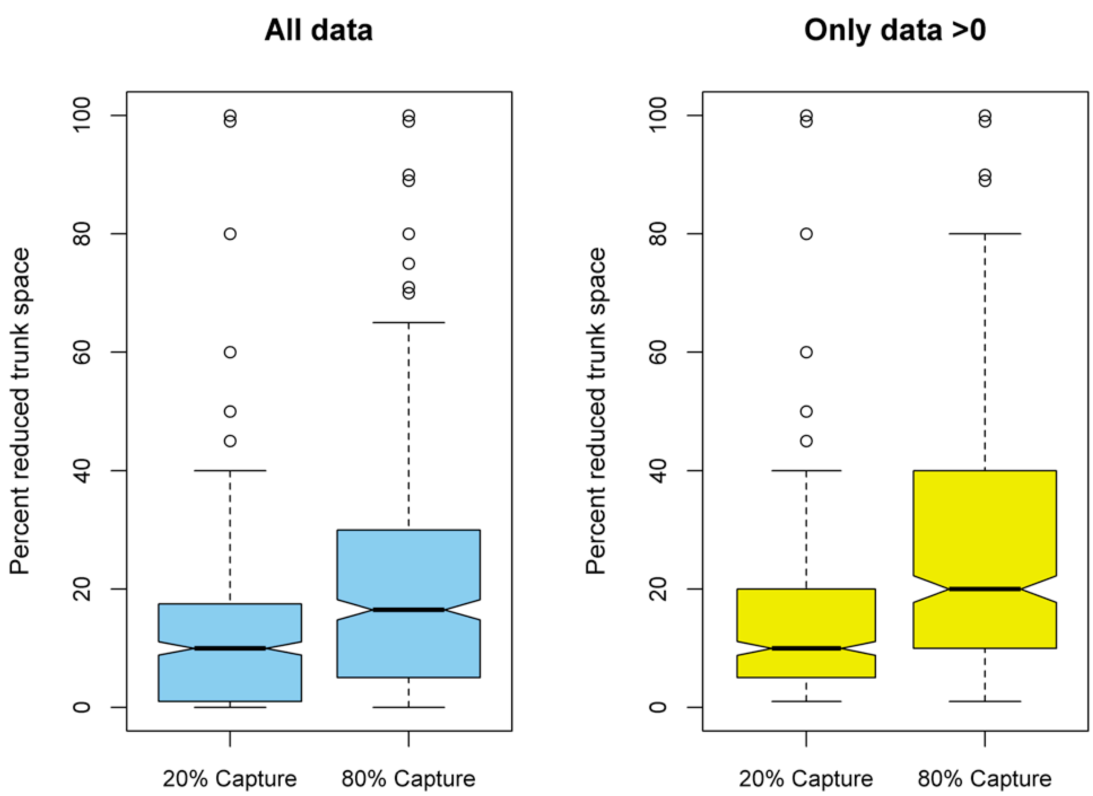

Figure 14. Boxplots showing approximate distribution of respondents' estimate of an acceptable reduction in trunk space for in-vehicle carbon-capture capability.

Table 3.
Acceptable trunk-space loss (percentage) to capture CO_2 emissions.
All respondents and respondents disaggregated by group.
(The entries in parentheses are based on cases with nonzero responses only.)

	Respondents (N)	20% reduction of CO2		80% reduction of CO2	
		50th percentile	75th percentile	50th percentile	75th percentile
	ALL (536)	10 (10)	19 (20)	16 (20)	30 (40)
Vehicle Type	subcompact (31)	5 (10)	15 (20)	15 (22)	30 (38)
	compact (144)	10 (10)	11 (20)	20 (20)	30 (32)
	family sedan (117)	10 (10)	20 (20)	20 (20)	40 (50)
	luxury sedan (50)	5 (8)	10 (16)	10 (15)	20 (32)
	SUV (122)	5 (10)	16 (20)	15 (20)	25 (30)
	minivan (42)	10 (10)	20 (20)	20 (23)	42 (50)
	pickup (44)	8 (10)	19 (20)	18 (25)	30 (30)
Power Type	internal combustion (505)	10 (10)	20 (20)	15 (20)	30 (40)
	hybrids (22)	8 (10)	10 (11)	18 (20)	30 (30)
	fully electric (9)	15 (30)	- -	20 (30)	- -
Weekly Miles	<25 miles per week (60)	10 (20)	20 (32)	20 (25)	50 (52)
	25-100 miles per week (213)	10 (10)	20 (20)	20 (20)	32 (40)
	101-250 miles per week (185)	5 (10)	10 (20)	15 (20)	30 (30)
	251-1,000 miles per week (72)	10 (10)	10 (18)	15 (20)	29 (30)
	>1,000 miles per week (6)	4 (4)	- -	14 (14)	- -
Annual Trips	0 trips >500 miles (163)	10 (10)	20 (20)	20 (20)	35 (40)
	1-2 trips >500 miles (259)	10 (10)	10 (20)	15 (20)	30 (30)
	3-6 trips >500 miles (88)	10 (10)	19 (20)	20 (20)	30 (40)
	7-12 trips >500 miles (19)	5 (10)	20 (20)	20 (20)	30 (45)
	≥13 trips >500 miles (7)	5 (20)	- -	10 (45)	- -
Sex	male (310)	9 (10)	20 (20)	19 (20)	35 (50)
	female (226)	10 (10)	10 (20)	15 (20)	30 (30)
Age Group	<30 years (124)	10 (10)	20 (20)	20 (25)	50 (50)
	30-44 years (126)	10 (10)	15 (20)	20 (20)	36 (40)
	45-60 years (171)	10 (10)	20 (20)	20 (20)	30 (30)
	>60 years (115)	5 (10)	10 (20)	10 (20)	25 (30)
Education	some high school (7)	10 (10)	- -	30 (30)	- -
	high school graduate (36)	10 (10)	24 (25)	20 (20)	39 (48)
	some college (124)	10 (10)	20 (20)	15 (20)	30 (45)
	associate degree (50)	6 (10)	11 (20)	15 (15)	37 (50)
	bachelor degree (166)	10 (10)	16 (20)	20 (20)	30 (40)
	graduate degree (153)	5 (10)	10 (20)	15 (20)	30 (30)
Transport Emissions	0% (10)	1 (15)	- -	1 (15)	- -
	1-25% (146)	5 (10)	10 (20)	10 (20)	25 (30)
	26-50% (186)	10 (10)	15 (20)	20 (20)	30 (40)
	51-75% (121)	10 (10)	20 (20)	20 (25)	40 (40)
	76-100% (73)	10 (10)	20 (20)	20 (20)	40 (50)
Global Warming	definitely not true (31)	1 (10)	10 (19)	1 (15)	20 (48)
	likely not true (66)	4 (10)	10 (10)	10 (15)	20 (26)
	not sure (79)	5 (10)	20 (20)	10 (15)	20 (25)
	likely true (191)	10 (10)	15 (20)	20 (20)	30 (34)
	definitely true (169)	10 (10)	20 (20)	25 (25)	48 (50)

Preference for Carbon Capture over Electric/Hybrid Vehicle

Respondents were also asked whether they would prefer a carbon-capture vehicle over an electric or hybrid vehicle. The results are shown in Table 4. They suggest that the percentage of carbon capture from emissions is likely to be an important criterion in vehicle selection.

Table 4.
Number of respondents' answers regarding choice between carbon-capture equipped vehicles and electric or hybrid vehicles.

Carbon Capture Capability	Prefer a carbon-capture vehicle over an electric or hybrid to reduce emissions	
	Yes	No
20% capture of emissions	201 (37.5%)	335 (62.5%)
80% capture of emissions	335 (62.5%)	201 (37.5%)

Respondent Factors and Inclination to Pay for Carbon-Dioxide Capture

In this analysis, respondents were divided into two groups: those willing to offer any amount of money in exchange for carbon-capture capability, and those who were not. Two generalized linear model analyses were performed using age group, gender, education, vehicle type, weekly miles driven, annual number of long trips, engine power source, and belief in global warming as predictors determining whether a respondent was likely to pay for carbon-capture capability for a 20% capture and an 80% capture system. Out of all the predictors, belief about global warming was the sole determiner of whether a respondent would pay something (or nothing) for in-vehicle carbon-dioxide capture ($F_{(4,516)}$=12.2, $p < 0.0001$ for 80% capture, and $F_{(4,516)}$=12.02, $p < 0.0001$ for 20% capture). That is, in each analysis, the degree to which the respondent believed that carbon emissions from human activity contributed to global warming predicted whether the respondent would offer to pay some amount of money for an in-vehicle carbon-capture system.

Comparisons between levels of belief are presented in Table 5 and Table 6. For the 80% carbon-capture system, no difference was observed in the pairwise comparisons of the odds of offering some money for carbon capture between respondents who responded *Definitely not true*, *Probably not true*, or *Not sure.* Similarly, little difference was observed between respondents who judged the statement about global warming as either *Probably true* or *Definitely true.* However, there were sharp differences between these two clustered groups. For example, the odds ratio of *Definitely not true* and *Definitely true* is 0.138 (see Table 5). This means that the odds that a respondent would offer money for an 80% carbon capture system after judging the truth of the global warming statement to be *Definitely not true* is about .138 times as likely as it for a respondent that judged the statement to be *Definitely true.* (Conversely, this also suggests that a person judging the global warming statement as *Definitely true* is about seven times more likely to offer money than a respondent that judges the statement to be *Definitely false.*) The pattern observed in the 80% system was much the same (see Table 6). The main difference was that the *Not Sure* response was clustered with the *Possibly true* and *Definitely true* judgments.

Table 5.
Pairwise comparisons between belief in global warming and odds that a respondent would pay something for an in-vehicle system capable of capturing 80% of the carbon dioxide generated in combustion. Red highlights indicate significant differences.

Belief in Global Warming		**Adj p**	**Odds Ratio**	**Lower Confidence Limits**	**Upper Confidence Limits**
Comparison 1	**Comparison 2**				
Definitely not true	Probably not true	1.000	0.925	0.257	3.331
Definitely not true	Not sure	0.420	0.391	0.106	1.433
Definitely not true	Probably true	0.001	0.140	0.041	0.487
Definitely not true	Definitely true	0.002	0.138	0.038	0.495
Probably not true	Not sure	0.21-	0.422	0.148	1.207
Probably not true	Probably true	<0.001	0.152	0.056	0.409
Probably not true	Definitely true	<0.001	0.149	0.053	0.416
Not sure	Probably true	0.031	0.360	0.136	0.947
Not sure	Definitely true	0.035	0.352	0.129	0.960
Probably true	Definitely true	1.00	0.979	0.379	2.532

Table 6.
Pairwise comparisons between belief in global warming and odds that a respondent would pay something for an in-vehicle system capable of capturing 20% of the carbon dioxide generated in combustion. Red highlights indicate significant differences.

Belief in Global Warming		Adj p	Odds Ratio	Lower Confidence Limits	Upper Confidence Limits
Comparison 1	**Comparison 2**				
Definitely not true	Probably not true	1.000	1.386	0.391	4.916
Definitely not true	Not sure	1.000	0.479	0.134	1.705
Definitely not true	Probably true	0.003	0.218	0.067	0.713
Definitely not true	Definitely true	0.002	0.196	0.057	0.667
Probably not true	Not sure	0.036	0.345	0.124	0.962
Probably not true	Probably true	<0.001	0.157	0.062	0.397
Probably not true	Definitely true	<0.001	0.141	0.053	0.373
Not sure	Probably true	0.136	0.456	0.186	1.115
Not sure	Definitely true	0.071	0.409	0.161	1.040
Probably true	Definitely true	1.000	0.897	0.388	2.072

In the earlier discussion about respondents' estimation of the maximum amount of money they would pay for a carbon-capture system, it was noted that the detailed breakdowns of respondents into separate groups seemed to exhibit little systematic relationship between those groups and the maximum amounts (see Table 1). The one noted exception to this was that there appeared to be a relationship between respondents' survey opinions and the amount offered. This influence was observed in the previous analysis in which the odds of offering something for carbon-capture capability appeared to be closely associated with respondents' opinion about global warming. To explore this further, a series of box plots were generated showing the distributions of the maximum amount of money offered for carbon capture (Figure 15), maximum reduction in fuel economy (Figure 16), and maximum allocation in trunk space acceptable to host a carbon capture-system (Figure 17), as a function of the amount of carbon captured from combustion (20% or 80%) and belief in the sample statement about global warming.

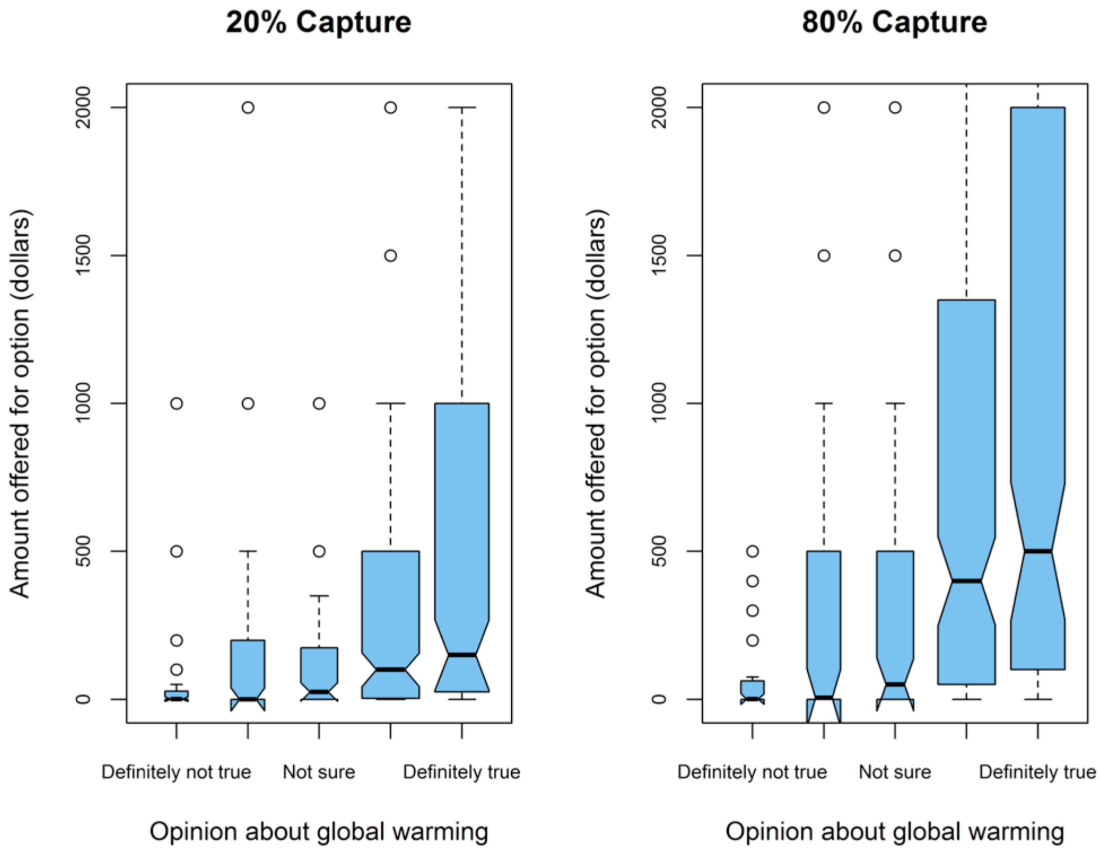

Figure 15. Box plots of amount of money respondents would pay for an on-board carbon-capture system. Median amounts increase as belief in a relationship between global warming and carbon-dioxide emissions caused by human activity increases.

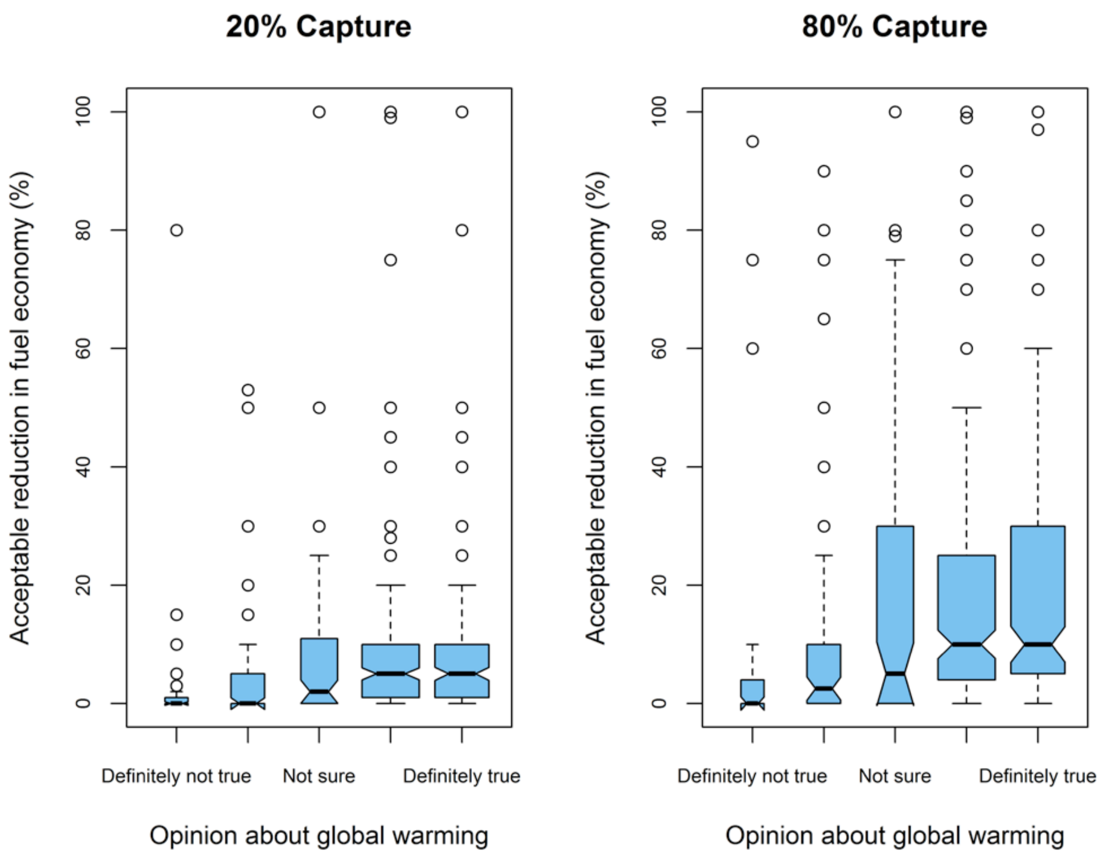

Figure 16. Box plots of maximum reduction in fuel economy respondents would accept for an on-board carbon-capture system. Median amounts increase as belief in a relationship between global warming and carbon-dioxide emissions caused by human activity increases.

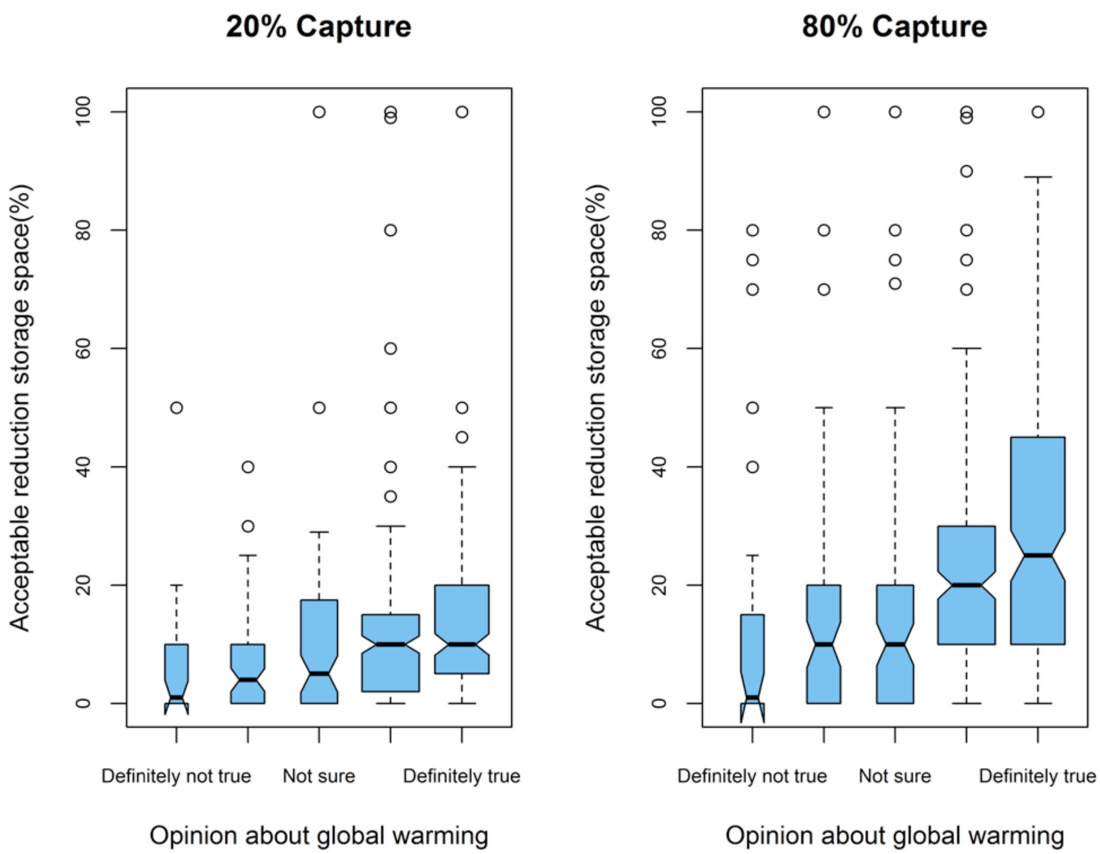

Figure 17. Box plots of maximum reduction in storage space respondents would accept for an on-board carbon-capture system. Median amounts increase as belief in a relationship between global warming and carbon-dioxide emissions caused by human activity increases.

Conclusion

Among the respondents in this survey, willingness to pay for or accept reductions in fuel economy or storage space in exchange for reduction in carbon-dioxide emissions seems to greatly depend on the belief that there is a relationship between carbon-dioxide emissions from human activity and global warming. Respondents appeared to be willing to pay about $100 for a 20% reduction in carbon-dioxide emissions and $250 for an 80% reduction; they also appeared to accept about a 5% reduction in fuel economy for a 20% reduction in carbon-dioxide emissions, and a 10% reduction in fuel economy for a 80% reduction; and finally, they appeared willing to accept about a 10% loss in trunk space for a 20% reduction in emissions, and a 16% loss in trunk space for an 80% reduction in emissions. It should be noted, however, there is substantial variability in these figures, as evidenced by the relatively wide range encompassed by the quartiles. This is especially true for the estimated maximum amounts respondents reported they would pay for carbon capture. This suggests that respondents have limited ability to place a sensible value on this new and unfamiliar capability. The estimates for reductions in fuel economy and trunk space show a similar trend toward variability, although the ranges seem better contained because the maximum cannot exceed 100. Nevertheless, outliers clearly span the full range of judgment.

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Appendix

Below is a copy of the on-line survey.

On Board Carbon Capture in Vehicles

1. What type of vehicle do you currently drive most often?

- [ ] subcompact
- [ ] compact
- [ ] family sedan
- [ ] luxury sedan
- [ ] SUV
- [ ] minivan
- [ ] pickup

2. How is your vehicle powered?

- [ ] internal combustion engine
- [ ] hybrid
- [ ] fully electric

3. About how many miles is your vehicle driven in a typical week?

- ○ less than 25 miles
- ○ 25 - 100 miles
- ○ 101 - 250 miles
- ○ 251 - 1000 miles
- ○ more than 1000 miles

4. How many times a year do you take a trip in your vehicle that is more than 500 miles?

- ○ 0 times
- ○ 1-2 times
- ○ 3-6 times

- 6-12 times
- more than 12 times

On Board Carbon Capture in Vehicles

Tell us a little about yourself:

5. What is your gender:

- male
- female

6. What is your age:

7. What is the highest level of education you completed?

- some high school
- high school graduate
- some college
- associate degree
- bachelor degree
- graduate degree

On Board Carbon Capture in Vehicles

8. Please estimate what percentage of the total carbon dioxide emissions generated by human activity is caused by transportation:

9. Rate the degree to which you think that the following statement is true: "Global warming is associated with the release of carbon dioxide into the atmosphere by human activity."

- definitely not true
- probably not true
- not sure
- probably true
- definitely true

Prev Next

On Board Carbon Capture in Vehicles

Factoid 1: After combustion, one pound of gasoline produces about three pounds of carbon dioxide (CO_2).

Factoid 2: The EPA estimates that, on average, a passenger vehicle puts about 11,000 pounds of carbon dioxide into the atmosphere each year.

Suppose a vehicle is developed that substantially reduces carbon emissions from gasoline combustion by capturing and storing some of the carbon dioxide emitted during combustion. The following questions are intended to understand the relative value you would place on such a capability.

10. Assume that a carbon-capture system could be put on a vehicle with the following property:

1. It does not alter your vehicle's fuel economy.
2. It does not add any time to dispose of the collected carbon dioxide; this can be done when refueling.

What is the maximum you would pay for this capability if the amount captured is:

20 percent of CO_2 emissions	
80 percent of CO_2 emissions	

Prev Next

On Board Carbon Capture in Vehicles

11. Suppose vehicles equipped with a carbon-capture capability have a lower fuel economy (miles per gallon) than similar vehicles that do not capture carbon dioxide (CO2).

What would be the maximum acceptable reduction in fuel economy if the amount captured was:

20 percent of CO2 emissions

80 percent of CO2 emissions

Prev Done

On Board Carbon Capture in Vehicles

12. Suppose a vehicle equipped with a carbon-capture capability required some additional space to store the collected carbon dioxide (CO2).

What would be the maximum percentage of trunk space that you would be willing to reserve for carbon dioxide storage, if the amount captured is:

20 percent of CO2 emissions

80 percent of CO2 emissions

Prev Done

13. Would you prefer a carbon-capture vehicle over an electric or hybrid vehicle to reduce emissions and keep the environment clean?

With:

20 percent capture of CO_2 emissions	Yes	No
80 percent capture of CO_2 emissions	Yes	No