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The Stanford Climate Change Behavior Survey (SCCBS): assessing greenhouse gas emissions-related behaviors in individuals and populations

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Abstract Many individual-level behaviors are associated with greenhouse gas (GHG) emissions. Reliable and valid assessment instruments are needed to (1) identify behaviors and populations to target with emissions-reduction programs and policies, (2) evaluate the effectiveness of such programs, (3) link self-reported and objective measures of GHG emissions to establish the impact of specific behaviors, and (4) estimate frequencies of behaviors and their changes over time to aid policy makers in understanding energy consumption trends. The self-administered Stanford Climate Change Behavior Survey (SCCBS) is shown to be a reliable and valid instrument that can be used for these purposes in college students, and we anticipate that it will also be useful for assessing these behaviors in other adolescent or adult populations in developed countries. Questions included behaviors likely to be within the control of most individuals and did not include behaviors specific to home owners (e.g. appliance purchases). Ten indices were identified: Energy Use, No-, Low-, and High-GHG Transportation, Waste, Food Packaging, High- and Low-GHG Food, Food Purchasing, and GHG Credits use. A Total GHG Behavior score

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was calculated. Test–retest reliabilities of individual items ranged from .64 to .91. Internal consistency reliabilities for each of the indices ranged from .51 to .89. Most indices were statistically significantly correlated with one another. Correlational validity of the SCCBS was demonstrated with statistically significant associations between behavior scores and perceived importance of environmental sustainability and membership in an environmental organization. The use of the SCCBS to identify potential target sub-populations and behaviors was demonstrated.

1 Introduction

It is estimated that, in the United States, the residential sector accounts for a significant proportion of the greenhouse gas (GHG) emissions produced each year: 57% of transportation emissions come from passenger cars and light trucks, and one-quarter of emissions from buildings come from residential sources (EIA 2009; Environmental Protection Agency 2008; Vandenbergh et al. 2008). Regarding food consumption, livestock alone contributes 18% to total global GHG emissions (Steinfeld et al. 2006). Many individual-level actions are associated with these emissions, and changes in these behaviors may play an important role in slowing climate change. Because of this, many policies and programs operate under the premise that they will achieve GHG emissions reductions by affecting individual level behavior either directly or through trickle-down effects. Although overall reductions in GHG emissions should be the final metric of such programs, substantial research on individual behavior change suggests that targeting specific behaviors is most effective in producing change—thus, programs and evaluation tools geared towards specific behaviors are important for maximizing change (Bandura 1986, 1997).

A survey tool measuring such behaviors could be used (1) by researchers, utilities, policy makers, or others who want to determine which demographic groups and/or behaviors to target with media, marketing, community-based, or technology programs or policies, (2) to evaluate the impact of those programs using pre-post test comparisons and/or comparison of treatment and control groups drawn from the population of interest, (3) to establish a correspondence between behaviors and objective measures of greenhouse gas emissions in order to better establish the impact of specific behaviors, for example, to inform the selection of target behaviors in future programs, and (4) to assess prevalences and/or changes in individual, group, or population-wide behaviors over time, for example, to improve models of energy use and to aid policy makers in understanding energy consumption trends. Without the ability to reliably and validly estimate greenhouse gas-related behaviors, substantial effort, time, and resources may be wasted without knowing whether programs and policies are needed at all, or are beneficial, ineffective, or even harmful; which programs and policies should be replicated and disseminated; and which need to be ended, revised, or replaced.

In the past few decades, many surveys have been developed to measure pro-environmental behaviors. To our knowledge, however, no tool is currently available that adequately measures a large and diverse set of climate relevant behaviors among individuals. Past surveys typically ask about a relatively small number of environment-related behaviors and have been used to investigate whether they are correlated with attitudes or other psychological constructs. Many cover sustainability in general, and include questions that are not specific to climate change (e.g., household chemical use, battery recycling, etc.; e.g., Kaiser 1998; Wiidegren 1998; Blake et al. 1997). Of the surveys that deal with climate relevant behaviors, some deal only with recycling (e.g., Barr 2007; Guagnano et al. 1995; Porter et al. 1995; Schultz and Oskamp 1996) or transportation (Haustein and Hunecke 2007; Steg and Vlek 1997; Van Lange et al. 1998), or estimate behaviors indirectly (e.g., appliance ownership). Gatersleben et al. (2002), and others code behaviors on a binary scale which diminishes their sensitivity for detecting variations and changes in behavior, particularly in individuals (e.g., Berger 1997; Painter et al. 1983). Recently, online carbon footprint calculators have become popular. Mostly, these calculators include only very general questions, such as overall home electricity use and miles driven. This makes them unsuitable for use in identifying specific target behaviors that can be changed or evaluating the efficacy of interventions. Also, their reliability and validity are not known, and large inconsistencies between these calculators have been shown (Padgett et al. 2008).

Another approach to assessing behaviors related to greenhouse gas emissions is to quantify the actual impact of individuals' or households' electricity or gas use using, for example, electricity meters (e.g., Katzev and Johnson 1984; Winett et al. 1985; for a review see Darby 2006). While measuring overall consumption, these measures do not disaggregate consumption by specific behaviors that are amenable to change. To date, technology capable of measuring consumption at the behavioral level are too labor or cost-intensive to be feasible for sufficiently powered population-based observational or experimental studies.

Thus, available measurement instruments and methods do not meet the needs of policymakers and intervention developers interested in monitoring and/or changing individual and population greenhouse gas emissions-related behaviors. The current paper describes a self-administered instrument designed specifically to assess climate change relevant behaviors performed by individuals, the Stanford Climate Change Behavior Survey (SCCBS). The goal was to be more comprehensive in the coverage of behaviors than previous instruments, while also allowing for subscales that measure subsets of behaviors for policymakers and intervention developers/evaluators interested in specific categories of behaviors (e.g., energy use, transportation, food, waste).

The SCCBS is intended for use in most adolescent or adult populations in the U.S., and many other developed countries. The SCCBS was initially developed for use in college students, however, and we present reliability and validity data for that population. In addition, we report the population distributions for a sample of college students. We acknowledge that this population is not representative of all of the age groups, education levels, and socioeconomic status found in the U.S. We chose to focus first on the student population because we consider them to be a group likely to be early adopters of behaviors to reduce their greenhouse gas emissions, many college campuses are currently developing and implementing interventions to promote climate-positive behaviors, college campuses may allow for more rapid diffusion of practices, homogeneity across campuses may allow for easier diffusion among campuses, establishing climate change-protective behaviors in a younger person will make a greater impact over a lifetime, and it is a life stage when individuals start to control most of their own behaviors (versus parents for younger children).

2 Methods

2.1 Participants

Participants were recruited through an email sent to Stanford dormitory email lists in August 2007. Students were asked to participate by completing a survey twice over 3–5 days and told they would be compensated with a $10 gift certificate to their choice of two popular online vendors after completing the second survey. A direct link to the online survey was provided in the email and the link to the second survey was not sent until 3 days after the completion of the first. The survey began with an informed consent letter and the study protocol was approved by the IRB at Stanford University. One hundred forty-one Stanford students completed the survey once (one subject was dropped from analyses for failing to respond to the majority of the questions), and 116 of those students completed a second identical version 3–5 days later. Ages ranged from 18 to 23 years (M = 20.22, SD = 1.28), and 65% of the participants were female. The average number of years individuals had attended college was 3.21 (SD = 1.04). The racial/ethnic distribution was as follows: 45% Caucasian, 34% Asian, 6% Latino, 4% African-American, 1% Pacific Islander, 0% Other, and 8% Multi-ethnicity. Compared to the general population of Stanford summer session students in 2007, our survey respondents contained relatively more females (65% in the sample compared to 44% in the population), more Asian and Pacific Islanders (35% compared to 23%), fewer Caucasians (45% compared to 36%), fewer African Americans (4% compared to 8%), and an equal percent of Latinos (data provided by Susan Hawke of the Stanford University Registrar's Office).

2.2 Survey development and formative testing

A 97 item survey investigated the impact of individuals' climate relevant behaviors in the categories of electricity (or natural gas), transportation, waste, and food, by measuring variables such as the frequency or duration of the behaviors. The survey also included 15 additional questions relating to demographics and perceived values to help assess validity.

Behaviors were selected based on a review of printed and online materials regarding the impact of individuals' environmental behaviors, as well as the judgments of the authors and several students and University staff involved in campus sustainability efforts. Food consumption questions were adapted from a commonly used and previously validated semi-quantitative food frequency questionnaire (Rimm et al. 1992; Willett et al. 1985). Items included in the high and low GHG food indices should be appropriate across many seasonal and geographic contexts because meat and dairy production generally produce much greater GHG emissions than fruit and vegetable production (Pimentel and Pimentel 2003, 2007). However, it should be noted that that this balance could conceivably shift in some situations (e.g., for imported produce during the winter months in cooler climates).

Decisions regarding the inclusion and exclusion of several specific categories of behavior warrants further explanation. The primary purpose of the survey is to assess behavior change relevant to the majority of individuals in the targeted populations. Questions covered behaviors engaged in by individuals (such as high school or college students, or renters) and did not include questions that would require that an individual own a home (e.g., there were no questions regarding insulation or the purchase of major appliances). A broader range of product purchases (e.g., clothing and furniture) was not included because of the infeasibility of including this large set of items on a survey, and because the differential impact of these goods is mostly uncertain. Regarding transportation, the number of trips made by different transportation modes was included because this is a direct measure of a malleable behavior; it is typically feasible for individuals to shift mode for some trips. In some applications of the survey it may be of interest to compute total distance traveled; in these situations a question could be added regarding distance between residence and work/class. Air travel and recreational ground transportation were not included because it was found during pilot work that these trips were highly variable, participants were unable to reliably estimate distances, and these behaviors seemed to exhibit limited room for change among the target population. Some future applications of the survey may choose to add such questions.

Regarding the formulation of questions, these were crafted to be able to assess specific behaviors that individuals have control over (e.g., number of laundry loads washed in hot water, not what type of machine they use) and be easily answerable (i.e., not requiring participants to look-up information). When individuals could answer in terms of actual frequencies or quantities, these were used to improve the accuracy of recalled estimates; however, in cases where the accuracy of recall was judged to be more difficult, options were provided on a five-point Likert Scale demarcated with the terms “never”, “sometimes”, “about half the time”, “most of the time”, and “all the time”.

The survey was developed in several stages. In winter 2007, an initial draft was completed by five Stanford undergraduates who talked aloud describing their thought processes in arriving at answers. A revised draft survey was completed by 166 undergraduates recruited from a small number of environment- and health-related courses in spring 2007. Based on those results, some individual items were deleted or revised and response options were modified to create the final 97 item survey used in the present study.

2.3 Creating indices representing categories of behaviors

The primary objective of the survey and indices are to help researchers, utilities, policy makers and others interested in monitoring and/or changing GHG relevant behaviors at the behavioral level, rather than the greenhouse gas or energy use level. This allows one to directly relate intervention and/or policy changes with specific behavioral targets. While single behaviors may be targeted, we also grouped behaviors into categories based on different conceptual classes of behaviors (e.g., transportation, waste, food, electricity). We did this because interventions are frequently classified or organized according to these conceptual categories, for improved learning or to fit specific needs (e.g., an electric utility program would only target electricity behaviors). This allows evaluation of behavior changes by category. Because items are clustered conceptually within categories some items may capture some of the same underlying constructs. However, as with the overall survey, the indices are designed to capture a diversity of GHG related behaviors within a given category, and thus differ from other surveys in which indices are solely intended to measure a single index construct.

Principal components analysis (PCA) using varimax rotation was also employed heuristically to help eliminate redundancies, of which there were none, and start to group questions in presumptive categories. Indices representing different categories of behavior were formed according to both the results of PCA and on a more subjective conceptual basis. Because the survey is intended to capture a very broad range of climate related behaviors, not to develop indices in which all items measure the same construct, our goal was not solely to minimize the number of indices with the highest possible eigenvalues; we also wanted the set of indices to make conceptual sense. Thus, questions were not deleted or grouped based on PCA results alone, if they were conceptually consistent with the indices generated. This process resulted in 10 indices: High GHG Transport, Low GHG Transport, No GHG Transport, Waste, Food Packaging (which included foods that required large amounts of food packaging and/or energy from freezing or transporting heavy items), High GHG Foods, Low GHG Foods, Food Purchasing, and GHG Credits.

The "Total GHG Behavior" score was created by averaging the four main categories of climate-relevant behavior: Electricity, Transportation, Waste, and Food. The Waste score was composed of the average of the Waste and Food Packaging scales; the Food score was composed of the average of the Food High GHG and Food Purchasing scales; and the Transportation scale was a weighted average of the Transport High GHG and Transport Low GHG, where the former was weighted twice as much as the latter.

2.4 Reliability and validity

2.4.1 Reliability

Cronbach's α was employed to assess internal consistency reliability of the indices. No internal consistency was calculated for the Low GHG and No GHG Transportation indices as they assessed behaviors likely to be used exclusive of one another, and the GHG Credits index includes only a single item. We expected to find internal consistency, for some of the other indices, given we hypothesized that an individual's knowledge (e.g., of energy lifecycle, impact, etc.) and motivation related to each behavior would generalize to a similar class of behaviors, and it is informative as to the extent to which internal consistency occurred or did not for each of the indices. In cases where it is not high, we recognize that this may be due to the different contexts and barriers specific to each particular behavior.

Test–retest reliability for each index was assessed using intraclass Spearman's correlations between the index scores at the first and second administrations of the survey. Non-parametric Spearman's correlations were used to avoid violating assumptions of normality. We anticipated high test–retest reliability for the majority of questions because they were crafted to be specific and easy to understand, to elicit recall, and to contain response options that were feasible to differentiate.

Table 1 Descriptive statistics for each question

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
ELECTRICITY						
On average, how many loads of laundry do you wash per week? (0.5–4)[c]	1.2	0.8	1	0.5–2	0.5–4	138
For how many of those loads do you use cold water? (0.5–4)[c]	1	0.8	1	0.5–1	0.5–4	140
How many times per week do you usually shower? (1–11)[c]	6.4	2	6.5	4.5–6.5	1–11	138
On average, how long is each shower, in minutes? (2.5–30)[c]	12.2	5.6	14.5	7.0–14.5	2.5–24.5	140
On a typical day, how many FLOORS do you take an elevator on average? (count each floor in each direction as 1; 0–35)[c]	3.1	7.1	0	0–3.5	0–35	139
Imagine a hot week in the summer. How many days per week would you use air conditioning at your residence, for any part of the day or night? (0–7)[b,c]	3.2	3.1	3.5	0–7	0–7	140
Imagine a hot week in the summer. How often would you use air conditioning when driving or riding in a car, truck, or van?[a,b,c]	0.6	0.3	0.8	0.5–1	0–1	139
How many hours of television do you watch on a typical day? (0–7)[c]	1.1	1.2	0.5	0.5–1.5	0–5.5	139
How many hours of videogames or computer games do you play on a typical day? (0–7)[c]	0.5	0.9	0	0–0.5	0–5.5	138
How many hours do you spend on a computer on a typical day? (0–7)[c]	4.4	1.9	5.5	3.5–5.5	0–7	137
What do you do when you are not using your computer for 20 minutes or more? (options of increasing energy intensity were coded from 0–1 on a 5-point scale)[c]	0.3	0.2	0.3	0.3–0.5	0–1	140
What do you do with your computer overnight? (options of increasing energy intensity were coded from 0–1 on a 5-point scale)[c]	0.2	0.2	0.3	0–0.3	0–1	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
For the following questions, please note about what percent of the time you currently do each of the following activities instead of their alternatives. (pick the closest answer; if you never do either one of the activities, pick "never")[a]						
Buy compact fluorescent light bulbs[b]	0.3	0.4	0.3	0–0.6	0–1	140
Turn off TV when leaving room[b]	0.9	0.2	1	0.8–1	0–1	140
Shut off lights when leaving room[b]	0.8	0.3	0.8	0.8–2	0–1	140
Turn off heater when leaving residence[b]	0.5	0.4	0.5	0–1	0–1	140
Keep windows closed while heat is on[b]	0.8	0.3	1	0.8–1	0–1	140
Use a clothesline[b]	0.2	0.2	0.3	0–0.3	0–0.8	140
Close drapes/blinds on hot sunny days[b]	0.5	0.3	0.5	0.3–0.8	0–1	140
Open drapes/blinds on cool sunny days[b]	0.6	0.3	0.8	0.3–1	0–1	140
TRANSPORT, HIGH GHG						
Approximately how often do you check your car tire inflation pressure? (0.5–12 times per year)[b,c,d]	4	3.7	4	0.5–6	0.5–12	77
At what speed do you typically drive on a highway/freeway? (55–80 MPH)[b,c,d]	69.3	5.6	70	65–75	55–80	117
Car drive most often (0–1, none to light truck/SUV)[b]	0.3	0.3	0.4	0–0.6	0–1	140
For the following questions, for each of the modes of transportation below, mark the answer corresponding to the NUMBER OF ONE WAY TRIPS PER WEEK you typically travel, to get between your residence and classes/meetings on campus. (If you are not currently at school, answer for your most recent quarter at school) [0–20, number of one-way trips per week]						
Car, truck, or van (alone or dropped off by someone else)	2.4	3.7	1.5	0–4	0–15.5	140
TRANSPORT, LOW GHG						
For the following questions, for each of the modes of transportation below, mark the answer corresponding to the NUMBER OF ONE WAY TRIPS PER WEEK you typically travel, to get between your residence and classes/meetings on campus. (If you are not currently at school, answer for your most recent quarter at school) [0–20, number of ONE-way trips per week]						
Carpool	1.4	2.6	0	0–1.5	0–15.5	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
Bus	0.9	1.7	0	0–1.5	0–8	140
[train] and/or [subway]	0.5	1.6	0	0–0	0–15.5	140
TRANSPORT, NO GHG						
For the following questions, for each of the modes of transportation below, mark the answer corresponding to the NUMBER OF ONE WAY TRIPS PER WEEK you typically travel, to get between your residence and classes/ meetings on campus. (If you are not currently at school, answer for your most recent quarter at school) [0–20, number of one-way trips per week]						
Walking	7.8	6.7	4	1.5–15.5	0–20	140
Biking	13.5	7.8	15.5	8–20	0–20	140
Skateboarding, unpowered scooter, rollerblade/roller-skate	0.4	2.4	0	0–0	0–20	140
WASTE						
How much trash do you personally produce each week in the place where you live? Estimate how many plastic grocery bags of trash you would fill. (Not including the items that you recycle.) (0.5–5)[c]	1.5	0.9	1	1–2	0.5–5	140
For the following questions, please note about what percent of the time you currently do each of the following activities instead of their alternatives. (pick the closest answer; if you never do either one of the activities, pick "never")[a]	0.7	0.3	0.8	0.5–1	0–1	140
Reuse paper as scratch[b]	0.7	0.3	0.8	0.5–1	0–1	140
Use both sides of paper[b]	0.7	0.3	0.8	0.5–1	0–1	140
Buy high post-consumer content recycled paper[b]	0.4	0.3	0.3	0–0.8	0–1	140
Dry hands on a towel or clothes rather than with a paper towel[b]	0.6	0.3	0.5	0.5–0.9	0–1	140
Recycle white paper[b]	0.7	0.3	0.8	0.5–1	0–1	140
Recycle newspaper and colored paper[b]	0.7	0.3	0.8	0.5–1	0–1	140
Recycle glass bottles[b]	0.8	0.3	0.8	0.8–1	0–1	140
Recycle aluminum and steel cans[b]	0.8	0.3	0.8	0.8–1	0–1	140
Recycle plastic containers and packaging[b]	0.7	0.3	0.8	0.5–1	0–1	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
FOOD PACKAGING						
For the following questions, please note about what percent of the time you currently do each of the following activities instead of their alternatives. (pick the closest answer; if you never do either one of the activities, pick "never")[a]	0.1	0.3	0	0–0.3	0–1	140
Reuse old bags when shopping for food[b]						
Bring a reusable cup to cafes, eateries, etc.[b]	0.1	0.2	0	0–0.3	0–1	140
Leave fruits and vegetables loose or put more than one type in a plastic bag when shopping for food[b]	0.2	0.3	0	0–0.3	0–1	140
For the following questions, for each food or drink listed, how often on average you have eaten, drank, or used the amount specified DURING THE PAST MONTH. For example, if, on average, you drank two 8 ounce servings (or one 16 ounce serving) of pre-bottled water every day, you would mark the 2–3 per day option. [Foods are coded in servings per week from 0.13–42]						
8 oz. serving of pre-bottled water	5.1	8	2	0.5–7	0.1–42	140
12 oz. serving of low calorie soda, flavored water, juice, or other diet drinks from a plastic, glass, or aluminum can or bottle	2.6	5.8	0.5	0.1–3	0.1–42	140
12 oz. serving of regular soda, flavored water, juice, or other sweet drinks with sugar from a plastic, glass, or aluminum can or bottle	1.5	2.4	0.5	0.1–1	0.1–17.5	140
1/2 cup frozen or canned fruit	0.6	1.7	0.1	0.1–0.5	0.1–17.5	140
1 salad serving prepackaged salad mix	2	3.9	0.5	0.1–3	0.1–31.5	140
1/2 cup frozen or canned vegetables or beans	1	1.9	0.3	0.1–1	0.1–17.5	140
3–4 oz. canned fish	0.5	0.8	0.1	0.1–0.5	0.1–5.5	140
1.5 oz. candy, including chocolate	2.8	4.5	1	0.5–0.1	0.1–42	140
1 slice prepackaged pie or cake, 1 large cookie, or 2 oz. other sweets	1.4	1.6	0.5	0.1–3	0.1–7	140
1/2 cup packaged snack foods	2.6	3.8	1	0.5–3	0.1–31.5	140
1 meal or snack from a fast food restaurant	0.7	1	0.5	0.1–1	0.1–5.5	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
FOOD, HIGH GHG						
For the following questions, for each food or drink listed, how often on average you have eaten, drank, or used the amount specified DURING THE PAST MONTH. For example, if, on average, you drank two 8 ounce servings (or one 16 ounce serving) of pre-bottled water every day, you would mark the 2–3 per day option. [Foods are coded in servings per week from 0.13–42]						
8 oz. serving of skim or low-fat milk	5.2	7	3	0.5–7	0.1–42	140
8 oz. serving of whole milk	0.7	2.9	0.1	0.1–0.1	0.1–31.5	140
1/2 cup of yogurt, cottage, or ricotta cheese cream cheese or sour cream	2.5	3.3	1	0.5–3	0.1–17.5	140
1 slice or 1 oz. serving of other cheese	3.7	3.7	3	0.5–5.5	0.1–17.5	140
1/2 cup of ice cream, ice milk, sherbet, sorbet, or frozen yogurt	2	2.2	1	0.5–3	0.1–17.5	140
1 packet of butter added to food or bread	1.5	2.6	0.5	0.1–1	0.1–17.5	140
1 fresh banana	2.5	3.6	1	0.5–3	0.1–17.5	140
1 egg	2	2.2	1	0.5–3	0.1–17.5	140
4–6 oz., 2 legs, or 1 breast chicken or turkey, with skin	1.1	1.9	0.5	0.1–1	0.1–17.5	140
4–6 oz., 2 legs, or 1 breast chicken or turkey, without skin	2.7	2.5	3	0.5–3	0.1–17.5	140
2 slices bacon or 1 hot dog	0.5	0.7	0.1	0.1–5	0.1–3	140
1 hamburger patty	0.7	0.9	0.5	0.1–1	0.1–5.5	140
1 piece or slice processed meats	1.1	1.9	0.5	0.1–1	0.1–17.5	140
Beef as a sandwich or mixed dish	1	1.3	0.5	0.1–1	0.1–7	140
Beef as a main dish	1	1.2	0.5	0.1–1	0.1–5.5	140
Pork, ham, or lamb as a sandwich or mixed dish	0.9	1.3	0.5	0.1–1	0.1–7	140
Pork, ham, or lamb as a main dish	0.7	1.1	0.3	0.1–1	0.1–7	140
3–5 oz. fish or seafood (other than salmon)	0.8	1.1	0.5	0.1–1	0.1–7	140
FOOD, LOW GHG						
For the following questions, for each food or drink listed, how often on average you have eaten, drank, or used the amount specified DURING THE PAST MONTH. For example, if, on average, you drank two 8 ounce servings (or one 16 ounce serving) of pre-bottled water every day, you would mark the 2–3 per day option. [Foods are coded in servings per week from 0.13–42]						
1/2 cup fresh strawberries	1.3	2.1	0.5	0.5–1	0.1–17.5	140
1/2 cup fresh blueberries, raspberries, or other berries	1.2	1.7	0.5	0.1–1	0.1–7	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
1 fresh apple, pear, or peach	3.1	4.5	3	0.5–3	0.1–42	140
1 nectarine, apricot, or plum	1.4	2.3	0.5	0.1–1	0.1–17.5	140
1 orange or 1/2 grapefruit	1.1	1.5	0.5	0.1–1	0.1–7	140
1/2 cup other fresh fruit	2.2	2.7	1	0.5–3	0.1–17.5	140
1 fresh tomato	2.7	3.9	1	0.5–3	0.1–31.5	140
1/2 cup fresh green or string beans	1.3	1.6	0.5	0.5–1	0.1–7	140
1/2 cup dried beans or lentils, not canned	0.8	1.8	0.1	0.1–1	0.1–17.5	140
1/2 cup fresh broccoli, cauliflower, or cabbage	1.7	1.7	1	0.5–3	0.1–7	140
1 ear fresh corn	0.8	1.4	0.5	0.1–1	0.1–7	140
1/2 fresh carrot or 2–4 sticks or baby carrots	2.1	2.8	1	0.5–3	0.1–17.5	140
1/2 stalk fresh celery or 2–4 cut sticks	0.6	1.2	0.1	0.1–5	0.1–7	140
1/2 cup fresh zucchini, squash, or eggplant	0.9	1.8	0.5	0.1–1	0.1–17.5	140
1/2 cup yam or sweet potato	0.4	0.8	0.1	0.1–0.5	0.1–5.5	140
1 cup raw or 1/2 cup cooked fresh spinach, kale, mustard or chard greens	1.4	2.5	0.5	0.1–1	0.1–17.5	140
1 salad serving lettuce (not prepackaged)	2.5	3.7	1	0.5–3	0.1–31.5	140
1/2 cup any other fresh vegetables	2.8	4.6	1	0.5–3	0.1–31.5	140
1/2 cup almonds, walnuts, pecans, or pistachios	1.4	2.2	0.5	0.1–1	0.1–17.5	140
FOOD PURCHASING						
When you buy fresh fruits and vegetables, how often do you make it a point to buy fresh fruits and vegetables that are locally grown (e.g., grown within the state)?[a,b]	0.2	0.3	0.3	0–0.5	0–1	140
When you buy fresh fruit and vegetables, how often do you buy them from a farmers' market or farm stand, direct from farmers?[a,b]	0.2	0.2	0	0–0.3	0–1	140
When you buy fresh and vegetables, how often do you make it a point to buy organic fruits and vegetables?[a,b]	0.2	0.2	0.3	0–0.3	0–1	140
When you buy beef from a store or order beef in a restaurant, how often do you make it a point to get grass fed beef (instead of grain/corn fed)?[b,e]	0.3	0.4	0	0–0.4	0–1	140

Table 1 (continued)

Question (range of response options	M	SD	Med	Interquartile range of answers	Full range of responses	Number
When you buy chicken from a store or order chicken in a restaurant, how often do you make it a point to get free range chicken?[b,e]	0.2	0.4	0	0–0.3	0–1	140
GHG CREDITS						
How much of your CO2 emissions do you offset by buying credits?[a,b]	0	0.1	0	0–0	0–0.8	140

[a]These items used a 5-point "never" (0) to "all the time" (1) Likert scale

[b]The not applicable (N/A) response option of either "I don't know" or "I don't perform [activity in question]" were available for these questions. For most questions, N/A indicated that a GHG producing behavior was not a part of a person's lifestyle, and it was recoded as the lowest frequency response for the purpose of scoring, unless otherwise noted in these table notes

[c]Values were left as missing if participants failed to respond on these questions. For questions on which this notation is absent, failures to respond or N/A values were recoded as the lowest frequency or smallest quantity response option for that question

[d]For these questions, N/A responses were kept as missing in this table in order to make the summary statistics more meaningful; however, these were recoded like all other N/A responses when computing the index scores

[e]For these questions, if a subject ate those meats less than once a day according to the relevant food frequency survey items, failures to respond and N/A were coded as better than "always purchase grass fed beef/free range chicken" because of the reduced CO2 impact associated with reduced meat consumption. Because of this, the scale was coded on six points ranging from 'do not eat' (0) and "always (purchase)" (0.17) to "never (purchase)" (1)

2.4.2 Validity

Finding associations between different categories of GHG-related behaviors in expected directions demonstrates correlational validity. Therefore, we tested associations between indices. To further validate the SCCBS, we also examined the relationship between the constructed GHG-related behavior indices and reports of personal environmental values. We predicted inverse correlations between GHG behavior scores and individuals' perceived importance of environmental sustainability, number of environmental organizations they belonged to, and number of environmental classes taken.

2.5 Coding

Table 1 reports summary statistics for all items, grouped by index. For purposes of easy interpretation, items that had meaningfully scaled numerical response options, like days per week, summary statistics are reported in the numerical units that were employed on the survey. For items that used ordinal responses, data were converted to a 0–1 scale. For any given question, the number of participants who failed to respond ranged from 0–8 ($M = 1.41$; $SD = 1.49$). On some questions, a not applicable (N/A) response option of either "I don't know" or "I don't perform [activity in question]" was available, and these questions are indicated in the notes of Table 1.

Table 2 Descriptive statistics for each index

Index	Range	Interquartile range	M	Med	SD	Internal consistency reliability (α)	Test-retest reliability (ρ)	Items in each index (n)
Electricity	12.6–65	31–46	38.2	37.9	10.1	0.66	0.88	20
Transport, High GHG	0–81	18–53	36.0	39.0	21.6	0.64	0.91	4
Transport, Low GHG	0–46.7	0–13	9.1	6.7	10.9	N/A[a]	0.64	3
Transport, No GHG	26.7–100	47–67	58.1	60.0	14.2	N/A[a]	0.75	3
Waste	5.1–60.4	26–40	33.4	32.3	10.6	0.81	0.85	10
Food Packaging	2.7–53.6	29–38	33.1	33.0	7.6	0.51	0.79	14
Food, High GHG	4.2–34	15–24	19.4	20.1	6.4	0.62	0.78	18
Food, Low GHG	0–59.2	12–24	19.3	17.8	10.1	0.89	0.83	19
Food Purchasing	15–100	62–95	77.3	83.5	20.7	0.71	0.86	5
GHG Credits	25–100	100–100	97.7	100.0	11.6	N/A	0.64	1

Responses to all survey items were converted to a 0–100 scale, reverse coded if necessary, and then averaged within each index to create index scores. Regarding reverse coding, items were recoded to make them directionality consistent with other items in their scale. In almost all cases a higher scale score corresponded to greater GHG production. Note that, consistent with this, for “Food Purchasing” and “GHG Credits” a higher score indicates that individuals are less likely to purchase environmentally friendly foods or carbon offsets. Exceptions to this rule that “higher scores indicates greater GHG” include the “Transport No GHG” and “Food Low GHG” indices. For those indices, scores have minimal implications for GHG produced, but the behaviors on those scales are often alternatives to high GHG impact behaviors, and thus higher values can be thought of as indicating climate-positive behavior

[a]These items were not intended to be internally consistent

Items were combined into summary index scores by converting each item to a 0–100 scale, reverse coding items if necessary, and then averaging items within each index. See Table 2 for further details.

3 Results

3.1 Descriptive statistics

For each survey item, descriptive statistics are presented in Table 1. Descriptive statistics for each summary index are presented in Table 2.

3.2 Reliability

As can be seen in Table 2, internal consistencies as measured with Cronbach's α ranged from .51 to .89, and test–retest reliabilities for the indices ranged from .64 to .91 ($N = 116$). Regarding the test–retest reliabilities for the individual items, 78% were above .65, 13% were below .65 but above or equal to .60, and the remainder were above .50. We retained some items close to .5 in order to include some behaviors that we considered important, and believe this was justified given the test–retest values for all indices, when including these items, were .64 or greater.

3.3 Validity

Relationships among indices were used to assess correlational validity. Spearman's correlations were used to examine the relationships between different categories of climate relevant behaviors and between each index and the Total GHG Behavior score (Table 3). The GHG Credits scale was not statistically significantly correlated with any other scales, possibly due to its narrow distribution. The transportation-related indices were also less likely to be significantly correlated with the other indices. Most other indices were statistically significantly correlated with one another and the Total GHG Behavior score in the expected directions.

To further assess correlational validity we examined the relationship between the constructed GHG-related behavior indices and reports of personal environmental values, as seen in Table 4. As expected, the Total GHG behavior scores were inversely correlated with individuals' perceived importance of environmental sustainability ($\rho = -.39$, $p < .001$)—in other words, when environmental sustainability was more important to an individual, they produced less emissions. Perceived importance of environmental sustainability was also inversely correlated with the individual Electricity, Waste, Food Packaging, Low GHG Food, Food Purchasing and GHG Credits Scales ($p < .05$), as expected. None of the Transportation behavior scales, nor the High GHG Food Scale, were statistically significantly related to the perceived importance of environmental sustainability. Members of environmental organizations had significantly lower Total GHG Behavior scores than those who did not according to the Wilcoxon Rank-Sum/Mann–Whitney U Test with a correction for continuity ($Z = -2.71$, $p < .01$; membership $N = 10$, M $\pm$ SD $= 30.4 \pm 6.1$, Mdn $= 31.0$, IQ Range $= 8.0$; non-membership $N = 130$, M $\pm$ SD $= 37.2 \pm 7.4$, Mdn $= 37.4$, IQ Range $= 10.0$). When looking at individual indices, statistically

Table 3 Correlation matrix for indices

	Transport, high GHG	Transport, low GHG	Transport, no GHG	Waste	Food packaging	Food, high GHG	Food, low GHG	Food purchasing	GHG credits	Total GHG behavior score
Electricity[a]	0.04	0.09	−0.12	0.58***	0.36***	0.18*	−0.22**	0.36***	0.00	0.73***
Transport, High GHG[a]		0.10	−0.02	0.01	−0.06	0.06	0.13	−0.17*	−0.12	0.46***
Transport, Low GHG[a]			−0.07	0.04	0.19*	0.15	0.05	0.02	−0.10	0.26**
Transport, No GHG				−0.04	−0.10	−0.13	0.02	−0.03	0.07	−0.11
Waste[a]					0.33***	0.15	−0.26**	0.35***	−0.02	0.67***
Food Packaging[a]						0.27***	0.07	0.23**	0.14	0.44***
Food, High GHG[a]							0.18*	0.31***	−0.05	0.40***
Food, Low GHG								−0.37***	0.02	−0.18*
Food Purchasing[a]									0.11	0.52***
GHG Credits										−0.03

Table values are Spearman's rho. See text for more details on the weightings of the indices in the Total GHG Behavior Score

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

[a]Included in Total GHG

Table 4 Correlations between predictor variables and index scores

Question	Index										
	Electricity	Transport, high GHG	Transport, low GHG	Transport, no GHG	Waste	Food packaging	Food, high GHG	Food, low GHG	Food purchasing	GHG credits	Total GHG behavior score
Number of environmental classes	−0.04	0.10	0.05	0.03	−0.15	−0.03	−0.05	0.25**	−0.29**	−0.14	−0.10
Importance of environmental sustainability	−0.45***	0.07	0.08	0.02	−0.38***	−0.22**	−0.09	0.28***	−0.44***	−0.20*	−0.39***
Importance of animal rights	−0.20*	0.11	0.11	−0.07	−0.31***	−0.16	0.09	0.27***	−0.30***	−0.18*	−0.19*
Importance of social justice	−0.26**	0.11	0.05	−0.05	−0.30***	−0.13	−0.06	0.10	−0.19*	−0.14	−0.19*
Distance of residence	−0.19*	0.19*	0.09	0.17*	−0.01	−0.04	−0.03	0.18*	−0.11	−0.15	−0.01
Class (e.g., freshman)	−0.15	0.07	−0.06	0.24**	−0.24**	−0.13	−0.09	0.09	−0.17*	0.00	−0.19*
Age	−0.06	0.13	−0.09	0.23**	−0.12	−0.07	−0.07	0.01	−0.01	−0.02	−0.03

Table values are Spearman's rho. $n = 139$ for questions 144, 135, 136, 137, and BMI. $n = 140$ for questions 129, 143, and age

$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$

significant differences ($p < .05$) between groups occurred in the predicted direction for indices of Electricity, No GHG Transport, Waste, Food Packaging, and Food Purchasing. Statistically significant relationships were not detected between GHG-related behavior indices and the reported number of environment classes taken, except with Low GHG Food and Food Purchasing behaviors, which occurred in the predicted direction.

3.4 Performance of sub-populations

We hypothesized that perceived importance or personal involvement in certain non-environmental causes, including animal rights, social justice, and vegetarianism, would also be related to lower GHG emissions-related behaviors, both for food and for non-food behaviors. As shown in Table 4, Total GHG Behavior scores were statistically significantly inversely correlated to the perceived importance of animal rights and social justice. Examining individual subscales, statistically significant inverse associations were found between perceived importance of both animal rights and social justice and the Electricity, Waste, and Food Purchasing indices, and importance of animal rights was also significantly related to consuming more Low GHG Food and buying GHG Credits. Self-reported vegetarians had statistically significantly lower Total GHG Behavior scores according to the Wilcoxon Rank-Sum/Mann–Whitney U Test with a correction for continuity ($Z = -3.98$, $p < .0001$; vegetarian $N = 10$, $M \pm SD = 26.9 \pm 5.4$, Mdn = 25.5, IQ Range = 10.0; not vegetarian $N = 130$, $M \pm SD = 37.5 \pm 7.2$, Mdn = 37.5, IQ Range = 9.7). Comparing vegetarians to non-vegetarians on their individual SCCBS indices showed statistically significant differences ($p < .05$) in the predicted direction for Electricity, No GHG Transport, High and Low GHG Foods, and Food Purchasing.

Males had greater Total GHG scores than females ($Z = 2.43$, $p = .01$; male $N = 49$, $M \pm SD = 38.7 \pm 6.9$, Mdn = 39.3, IQ Range = 9.1; female $N = 89$, $M \pm SD = 35.5 \pm 7.6$, Mdn = 35.1, IQ Range = 11.1). Males scored higher on the Waste ($Z = 2.60$, $p = .01$), High GHG Food ($Z = 2.22$, $p < .05$), and Food Purchasing ($Z = 2.00$, $p < .05$) indices. As shown in Table 4, college class (freshman to senior) was inversely related to emissions, with underclass students reporting lower scores on Waste and Food Purchasing indices. The distance of one's residence from the campus was not significantly related to the overall GHG emissions score but was significantly positively associated with both reported High GHG and No GHG transportation. The ethnic groups did not differ significantly on Total GHG emissions or any of the scales, except for the Electricity scale, as demonstrated by the Kruskal–Wallis Test (χ^2 (5, $N = 140$) = 12.13, $p < .05$). This was due to Asians having significantly lower scores on the Electricity scale.

3.5 Frequency of specific behaviors

The frequencies of many specific behaviors are presented in Table 5. It can be seen that several behaviors would serve as good targets for behavior change interventions. Examples include reducing the length of showers; turning off lights and technologies; and reducing waste, car trips, elevator use, and meat consumption. The frequencies of other behaviors are likely due to environmental constraints or opportunities. For example, 31% of students report that purchasing compact fluorescent light bulbs

Table 5 Potential intervention target behaviors

Behavior	% of Students
Electricity (or gas)	
Students who shower longer than 10 min on average	60%
Students who leave the lights on at least half of the time when leaving a room	20%
Students who leave the television on at least half of the time when leaving a room	10%
Students who do not turn off their computers at night	50%
Students who do not put their computers into sleep mode at night	10%
Students who never use a clothesline	49%
Students who use elevators	36%
Transporation	
On-campus residents making 1+ (6+) car trips per week to an on-campus location	53% (11%)
Waste	
Students who recycle only half of the time or less	30%
Students who do not reuse old bags half the time or more when food shopping	87%
Students who do not leave produce loose half the time or more when food shopping	84%
Students who drink 3+ servings per week of bottled canned water or soda beverages	70%
Students who never bring a reusable drinking container to eating venues that provide disposables	70%
Food	
Students who eat meat more than once a day (not including fish)	64%
Students who eat 3+ servings per week of beef	36%
Students who eat 3+ servings per week of prepackaged processed snack foods	64%
Carbon credits	
Students who never purchase carbon credits	96%

is not applicable to them, 22% report that purchasing recycled paper is not, 10% report that purchasing produce is not, and 31% report that purchasing meat is not. It is worth noting that constraints can be environmentally advantageous as well; for example, almost half of the students do not have residential air conditioning (38%) or a car that they regularly use (45%). Some behaviors may be due to educational barriers; for example, on the question regarding carbon credits purchases, 55% of students selected the option "I do not know what this means."

4 Discussion

4.1 Summary

Tools for measuring climate-relevant behaviors are needed to (1) identify which populations and behaviors should be targeted with behavioral, technological, and/or policy interventions that reduce greenhouse gas emissions, (2) evaluate the efficacy of such interventions, (3) test associations between self-reported behaviors and objective measures of greenhouse gas emissions in order to better establish the impact of specific behaviors, and (4) describe the population frequencies of GHG-emissions related behaviors and track these over time, for example, to improve models of energy use and to aid policy makers in understanding energy consumption trends.

To accomplish these goals, measurement tools need to be capable of evaluating a large number of potentially malleable individual behaviors (as opposed to aggregating over them), provide data on specific behaviors instead of on knowledge, attitudes, beliefs or intentions, and be reliable and valid. To date, surveys have not met these criteria. Our results indicate that the SCCB Survey is a reliable and valid instrument for assessing individual-level behaviors associated with greenhouse gas emissions in college students, and we anticipate that it will also be useful for assessing these behaviors in other adolescent or adult populations.

4.2 Establishing the measure

Test–retest reliability is important to minimize measurement error that could obscure differences between individuals or groups, changes over time, or relationships with other behaviors or characteristics. Test–retest reliability of each individual SCCBS question was moderate to high. We also assessed internal consistency reliability for each of the ten different indices in four main end use categories of energy, including transportation, electricity, waste, and food. Internal consistency reliability is an indication of whether responses to the questions in an index are similar when answered by the same participant. In some cases we accepted internal consistency reliability lower than the typical 0.7 (Nunnally 1978) because the items in each scale were primarily selected to capture the range of possible behaviors, and only secondarily to provide multiple measures of the same construct (how internal consistency reliability is often used).

Validity is important to demonstrate that a measure is assessing the construct of interest. We assessed validity by examining associations between measures that are expected to be related (correlational validity). We first assessed validity by testing correlations between individual indices. As expected, we found that individuals who report GHG-related behaviors in one domain are also generally more likely to report other GHG-related behaviors in other domains. The absence of correlations between the transportation and other scales may have occurred because transportation behaviors may be more constrained by situational variables among college students than some of the other behaviors (e.g., access to automobiles, location of residences).

We also examined the correlational validity of the SCCBS by testing whether students who say they value environmental sustainability or are members of an environmental group also report lower levels of GHG emissions-related behaviors. As expected, GHG-related behaviors scores were significantly inversely associated with reported importance of environmental sustainability, as well as membership in an environmental group. We also anticipated that students who valued social justice and animal rights, and those who identify themselves as vegetarians, would report less food as well as non-food GHG emissions-related behaviors. This was borne out by the data. These various findings of correlational validity increase our confidence that the SCCBS is a reliable and valid tool for assessing GHG emissions-related behaviors in college students. The weak relationship between the number of environmental courses one had taken and emissions behaviors may be the result of the heavy emphasis on technological and policy-oriented solutions in the courses, rather than personal behavior change. This is consistent with literature reporting a limited relationship between behavior and environmental education when the latter does not specifically target behavior change (Zelezny 1999).

4.3 Identifying specific target populations and behaviors

In the present study, several subgroups of students could be identified as needing improvement, including those who were male, and those with fewer years in college. Other subgroups were identified who report low GHG emissions-related behaviors. These groups could be studied in more detail, in order to elucidate hypotheses regarding how to facilitate change in groups with high GHG emissions. Groups of students who participated in fewer GHG-emissions behaviors included those for whom social justice or animal rights were important. Vegetarians participated in fewer GHG-emissions behaviors than non-vegetarians, and these effects were not merely due to eating patterns but also to reduced electricity use and other behaviors. Also, Asians used less electricity than other groups.

Many behaviors were identified that could be targeted for improvement. Additional behaviors that showed room for improvement may be influenced by environmental constraints or opportunities, and, as a result, may need to be addressed through campus infrastructure. Specifically, a large percent of students do not purchase light bulbs, paper, or produce and meat, and thus do not exercise control in choices related to these items, presumably because these items are provided by the university in on-campus housing and dining situations. Half of students never use a clothesline, likely because there are almost no clotheslines on campus and little space for drying racks. It is worth noting that constraints can be environmentally advantageous as well, so that universities can promote sustainability through institutional practices, as was seen here with constraints on residential air conditioning and on-campus car use. Carbon credit purchases could perhaps be increased through education, given that a lack of knowledge appears to be a major barrier to this behavior.

4.4 Evaluating programs, assessing the impact of behaviors, and projecting trends

In addition to identifying populations and behaviors to target with interventions, the survey can be used for evaluating these interventions. The scale on each survey question was specifically developed to be sensitive to behavior change within individuals so that it could be used for pre- and post-assessments of interventions. Evaluating interventions is important for improving their efficacy, for identifying best practices, and for demonstrating results to policymakers, regulators, and funding sources.

In future work, a correspondence between survey questions and emissions could be established by collecting self-report survey data on individuals during the same period that their appliance-specific electricity use is directly measured. This would be useful for acquiring impact estimates of specific behaviors, so that when objective measures of emissions are not feasible the present survey could be used to estimate the GHG footprint. Establishing a relationship between behaviors and objective measures of greenhouse gas emissions could also improve carbon calculators (Padgett et al. 2008).

The survey can also be used to estimate individual and population frequencies of greenhouse gas emissions-related behaviors and changes in their frequencies over time. These data are useful for a variety of reasons. For example, an understanding of the frequencies with which building residents engage in various energy-consuming behaviors could help elucidate why actual building energy performance is typically poorer than predicted (or modeled) performance (Turner and Frankel 2008). An understanding of changes in frequencies of behaviors over time could also be useful for describing trends and developing projections, in order to improve models and guide policy.

4.5 Strengths and limitations

To meet the need of providing a more comprehensive assessment of GHG-related behaviors, the SCCB Survey typically takes twenty or more minutes to complete. It may be appropriate for some users to administer the survey without some of the low impact or rarely performed behaviors or to focus on just those indices of most interest in their particular context.

The SCCB Survey was developed for college students, and is also appropriate for high school students and renters. Modified versions could be developed to make it more appropriate for other populations as well. For example, including behaviors related to performing retrofits and purchasing appliances might be relevant when surveying homeowners (Mills 2007a). Also, given the survey was developed with Stanford students, future evaluations of the survey in more diverse populations is warranted to ensure its appropriateness with different target populations.

In order to select target behaviors, several characteristics of behaviors should be taken into account including their frequencies and durations, the quantity of GHG emissions produced by each behavior, and the malleability or the ease of changing of each type of behavior. The SCCBS assessed the frequencies/durations of behaviors. A first step in measuring the quantity of GHG emissions produced by each behavior might be to obtain impact estimates from existing sources. Such estimates could be derived from government or academic documents (e.g., Ekvall et al. 1998; Hekkert et al. 2000; Foster et al. 2006; Mills 2007b; Vandenbergh et al. 2008), although this would require additional calculations and assumptions to produce carbon footprint lifecycle impact estimates for individual behaviors. With this information, each item in our survey could then be weighted appropriately with its impact to be predictive of energy use, and summing across items in a scale should be predictive of energy use for the designated category. It may be worth emphasizing that, although useful to extend in the aforementioned way, the current survey is not intended to quantify individuals' cumulative GHG impact. In contrast to other tools such online calculators, the current survey was primarily developed to be sensitive to change in GHG relevant behaviors, with an emphasis on behaviors under the control of individuals who may not own their own homes.

Surveys are useful and necessary in large samples and in situations where behavior is difficult to measure objectively, as is currently the case with GHG relevant behaviors. However, this survey suffers from the same difficulties that all surveys do in that the answers are self-reported, and subjects might not fully recollect their actions or might answer in the way that they believe is socially desirable. Further work could include validating the study with empirically observable behaviors, where possible. As smart meters and other wireless energy sensors become pervasive, objective measures of energy consumption can be used as proxies for GHG emissions for some of the behaviors surveyed here.

4.6 Conclusions

The findings presented here suggest that the SCCB Survey is a reliable and valid instrument that can be used to assess individual-level behaviors associated with greenhouse gas emissions in college students, and we anticipate it to also be useful for assessing these behaviors in other adolescent or adult populations. It can be used for a variety of purposes, ranging from intervention planning and evaluation to establishing energy use trends in populations to help inform policy.

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References

Bandura A (1986) Social foundations of thought and action. Prentice-Hall, Englewood Cliffs

Bandura A (1997) Self-efficacy: the exercise of control. Freeman, New York

Barr S (2007) Factors influencing environmental attitudes and behaviors: a U.K. case study of household waste management. Environ Behav 39:435–473

Berger IE (1997) The demographics of recycling and the structure of environmental behavior. Environ Behav 29:515–531

Blake DE, Guppy N, Urmetzer P (1997) Canadian public opinion and environmental action: evidence from British Columbia. Can J Polit Sci 30:451–472

Darby S (2006) The effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays. Environmental Change Institute, University of Oxford, Oxford

EIA (2009) Annual energy outlook 2009 with projections to 2030. Updated Annual Energy Outlook 2009 Reference Case with ARRA. http://www.eia.doe.gov/oiaf/servicerpt/stimulus/aeostim.html Accessed 6 August 2010

Ekvall T, Person L, Ryberg A, Widheden J, Frees N, Nielsen PH, Pedersen BW, Wesnaes M (1998) Life cycle assessment of packaging systems for beer and soft drinks: main report. Environmental Project, Report No. 399, 1–388. Ministry of Environment and Energy. Danish Environmental Protection Agency, Denmark

Environmental Protection Agency (2008) Inventory of U.S. greenhouse gas emissions and sinks: 1990–2006. Report no. 430-R-08-005

Foster C, Green K, Bleda M, Dewick P, Evans B, Flynn A, Mylan J (2006) Environmental impacts of food production and consumption: a report to the department for the environment, food, and rural affairs. Manchester Business School. Defra, London

Gatersleben B, Steg L, Vlek C (2002) Measurement and determinants of environmentally significant consumer behavior. Environ Behav 34:335–362

Guagnano GA, Stern PC, Dietz T (1995) Influences on attitude behaviour relationships, a natural experiment with curbside recycling. Environ Behav 27:699–718

Haustein S, Hunecke M (2007) Reduced use of environmentally friendly modes of transportation caused by perceived mobility necessities: an extension of the theory of planned behavior. J Appl Soc Psychol 37:1856–1883

Hekkert MP, Joosten LAJ, Worrell E, Turkenburg WC (2000) Reduction of CO2 emissions by improved management of material and product use: the case of primary packaging. Resour Conserv Recycl 29:33–64
Kaiser FG (1998) A general measure of ecological behavior. J Appl Soc Psychol 28:395–422
Katzev RD, Johnson TR (1984) Comparing the effects of monetary incentives and foot-in-the-door strategies in promoting residential electricity conservation. J Appl Soc Psychol 14:12–27
Mills E (2007a) Home energy saver. Ernest Orlando Lawrence Berkeley National Laboratory. http://HomeEnergySaver.lbl.gov. Accessed 10 May 2008
Mills E (2007b) The home energy saver: documentation of calculation methodology, input data, and infrastructure. Ernest Orlando Lawrence Berkeley National Laboratory, Report No. LBNL-51938
Nunnally JC (1978) Psychometric theory, 2nd edn. McGraw-Hill, New York
Padgett P, Steinemann AC, Clarke JH, Vandenbergh MP (2008) A comparison of carbon calculators. Environ Impact Assess Rev 28:106–115
Painter J, Semenik R, Belk R (1983) Is there a generalized energy conservation ethic? A comparison of the determinants of gasoline and home heating energy conservation. J Econ Psychol 3:317–331
Pimentel D, Pimentel M (2003) Sustainability of meat-based and plant-based diets and the environment. Am J Clin Nutr 78:660S–663S
Pimentel D, Pimentel M (2007) Food, energy, and society, 3rd edn. CRC, Boca Raton
Porter BE, Leeming FC, Dwyer WO (1995) Solid waste recovery: a review of behavioral programmes to increase recycling behaviour. Environ Behav 27:122–152
Rimm EB, Giovannucci EL, Stampfer MJ, Colditz GA, Litin LB, Willet WC (1992) Reproducibility and validity of an expanded self-administered semiquantitative food frequency questionnaire among male health professionals. Am J Epidemiol 135:1114–1126
Schultz WP, Oskamp S (1996) Effort as a moderator of the attitude-behaviour relationship: general environmental concern and recycling. Soc Psychol Q 59:375–383
Steg L, Vlek C (1997) The role of problem awareness in willingness-to-change car use and in evaluating relevant policy measures. In: Rothengatter JA, Carbonell Vaya E (eds) Traffic and transport psychology. Theory and application. Pergamon, Elmsford, pp 465–475
Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (2006) Livestock's long shadow - environmental issues and options. Food and Agriculture Organisation of the United Nations, Rome. ftp://ftp.fao.org/docrep/fao/010/a0701e/a0701e00.pdf Accessed 2 May 2010
Turner C, Frankel M (2008) Energy performance of LEED® for new construction buildings. Final Report. U.S. Green Building Council, Washington
Van Lange PAM, Van Vugt M, Meertens RM, Ruiter RA (1998) A social dilemma analysis of commuting preferences: the roles of social value orientations and trust. J Appl Soc Psychol 28:796–820
Vandenbergh MP, Barkenbus J, Gilligan J (2008) Climate change: the low-hanging fruit. UCLA Law Rev 55:1701–1758
Wiidegren O (1998) The new environmental paradigm and personal norms. Environ Behav 30:75–100
Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, Hennekens CH, Speizer FE (1985) Reproducibility and validity of a semiquantitative food frequency questionnaire. Am J Epidemiol 122(1):51–65
Winett RA, Leckliter IN, Chinn DE, Stahl B, Love SQ (1985) Effects of television modeling on residential energy conservation. J Appl Behav Anal 18:33–44
Zelezny L (1999) Educational interventions that improve environmental behaviors: a meta-analysis. J Environ Educ 31(1):1–20