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Kate Robertson
Energy Efficiency Specialist
krobertson@edf.org
512-691 3423

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What is the difference between energy conservation and energy efficiency?

Although the terms "energy conservation" and "energy efficiency" are often used interchangeably, they do not in fact mean the same thing. *Energy conservation* means cutting waste. *Energy Efficiency* means using technology to achieve the same result while using less energy. For example, a new air conditioning unit will cool a house the same as the older unit, but will do so more efficiently, or by using less energy. But if a person runs the new unit all day at low temperatures, that is wasting energy. Basically, efficiency involves technology and conservation involves behavior.

Public perceptions of conservation and efficiency

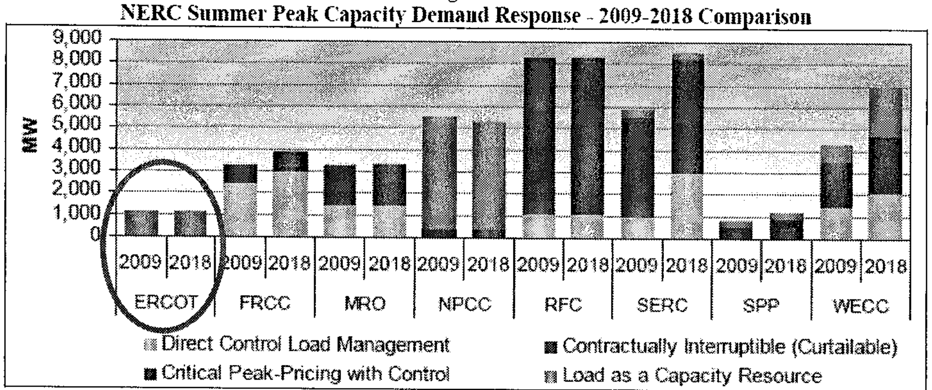
Efficiency can lead to conservation, but not necessarily. These concepts can be confusing to the average consumer and programs and outreach initiatives may not be adequate to help clear up the confusion. In a recent survey whose results were published in the Proceedings of the National Academies of Science (see attached), researchers found that participants were misinformed about what are the most effective energy-saving strategies. The majority of participants believed that conservation measures were more effective than efficiency measures, despite recommendations from efficiency experts. 19.6 percent of participants believed that turning off lights was the single most effective thing they could do to conserve energy whereas only 3.2 percent believed that using efficient appliances was the most effective. Conservation is often equated with sacrifice, and this survey shows that many people still equate conservation or efficiency with that—picture Jimmy Carter in his sweater urging people to conserve. But actually the biggest bang for the buck is a combination of *efficiency* with *conservation*. Outreach initiatives do not seem to be getting this point across effectively.

Most people have no idea how much energy they use in daily life. A solution to this problem could be smart meters, which some utilities in Texas are rolling out into homes and businesses across the state. A smart meter would enable a consumer to see how much electricity they're using and the differences in pricing of that electricity, and could encourage them to change their behavior to save money. But understanding the smart meters and how to adapt to them will still require some consumer education. Energy use and efficiency are complicated, and most consumers need some guidance to take the best advantage of the options that will save energy and money.

Demand Side Management

In addition to educating consumers about the basics of efficiency versus conservation, a demand side management program could enable consumers to have greater control over their energy information and usage. Currently, very a number of other grid operators have effectively deployed economic demand side management (DSM) that is bid into grid marketplaces. In Texas, as shown in the chart below ERCOT has lagged behind this national trend that has benefitted customers by reducing market costs and paying DSM participants. Texas expanding smart grid infrastructure provides a critical opportunity to take advantage of this inexpensive resource through programs such as dynamic pricing and demand response.

Figure 4
NERC Summer Peak Capacity Demand Response - 2009-2018 Comparison



Source: NERC, Long-Term Reliability Assessment, 2009, Figure 7 (page 18).

It is important to achieve the greatest economic efficiency in deploying such programs, i.e. the full value of the service provided by participants is passed to them as efficiently as possible. Economic efficiency ensures that programs are neither over subsidized nor undervalued – which could lead to less DSM being subscribed than would benefit the market. The best way to accomplish this goal is to allow participants to bid (either directly or through aggregators) into the ERCOT energy market. Some utilities have internal programs, but to capture the full value of these programs for both utilities and customers it is important to allow them to participate in the ERCOT market directly.

These programs have been shown to work effectively without subsidies in other regions; they did not work historically in ERCOT because little energy was actually traded directly in the ERCOT marketplace (about 5%). As ERCOT transitions to the nodal market the energy market is expected to grow substantially, yet there is currently no plan to develop DSM programs in the new nodal market despite clear benefits to customers.

DSM programs are fundamentally customer driven market participation programs – each customer chooses whether or not they wish to participate. Customers who want to participate in the market can get paid and at the same time help reduce the costs of system services, this benefit is estimated to cover 5-10% of a customer's bill for economic. By allowing customers to bid into the market competitive forces will ensure that economically efficient demand side management will be used, resulting in downward pressure on energy market prices.

James A. Baker III Institute for Public Policy
Rice University

Participation in the City of Houston's Residential Energy Efficiency Program

By

Alexandra Ernst
Rebecca Jaffe
Noemie Levy
Claire O'Connor
Rachel Solnick
Robert M. Stein
Stephanie Post

Rice University

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Introduction

The City of Houston's (COH) Residential Energy Efficiency Program (REEP) has weatherized more than 8,300 homes in 12 different neighborhoods since 2006. Homeowners who participated in the program have seen monthly "weather-adjusted" kWh energy reductions[1] of 12 to 15 percent and up to 20 percent in the summer months, when Houston residents use their air conditioning the most. These homeowners will continue to realize savings for the next 10 to 15 years.

Despite significant savings that directly benefit REEP participants, approximately 64 percent of qualified Houston households have yet to participate. This study seeks to identify the reasons individuals agree or decline to participate in the program. Using survey data, we examine the factors that influence the likelihood of participation, including an individual's attitude toward energy conservation, neighborhood social networks, energy costs, and demographic traits. The goal of the study is to help the COH enhance program participation.

Survey

To examine the reasons why people chose to participate or not to participate in the REEP program, we conducted a survey of 500 potentially eligible households in the southwest Houston neighborhood of Sharpstown.[2] Sharpstown is an ethnically diverse community of approximately 10,000 families. This neighborhood was selected because a large number of Sharpstown

[1] Weather adjustments describe the different techniques used to protect a home from the elements and to optimize energy efficiency of a home. These seasonal adjustments can include caulking windows, installing attic insulation, sealing doors, and other energy conservation techniques that mitigate the effects of weather on a home. However, "weather adjustments" depend upon the climate of the region due to the different uses of the adjustments when subjected to either extreme "heating" or "cooling" days.

[2] This was a random digit dial telephone survey of 500 households in the Sharpstown neighborhood between May 18 and June 1, 2010. The error rate for this survey is ± 4.5 percent. The American Association for Public Opinion Research response rate is 28 percent.

residents potentially meet the income requirements for the REEP. In 2008, 26 percent of Sharpstown residents had incomes below the federal poverty line; the average annual household income was approximately $27,000.

Respondents were initially asked if they would be willing to participate in a City of Houston program that provides qualified residents with free home improvements designed to reduce heating and air conditioning costs. This program includes attic insulation, weather stripping, window caulking, energy saving light bulbs, and insulation for household water heaters. All labor and material costs are paid for by the city. At the beginning of the survey, 56 percent of the respondents indicated they would participate.

The survey then queried respondents about items such as:

- their monthly energy bills
- concern about their energy bills
- current efforts to save energy
- trust in city government to do the right thing
- the influence of their neighbors and other social networks on their decision
- demographics such as age, income, and marital status

Respondents were also read a series of statements about the program designed to highlight some of the advantages and disadvantages of participation. After each statement, respondents were asked if that statement made them more or less likely — or made no difference in their decision — to participate in the program. These statements included:

- Improvements would save an average of $50 to $100 on monthly energy bills over the next 10 years.
- The program provides free labor and materials.
- Improvements would increase the resale value of their house.
- Participants need to fill out paperwork that requires personal information, such as annual income.
- Home improvements would require a professional to visit the home at least three times.

After hearing information regarding the program's benefits, 62 percent expressed interest in participating in the program, reflecting a net gain of 6 percent.

Findings

Concerns about energy bills, the size of energy bills, and promises of reduced energy bills are the key factors influencing a respondent's willingness to participate in the program. Specifically, single respondents were more likely than married individuals to express concern about their energy bills. People of African-American descent and women were more likely to be concerned about their energy bills. Respondents who thought they had high energy bills also were more likely to participate in the program, regardless of income level.

When respondents were told REEP home improvements would allow them to save an average of $50 to $100 on monthly energy bills over the next 10 years, 69 percent indicated they would participate. Similarly, 61 percent of respondents indicated they would be interested in program participation if it increased the resale value of their home.

A significant proportion of respondents were more likely to participate in the REEP if they knew their neighbors were also participating in the program.

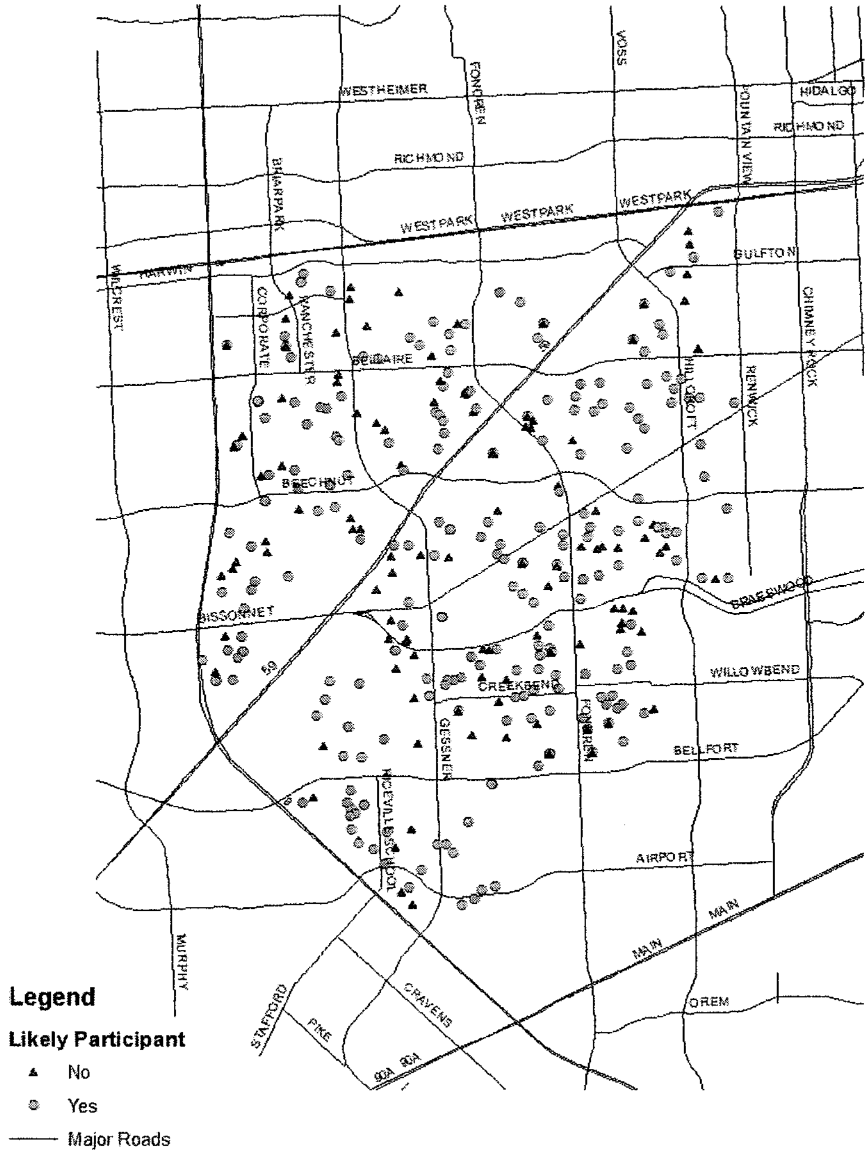
Interestingly, the respondents' experience with and attitudes toward government showed no effect on their willingness to participate in the program. In addition, attitudes about the environment and conservation did not influence the likelihood of participation in this program. Internet websites were cited by 38 percent of all respondents as a source of information they would use when "considering to participate in the COH's home weatherization program."

Recommendations

Now is a good time to advertise the program. People are especially concerned about their ability to pay for utilities during a recession and the summer months. With this in mind, the City of Houston should consider the following when promoting the program:

- Promotional materials for the REEP should emphasize the potential reduction of monthly energy bills and increased resale value of a home.
- Advertising materials should target singles, women, and people of African-American descent.
- Because people are more likely to participate if their neighbors do as well, homes undergoing weatherization should post lawn signs advertising the REEP.
- Educational and advertising programs should encourage potential participants to visit the COH's REEP website for additional information and as a means of enrolling in the program.
- The Sharpstown neighborhood bounded by Bellaire on the north, Fondren on the west, Beechnut on the south, and Hillcroft on the east should be targeted for participation in the REEP. Other neighborhoods where respondents expressed interest in the REEP include: S. Braeswood (North), S. Gessner (West), W. Bellfort (South), and Fondren (East); Harwin (North), S. Gessner (West), Bellaire (South), and Fondren (East).

Potential Participants in REEP



Public perceptions of energy consumption and savings

Shahzeen Z. Attari[a,1], Michael L. DeKay[b], Cliff I. Davidson[c,d,2], and Wändi Bruine de Bruin[c,e]

[a]The Earth Institute and Center for Research on Environmental Decisions, Columbia University, New York, NY 10027; [b]Department of Psychology, Ohio State University, Columbus, OH 43210; and Departments of [c]Engineering and Public Policy, [d]Civil and Environmental Engineering, and [e]Social and Decision Sciences, Carnegie Mellon University, Pittsburgh, PA 15213

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In a national online survey, 505 participants reported their perceptions of energy consumption and savings for a variety of household, transportation, and recycling activities. When asked for the most effective strategy they could implement to conserve energy, most participants mentioned curtailment (e.g., turning off lights, driving less) rather than efficiency improvements (e.g., installing more efficient light bulbs and appliances), in contrast to experts' recommendations. For a sample of 15 activities, participants underestimated energy use and savings by a factor of 2.8 on average, with small overestimates for low-energy activities and large underestimates for high-energy activities. Additional estimation and ranking tasks also yielded relatively flat functions for perceived energy use and savings. Across several tasks, participants with higher numeracy scores and stronger proenvironmental attitudes had more accurate perceptions. The serious deficiencies highlighted by these results suggest that well-designed efforts to improve the public's understanding of energy use and savings could pay large dividends.

climate change | decision making | judgment | environmental behavior | anchoring

Anthropogenic CO_2 emissions are contributing to global climate change (1) and could negatively impact our way of life if serious action is further delayed. The United States produces 21% of the world's CO_2 emissions, with 98% of US emissions attributed to energy consumption (2).

According to Pacala and Socolow (3), increasing energy efficiency and curtailing activities that consume energy may be our cheapest options for stabilizing atmospheric CO_2 concentrations below a doubling of preindustrial concentrations. Following the analogy of *stabilization wedges* (3), Dietz et al. (4) devised a potential *behavioral wedge*, recommending specific behavioral changes, such as weatherization investments, to be adopted by US households to decrease their emissions. Vandenbergh et al. (5) identified seven actions, such as reducing automobile idling and substituting compact fluorescent light bulbs (CFLs) for incandescent bulbs, that have the potential to achieve large emission reductions at a low cost to the government and with a net savings for individuals. In related work, Gardner and Stern (6) identified a *short list* of the most effective actions US households could take to decrease their contributions to climate change. They argued that by changing the selection and use of household and motor vehicle technologies, households could reduce their energy consumption by nearly 30%—without waiting for new technologies, making major economic sacrifices, or losing a sense of well-being. If households effectively implemented all of Gardner and Stern's recommended changes, US energy consumption would be reduced by approximately 11%. Similarly, Dietz et al. (4) estimated that behavioral interventions could reasonably achieve a 20% reduction in CO_2 emissions from household energy use (a 7.4% reduction in total US emissions) within 10 y.

Gardner and Stern (6) also speculated that people harbor misconceptions about the effectiveness of their actions. For example, "turning out lights when leaving the room" is often suggested as a way to save energy, but it actually saves very little (7). Although Gardner and Stern did not examine people's perceptions of the behaviors on their short list, other research indicates that members of the general public have a poor understanding of the mechanisms involved in climate change (8, 9) and of the energy consumption associated with familiar activities, even though the public may believe that climate change is real (10). For example, Larrick and Soll (11) reported that people in the United States mistakenly believe that gasoline consumption decreases linearly rather than nonlinearly as an automobile's gas mileage (in miles per gallon) increases. Describing vehicles' fuel efficiency in terms of "gallons per 100 miles" corrected this misperception and led to more fuel-efficient choices. The authors therefore recommended that the United States switch to the latter metric.

Demand-side policy responses to climate change, such as encouraging consumers to adopt more efficient technologies, would benefit from a better understanding of how much individuals know about energy consumption in situations in which they have some direct control. In this study, we investigated public perceptions of energy use and potential energy savings associated with a variety of activities, devices, and technologies, many of which were drawn from Gardner and Stern's (6) short list.

For a key portion of our study, we used the classic risk-perception research of Lichtenstein et al. (12) as a guiding analogy. Those authors asked people to estimate the number of annual deaths in the United States from 30 causes (e.g., heart disease, tornadoes). Although participants' estimated fatality rates were positively correlated with actual fatality rates, the slope of the relationship was relatively flat, with overestimates for low risks and underestimates for high risks. The availability heuristic (13–15), a judgment process in which the frequency of an event is estimated according to the ease with which specific instances come to mind, provides one explanation for this result. Judging by availability can result in estimates that are generally accurate but with systematic overestimates for frequencies of vivid low-probability events (13, 15). A second explanation is provided by the anchoring-and-adjustment heuristic (14, 16), in which a person generates a numerical judgment by first adopting a salient reference point as a starting value and then adjusting his or her judgment in the desired direction. Adjustment is typically insufficient, leading to relative insensitivity to the magnitudes of true differences in frequency estimation tasks. Hertwig et al. (17) replicated Lichtenstein et al.'s (12) results using German fatality rates but argued that the primary pattern could be explained either by the availability heuristic or by direct frequency encoding (learning the true frequencies through experience) combined with regression toward the mean. Because similar judgment processes are likely to affect estimates of energy use and savings, we anticipated that the relationship between participants' estimates and the actual values would be relatively flat. In addition, we expected that some in-

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[1]To whom correspondence should be addressed: E-mail: shahzeen.attari@gmail.com.

[2]Present address: Syracuse Center of Excellence in Environmental and Energy Systems and Department of Civil and Environmental Engineering, Syracuse University, Syracuse, NY 13244.

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SUSTAINABILITY SCIENCE

dividual differences, such as education, numeracy, and pro-environmental attitudes and behaviors, would be associated with more accurate perceptions of energy consumption and savings.

Results

Perceptions of the "Most Effective Thing." The study began with an open-ended survey question that asked participants to indicate the most effective thing they could do to conserve energy. Two judges identified 17 mutually exclusive categories of responses in an initial set of 40 surveys (Table 1) and then independently coded the remaining responses. Interrater agreement was "almost perfect," with $\kappa = 0.82$ (18). We further classified these categories as curtailment actions (e.g., *Turn off lights*) or efficiency actions (e.g., *Use efficient light bulbs*), although some ambiguous responses (e.g., *Conserve energy*, *Recycle*) could not be classified in this manner. Despite Gardner and Stern's (6) conclusion that efficiency-improving actions generally save more energy than curtailing the use of inefficient equipment, only 11.7% of participants mentioned efficiency improvements, whereas 55.2% mentioned curtailment as a strategy for conserving energy.

Perceptions of Energy Used and Saved. Each participant estimated the energy used by nine devices and appliances and the energy saved by six household activities, with the energy used by a 100-W incandescent light bulb in 1 h provided as a reference point. For each participant, we assessed the correlation between these perceptions and actual energy use and savings (as determined from the literature), after transforming both distributions with base-10 logarithms to reduce positive skew. The mean correlation between log10*Perception* and log10*Actual* was $r = 0.51$ [$t(488) = 36.34$, $P < 0.0001$, $\eta^2 = 0.70$], indicating that participants had significant (but imperfect) knowledge of which devices and activities were associated with greater energy use and savings.

To examine this relationship in more detail, we used the multilevel regression model (18, 19) in Eq. **1** to predict participants' perceptions of energy use and savings as a function of actual energy use and savings.

$$\log10Perception_{ij} = \beta_{0j} + \beta_{1j}\log10Actual_i + \beta_{2j}(\log10Actual_i)^2 + r_{ij} \quad [1]$$

In this equation, i indicates the device or activity and j indicates the participant. We modeled variation among participants by letting β_{0j} and β_{1j} vary about their average values, thereby allowing each participant to have his or her own regression equation (i.e., participant j's intercept and slope differed from the average intercept and slope). In contrast, we treated the quadratic effect as fixed, so β_{2j} was the same for all participants (see *SI Text*). The functional form in Eq. **1** is the same as that used in studies of risk perception (12, 17), but we centered the values of log10*Perception* and log10*Actual* relative to the original mean of log10*Actual*, so that the coefficients would be more interpretable. The intercept β_{0j} indicates over- or underestimation, the slope β_{1j} indicates the general relationship between perceptions and actual values, and the coefficient for the quadratic term β_{2j} indicates the curvature in that relationship. This specification allows for a detailed assessment of the accuracy of participants' perceptions; for perfectly accurate perceptions, $\beta_{0j} = 0$, $\beta_{1j} = 1$, and $\beta_{2j} = 0$.

The two predictors in Eq. **1** accounted for 40% of the within-participant variation in energy perceptions (see *SI Text*). Results for the average parameter estimates are shown in Fig. 1, along with mean perceptions for the 15 devices and activities (Fig. 1 *Inset*, which highlights variation across participants, is discussed in the next section). The average intercept, which gives the average elevation of perceptions at the mean of log10*Actual*, was significantly negative [$M(\beta_{0j}) = -0.44$, $t(492) = -18.03$, $P < 0.0001$]. On average, participants underestimated energy use and savings by a factor of $10^{0.44} = 2.8$.

The average slope, evaluated at the mean of log10*Actual*, was significantly greater than zero [$M(\beta_{1j}) = 0.28$, $t(6824) = 26.91$, $P < 0.0001$] but significantly less than 1 [$t(6824) = -69.70$, $P < 0.0001$]. This gradual slope reflects two features of the data. First, it reflects the imperfect correlation between perceived and actual values. This regression toward the mean occurs whenever variables are imperfectly correlated, but it does not "explain" why the correlation is imperfect (21). Second, participants' perceptions of energy use and savings were much less variable than actual energy use and savings: The mean SD of log10*Perception*, 0.44, was approximately half that of log10*Actual*, 0.82. On average, participants demonstrated only slight sensitivity to the size of actual energy differences. For example, participants correctly reported that desktop computers consume more energy than laptop computers, but they greatly underestimated the magnitude of this difference (a perceived ratio of 1.2 rather than 2.9). This compression bias (22) is consistent with participants using the 100-Wh reference point as an anchor from which they adjusted insufficiently (15, 16).

The quadratic effect was significant and negative [$M(\beta_{2j}) = -0.19$, $t(6824) = -18.56$, $P < 0.0001$], yielding a function that is essentially flat when actual consumption and savings are high. Indeed, participants did not make accurate distinctions among large appliances, despite a 10-fold difference in actual energy use. For example, participants estimated that line-drying clothes saves more

Table 1. Categorized responses to an open-ended question about the single most effective thing that participants could do to conserve energy in their lives

Behavior category	Curtailment (C) or efficiency (E)	Percentage of participants
Turn off lights	C	19.6
Conserve energy		15.0
Drive less/bike/use public transportation	C	12.9
Change the setting on the thermostat	C	6.3
Change my lifestyle/not have children	C	5.9
Unplug appliances	C	5.7
Shut off appliances/use appliances less	C	4.9
Recycle		4.2
Other (for behaviors only mentioned once)		4.0
Education/think about my actions		3.8
Use efficient light bulbs	E	3.6
Use efficient appliances	E	3.2
Use efficient cars/hybrids	E	2.8
Sleep more/relax more		2.8
Buy green energy/solar energy/alternative energy		2.6
Insulate my home	E	2.1
There is no way/I don't know		0.8

Some behaviors could not be unambiguously classified as curtailment or efficiency.

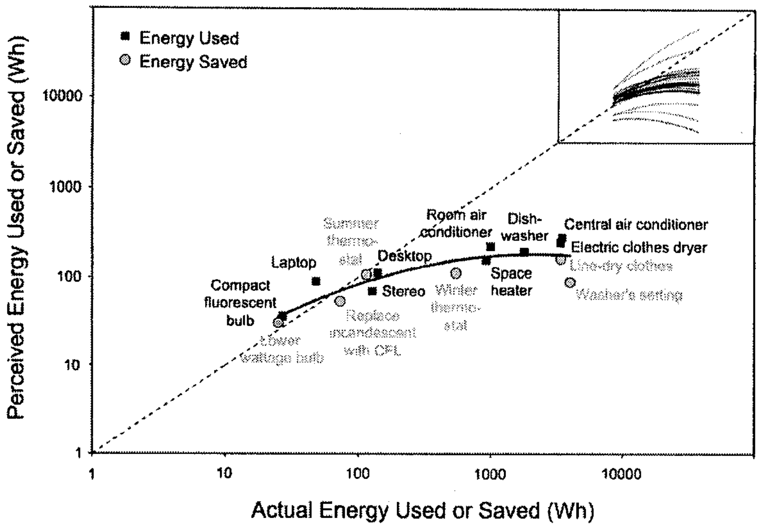

Fig. 1. Mean perceptions of energy used or saved as a function of actual energy used or saved for 15 devices and activities. Error bars for 95% confidence intervals are omitted because they are typically no taller than the symbols themselves. The diagonal dashed line represents perfect accuracy. *Inset:* Individual regression curves for 30 randomly selected participants.

energy than changing the washer's settings (the reverse is true) and estimated that a central air conditioner uses only 1.3 times the energy of a room air conditioner (in fact, it uses about 3.5 times as much). Respondents were relatively more accurate for behaviors in the middle and lower end of the range (e.g., using a desktop computer, changing their summer thermostat, replacing an incandescent bulb with a CFL, replacing a 100-W bulb with a 75-W bulb). Overall, the combination of mean underestimation and a gradual slope that is flatter for high-energy values reflects very minor overestimates when actual energy use and savings are low and large underestimates when actual use and savings are high (Fig. 1).

We conducted similar multilevel regressions (but without the quadratic term) for (*i*) estimates of the energy saved by three automobile-related activities, (*ii*) rankings of the energy used by different modes of transportation, and (*iii*) rankings of the energy used to make aluminum and glass beverage containers from virgin and recycled materials (see *SI Text*). Average results for these analyses appear in Fig. 2. In all three instances, the average slope was substantially less than the correct slope.

As shown in Fig. 2*A*, the average elevation of perceived gasoline savings was very close to the average of actual savings [$M(\beta_{0j}) = -0.016$, $t(475) = -0.70$, $P = 0.49$], indicating that participants did not underestimate or overestimate energy savings for these three behaviors, at least on average. Although the actual and perceived energy savings (in Wh) are much greater than those in Fig. 1, the average slope for gasoline savings was very similar, at 0.23, indicating a relatively flat relationship. For example, the energy saved by reducing one's highway speed from 70 to 60 miles per hour on a 60-mile trip was overestimated, consistent with the relatively small amount of energy saved (0.4 gallons of gasoline). For consistency with the survey, we frequently use US rather than metric units in the text and figures.

As shown in Fig. 2*B*, participants correctly reported that transporting goods via airplanes consumes more energy than using other modes of transportation, and that the energy difference between trains and ships is small. However, they incorrectly reported that trucks consume approximately as much energy as trains and ships, even though trucks actually consume 10 times more energy per ton-mile. Apparently, recent advertising touting the much greater fuel efficiency of trains relative to trucks has been ineffective, at least among this sample of the general public.

As shown in Fig. 2*C*, participants correctly reported that making a can or bottle from virgin aluminum or glass requires more energy than making the same container from recycled materials. However, they incorrectly reported that making a glass bottle requires less energy than making an aluminum can. In fact, the reverse is true: A glass bottle requires 1.4 times as much energy as an aluminum can when virgin materials are used and 20 times as much energy when recycled materials are used. In part because glass is so heavy, making a recycled glass bottle actually requires more energy than making a virgin aluminum can.

Individual Differences in the Accuracy of Perceptions. The Fig. 1 *Inset*, which shows the results of Eq. **1** for 30 randomly selected participants, indicates substantial variation in elevations and slopes. Although not shown in Fig. 2, there was also substantial variation around the average elevation and slope in Fig. 2*A* and around the average slopes in Fig. 2 *B* and *C* (but not around the average elevations in Fig. 2 *B* and *C*, because the average ranks were constrained to be 2.5). In a series of exploratory analyses, we attempted to account for this variation by adding 16 centered individual-difference variables (e.g., numeracy, proenvironmental attitudes) as predictors in our multilevel regression models. For example, we allowed the intercept β_{0j} and slope β_{1j} in Eq. **1** to depend on these additional variables (*SI Text*). The effects on β_{0j} are the main effects of the new variables, whereas the effects on β_{1j} are the interactions between these variables and log10*Actual*. We used similar models to assess the effects of the individual-difference variables on the slopes in the three panels of Fig. 2 (*SI Text*).

Results for these augmented models appear in Table 2, with the results for household devices and activities split over two columns. The average elevation in Fig. 1 was negative (indicating underestimation), and the four average slopes in Figs. 1 and 2 were all substantially less than the correct slopes. As a result, positive coefficients for the individual-difference variables imply more accurate perceptions of energy use and savings (less underestimation or steeper slopes) in all five columns of Table 2. Thus, the easiest way to understand these results is to look for variables with consistent significant effects across regressions (i.e., by row rather than by column).

The coefficient for numeracy (23) was positive in all five tests and significant in four, indicating that participants with a better understanding of numerical concepts had more accurate perceptions of energy consumption and savings. The coefficient for the New Ecological Paradigm (NEP) score (24) was positive and significant in four of the five tests, indicating that participants with more proenvironmental attitudes had more accurate perceptions. These two effects were substantial. For the 115 participants with above-average numeracy and NEP scores (numeracy >1.5 and NEP >3.7), the average elevation for predictions of energy use and savings for the devices and activities in Fig. 1 was −0.25 (instead of −0.44 for the whole sample), and the average slope was 0.38 (instead of 0.28).

Surprisingly, participants' self-reported environmental behaviors scale always had a negative coefficient and was significant in three of the five tests, indicating that participants who reported engaging in a greater number of proenvironmental energy-related behaviors had less accurate perceptions.

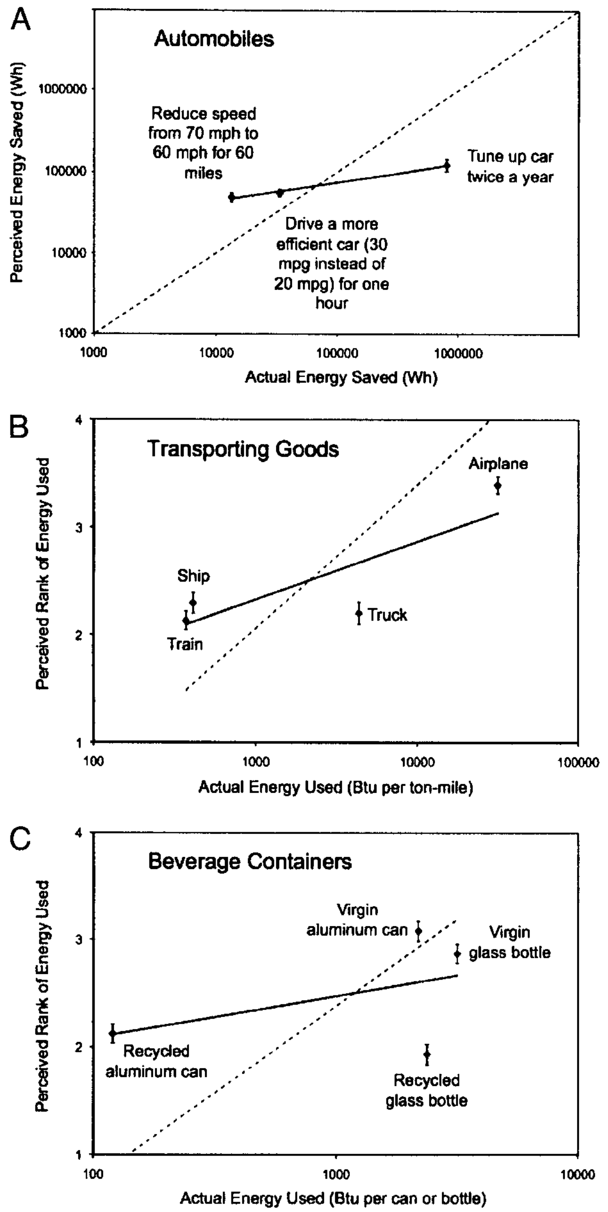

Fig. 2. Mean perceptions of energy used or saved as functions of actual energy used or saved for automobile-related activities (*A*), modes of transporting goods (*B*), and methods of manufacturing beverage containers (*C*). Error bars indicate 95% confidence intervals for mean perceptions. Diagonal dashed lines represent accurate responses. In *B* and *C*, the dashed lines were derived by regressing the correct ranks onto actual energy use.

Finally, several variables that one might expect to be related to accuracy (e.g., climate-change attitude, home ownership, age, income, education) were not reliable predictors in these regressions. Overall, the percentages of variation in elevations and slopes explained by the individual-difference variables were small to modest (*SI Text*).

Discussion

Notwithstanding a few bright spots (e.g., knowing roughly how much energy is saved by a CFL), participants in this study exhibited relatively little knowledge regarding the comparative energy use and potential savings related to different behaviors. Relative to experts' recommendations, participants were overly focused on curtailment rather than efficiency, possibly because efficiency improvements almost always involve research, effort, and out-of-pocket costs (e.g., buying a new energy-efficient appliance), whereas curtailment may be easier to imagine and incorporate into one's daily behaviors without any upfront costs.

Participants were also poorly attuned to large energy differences across devices and activities and unaware of differences for some large-scale economic activities (transporting goods by train vs. truck) and everyday items (aluminum vs. glass beverage containers). Knowing these relative magnitudes would allow individuals to make more informed choices regarding energy-saving behaviors.

The observed correlations between judged and actual energy values, although positive, may be too small to support sound decision making. In their studies of risk perception, Lichtenstein et al. (12) noted that positive correlations between perceived and actual fatality rates are almost guaranteed when the actual rates span several orders of magnitude: "Subjects who could make only the roughest discriminations, for example, knowing that death from botulism or lightning is less likely than death from all cancer or all accidents, would show high correlations" (pp 566–567). Similarly, participants in our tasks may have needed only basic knowledge to obtain significant positive slopes. It may not require much insight to realize that a major appliance (of any variety) uses more energy than a single light bulb (be it incandescent or fluorescent) or that tuning one's car saves more energy in a *year* than reducing one's highway speed saves in an *hour*. Despite displaying some sensitivity to these and other differences, participants severely underestimated their magnitudes. In addition, the nonlinearity in Fig. 1 indicates that participants were least accurate when energy use and savings were high (e.g., for large appliances). In other words, people's understanding may be worse where the potential for CO_2 reductions is large, although other considerations such as how often a device is used over the course of a year are also relevant.

As in previous research on judgment and decision making, participants with higher numeracy scores had more accurate perceptions (25). Participants with stronger proenvironmental attitudes were also more accurate. Even so, participants who scored high on both measures still had relatively flat slopes. Unexpectedly, participants who engaged more in energy-conserving behaviors had less accurate perceptions of energy use and savings, possibly reflecting unrealistic optimism about the effectiveness of their personal energy-saving strategies compared with alternative ones (26). Alternatively, people may focus primarily on the behaviors they have already adopted, leading to inaccuracies in judging how much energy other behaviors use or save (13).

This study, like others, has limitations. First, we did not offer incentives for accuracy, and we did not assess perceptions in real-world settings that might foster greater accuracy (e.g., among consumers shopping for new appliances). We doubt that financial incentives would have improved participants' accuracy, however, because they are typically ineffective for reducing anchoring effects (16) or improving calibration (17). Second, our Internet sample, although diverse, was not completely representative of the adult US population. Even so, the regression results in Table 2 indicate that most demographic variables were not predictive of accuracy. Third, we do not know whether the reported misperceptions affect actual energy-related behavior.

Given our results, the key question is why most people have difficulty judging energy use and savings. In sorting through the possibilities, it is helpful to note that the simple slope of the relationship between perceived and actual values is just the product of the Pearson correlation and the ratio of the two SDs: $b = r(s_Y/s_X)$. In our primary analysis, these two components contributed roughly equally to the flat slope, with mean values of 0.51 for r and 0.53 for s_Y/s_X. Considering the ratio of SDs, participants' estimates of energy use and savings were greatly compressed relative to the actual values. This compression almost certainly resulted from an anchoring bias (14, 16, 22) in which the reference point provided in the task served as an anchor for participants' estimates, causing those estimates to be too similar to the reference point. The underestimation of energy use and savings in Fig. 1 is consistent with the relatively low reference point provided in our primary task (a 100-W light bulb used for 1 h). We selected the light-bulb reference

Table 2. **Results of multilevel regressions for predicting individuals' perceptions of energy use and savings**

Parameter	Household activities (Fig. 1): Elevation, slope, and main effects (effects on elevation)	Household activities (Fig. 1): Interactions (effects on slope)	Automobiles (Fig. 2*A*) (elevation, slope, and interactions)	Transporting goods (Fig. 2*B*) (slope and interactions)	Beverage containers (Fig. 2*C*) (slope and interactions)
Intercept (elevation)	−0.44*	—	−0.010	—	—
Within-participant (level-1) predictors					
Actual energy use or savings, log10*Actual*	0.28*	—	0.24*	0.54*	0.39*
Quadratic term, $(\log 10 Actual)^2$	−0.19*	—	—	—	—
Between-participant (level-2) predictors					
Numeracy (0–3, α = 0.59)	0.076*	0.063*	$0.056^{\dagger}$	$0.078^{\ddagger}$	0.017
NEP (0–6, α = 0.81)	$0.12^{\dagger}$	0.086*	−0.003	$0.12^{\ddagger}$	$0.21^{\ddagger}$
Climate-change attitude (0–6, α = 0.79)	−0.001	$-0.027^{\ddagger}$	$0.060^{\ddagger}$	0.037	−0.016
Environmental behaviors (0–9, α = 0.65)	$-0.033^{\dagger}$	−0.008	−0.021	−0.063*	−0.12*
Uses more energy than average	−0.005	−0.026	−0.005	−0.048	$-0.12^{\ddagger}$
Owns car	−0.030	0.047	−0.13	0.065	0.10
Owns home	0.045	0.015	0.048	0.10	$0.24^{\ddagger}$
Voted Democrat	$-0.14^{\ddagger}$	−0.037	0.006	−0.11	0.049
Voted Republican	$-0.13^{\ddagger}$	−0.029	0.042	−0.19	0.11
Chose not to vote	$-0.25^{\dagger}$	$-0.085^{\ddagger}$	0.040	$-0.33^{\ddagger}$	0.058
Could not vote	$-0.32^{\dagger}$	$-0.10^{\ddagger}$	−0.068	−0.051	−0.42
Political views (1–7)	0.018	0.001	0.021	0.015	0.014
Male	0.043	0.006	0.002	−0.027	−0.040
Age	−0.003	0.002	−0.001	0.006	−0.004
Income (1–8)	0.023	0.008	0.005	−0.045	−0.026
Education (1–6)	0.005	0.004	$0.045^{\ddagger}$	0.050	−0.003

Elevation and slope are reported at the relevant mean of log10*Actual*, the *x* axis variable in Figs. 1 and 2. When elevation varied, it was tested against the relevant mean of actual energy use or savings. Elevation did not vary for transporting goods (Fig. 2*B*) or beverage containers (Fig. 2*C*) because the ranking task required each participant's mean elevation to be 2.5. For automobiles (Fig. 2*A*), the main effects are omitted for brevity. All slopes were tested against the correct slopes (1, 1, 1.33, and 1.61 for the four regressions, respectively). For political categories (e.g., Voted Democrat, Could not vote), the excluded category was "Do not want to divulge." The components of the environmental behaviors scale were: owns CFLs, considers efficiency for large appliances, considers efficiency for small appliances, conducted an energy audit of home, weatherized home, installed double-pane windows, bought renewable energy, wrote a letter about energy, and considers oneself an environmentalist.

*$P < 0.001$.

$^{\dagger}P < 0.01$.

$^{\ddagger}P < 0.05$.

point because it was the most understandable to participants in our pilot tests. If, as we suspect, incandescent light bulbs serve as natural reference points for judgments about energy, then the observed underestimation of household energy use and savings should generalize beyond our survey procedures.

Turning to the imperfect correlation between perceived and actual values, there are several plausible reasons (in addition to random error in reported perceptions) for r to be less than 1. For example, participants may have imagined specific examples of devices or appliances whose energy consumption differed from the *Actual* values we used, or they may have failed to consider important factors related to actual energy consumption and savings (e.g., the volume of air cooled by a central air conditioner usually far exceeds that cooled by a room air conditioner). A more general explanation is that people usually make energy comparisons within rather than across categories of devices (e.g., they compare different models of air conditioners rather than comparing air conditioners to clothes dryers), in part because energy-efficiency labels generally highlight within-category comparisons. For a more thorough discussion of potential explanations for the flat slopes in Figs. 1 and 2, see *SI Text*.

Many people's concerns about energy are simply not strong enough, relative to their other concerns, to warrant learning about energy conservation (27). Although it may be appropriate to criticize the media for not presenting the case for climate change more strongly and for not presenting the implications of individual behavior more clearly (28), scientists share at least some of the responsibility for the current state of affairs. For example, Fischhoff (29) recently argued that scientists may have failed the public by not providing information in a credible and comprehensible manner to facilitate better climate-related decisions. In addition to improved communication efforts, increasing fossil fuel prices to reflect the true environmental costs of CO_2 emissions would also provide strong incentives for learning and behavior change.

Research has demonstrated that successful risk communication requires an understanding of people's knowledge gaps and misconceptions (30), and the same is likely to be true for communications about energy. The results of this study imply that well-designed efforts to increase the public's knowledge of energy use and savings could be quite beneficial, although we hasten to add that providing appropriate information is only one component of a successful intervention strategy (4, 31, 32) and that other barriers to individual emissions reductions must also be addressed (33, 34). Recent research indicates that investments in non–price-based behavioral interventions can be effective in decreasing energy use (27). However, many campaigns have focused on behaviors that save relatively small amounts of energy, such as unplugging one's cell phone charger, whereas other more effective behaviors have been neglected. So long as people lack easy access to accurate information about relative effectiveness, they may continue to believe they are doing their part to reduce energy use when they engage in low-effort, low-impact actions instead of focusing on changes that would make a bigger difference. If people are uninformed, the substantial potential of behavioral interventions to reduce energy consumption (5–8) may go unrealized. It is therefore vital that public communications about climate change also address misconceptions about energy consumption and savings, so that people can make better decisions for their pocketbooks and the planet.

Methods

Participants. We recruited 505 participants through Craigslist in seven US metropolitan areas: New York, Philadelphia, Washington DC, Houston, Dallas, Denver, and Los Angeles. The sample represented 427 ZIP codes in 34 states (plus Washington DC). The online survey was conducted from 9:00 AM to 3:00 PM on Wednesday, February 11, 2009. Each participant received a $10 gift certificate to Amazon.com.

On the basis of 471 participants who provided demographic data, the median age was 31 y, compared with 36.4 y in the US [US Census Bureau (2007) 2005–2007 American Community Survey 3-year estimates]; 35% of participants were male (49% in the US); and 63% owned their homes (67% in the US). The median family income was $50,000–$79,999 ($60,400 in the US). All participants who were aged 25 y or older held high school diplomas (84% in the US), and 41% held bachelors' degrees (27% in the US). Forty-seven percent self-identified as liberals (score = 1–3), 31% as moderates (score = 4), and 22% as conservatives (score = 5–7). Thirty-seven percent considered themselves environmentalists. These figures may indicate some selection bias or response bias.

Survey Materials. The complete survey and tables of actual energy values are presented in the *SI Appendix* and *SI Text*, respectively.

At the beginning of the survey, participants answered an open-ended question about the most effective thing they could do to conserve energy in their life. Next, participants estimated the number of energy units typically used in 1 h by nine devices and appliances (e.g., a stereo, a dishwasher, a CFL that is as bright as a 100-W incandescent bulb). They also estimated the number of energy units that would be saved by six activities (e.g., changing washer temperature settings from "hot wash, warm rinse" to "warm wash, cold rinse" for one load of laundry). To help participants make these comparisons, both questions provided a reference point indicating that a 100-W incandescent bulb uses 100 units of energy in 1 h—chosen after pilot tests suggested that this reference point improved understanding.

Participants then indicated how many energy units they thought three automobile-related activities would save (e.g., reducing speed from 70 to 60 miles per hour when driving a 20-miles-per-gallon car for 60 miles). Here, the reference point stated that a "20-miles-per-gallon car going 60 miles per hour uses 100 units of energy in one hour." Thus, 100 units equaled 3 gallons of gasoline, or approximately 101 kWh.

Subsequently, participants ranked the amount of energy needed to transport 1 ton of goods for 1 mile by truck, train, ship, and airplane. They also ranked the energy used to make a can from virgin aluminum, a can from recycled aluminum, a bottle from virgin glass, and a bottle from recycled glass.

Participants then completed the Revised NEP scale (23), a 15-item instrument for assessing proenvironmental attitudes. We coded the original responses (0 = *completely disagree*, 6 = *completely agree*) in the proenvironmental direction and averaged them to yield an overall NEP score for each participant. They also rated four statements regarding personal efficacy and belief in climate change (e.g., "I believe that I need to change my lifestyle to address global warming and climate change"), which we used to calculate an overall *climate-change attitude* score. In addition, participants completed Schwartz et al.'s (22) *numeracy* assessment, which consists of three open-ended questions. For example, "In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1000 people each buy a single ticket to BIG BUCKS?"

Near the end of the survey, participants answered eight questions regarding their own energy-related actions (e.g., whether they had weatherized their home, whether they thought of energy efficiency when buying large household appliances). Responses were combined with an additional item (considering oneself an environmentalist) to yield a nine-item *environmental behaviors* scale (a count of Yes responses). Demographic questions concluded the survey.

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