Title

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Journal
Journal of Environmental Economics and Management, 67(3)

ISSN
0095-0696

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Publication Date
2014-05-01

DOI
10.1016/j.jeem.2013.12.009

Peer reviewed

Journal of Environmental Economics and Management 67 (2014) 353–370

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

Saving power to conserve your reputation? The effectiveness of private versus public information ☆

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ARTICLE INFO

Article history:
Received 20 April 2013
Available online 5 February 2014

Keywords:
Conservation behavior
Conspicuous consumption
Image motivation
Electricity
Energy efficiency
Signaling
Public information

ABSTRACT

Environmental damage is often an unseen byproduct of other activities. Disclosing environmental impact privately to consumers can reduce the costs and/or increase the moral benefits of conservation behaviors, while publicly disclosing such information can provide an additional motivation for conservation - cultivating a green reputation. In a unique field experiment in the residence halls at the University of California – Los Angeles, we test the efficacy of detailed private and public information on electricity conservation. Private information was given through real-time appliance level feedback and social norms over usage, and public information was given through a publicly visible conservation rating. Our analysis is based on 7,120 daily observations about energy use from heating and cooling, lights and plug load for 66 rooms collected over an academic year. Our results suggest that while private information alone was ineffective, public information combined with private information motivated a 20 percent reduction in electricity consumption achieved through lower use of heating and cooling. Public information was particularly effective for above median energy users.

Introduction

Environmental damage is often an unseen byproduct of other activities, with both consumers and those around them unable to gauge the impacts of their actions. Policies that correct this information asymmetry have the potential to encourage environmentally friendly behavior by consumers. Such information policies are becoming increasingly prevalent: eco-labels, which intend to reduce the information asymmetry between producers and consumers (Crespi and Marette, 2005; Leire and

☆ The authors would like to thank the UC Center for Energy and Environmental Economics (UCEEE) and the Green Initiative Fund at UCLA for their financial support. We would also like to thank Mathew Kahn, Dora Costa, Leah Boustan, Pascaline Dupas, our anonymous referees and associate editor for invaluable advice and useful criticism. We owe a huge debt of gratitude to William Kaiser and his engineering team: without their continuous support this study would not have been possible. Special thanks to Victor Chen who designed the Engage Web Portal, meters and software and was instrumental in their deployment and maintenance. We thank Robert Gilbert who contributed to the conceptual design and ensured us access to the dormitories. Thanks to Yangmun Choi, Manda Paul, Stoytcho Stoytchev, Joe Tsai and Jackson Ding, who built, installed and maintained the energy meters and accompanying software. Thanks to Mike Franks and his team, who created the Engage Web Portal and Cassie Tricket, Emily Parker, Kim Bowen, Nina Gupta and Sirena Lao, who helped maintain the meters and distributed posters. Thanks to Kenny Wei for shooting and producing instructional videos on the equipment. Thanks to all the volunteers from the UCLA Institute of the Environment and Sustainability who helped install energy meters and to the members of UCLA housing who escorted and assisted us during installation and maintenance. Finally, a big thank you to all of the of the experiment participants for their time and patience.

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http://dx.doi.org/10.1016/j.jeem.2013.12.009
0095-0696

Thidell, 2005), have expanded from a mere dozen worldwide in the 1990s to more than 440 programs today.[1] The mass rollout of smart energy meters, with over 76 million already installed worldwide, allows utilities to provide improved feedback to consumers about the impacts of their energy consumption (Fischer, 2008).[2] Mandatory and voluntary corporate disclosure systems are increasingly being used to replace or augment environmental government regulation (Khanna, 2001; Delmas et al., 2009), with common examples including the Toxics Release Inventory, lead paint disclosures, drinking water quality notices, and the international Environmental Management Standard ISO 14001 (Delmas and Montes-Sancho, 2011). Yet despite the popularity of environmental information policies, we still have little understanding of their effectiveness.

In this paper we evaluate the effectiveness of two different information policies in inducing electricity conservation. Electricity usage is a useful vehicle for assessing the impact of information treatments because it is generally invisible to both consumers and those around them. In the United States, most residential and commercial electricity users receive no information over their electricity usage apart from their monthly bills, which do not disaggregate across time periods or sources of usage. Understanding the potential mechanisms to induce energy conservation is an essential part of addressing climate change since more than one quarter of all U.S. carbon dioxide emissions stem from electricity generation for commercial and residential customers (EIA, 2010; EPA, 2010).[3] Recent studies estimate that residential energy consumption could be reduced by 22 to 30 percent within the next five to eight years purely through behavioral changes (Gardner and Stern, 2008; Laitner et al., 2009). Thus information policies, which can change the costs and benefits of conservation, have the potential to become a major driver of behavioral change.

One potentially powerful informational tool is the provision of detailed appliance feedback to consumers over their own energy usage. Such information can allow consumers to better understand when and how they are using electricity, leading to improved energy usage decisions (Fischer, 2008). Feedback can also illustrate individual usage relative to comparable users (Schultz et al., 2007; Ayres et al., 2009; Allcott, 2011). This can create a social norm over electricity usage that increases the moral cost of not conserving (Levitt and List, 2007). Surveys of the existing feedback literature report savings from 4 to 12 percent, with the highest savings coming from real-time feedback (Abrahamse et al., 2005; Darby, 2006; Delmas et al., 2013; Ehrhardt-Martinez et al., 2010). However, not all results are this positive, and many studies have found no statistically significant reduction (Allen and Janda, 2006; Klos et al., 2008; Kihm et al., 2010), increased usage (Sexton et al., 1987; Sulyma et al., 2008) and heterogeneous responses (Van Houwelinger Jeannet and Fred Van Raaij, 1989; Brandon and Lewis, 1999; Parker et al., 2008; Costa and Kahn, 2013). Moreover many of these studies suffer from methodological difficulties (Delmas et al., 2013). They often involve small samples (e.g. Allen and Janda, 2006; Parker et al., 2008), short time periods (e.g. Petersen et al., 2007), or lack of controls.

Individual feedback can be termed *private information* in that it is privately disclosed information about an agent's own (relative) energy use or environmental impact. We introduce a behavioral innovation – public information - and evaluate its efficacy relative to private information in a unique field experiment in the residence halls of the University of California, Los Angeles (UCLA). *Public information* is information about a specific agent's behavioral impact that is publicly disclosed, allowing environmentally friendly behaviors to act as a signal of "green" virtue. These reputational benefits can motivate conservation amongst consumers. Since both private and public information are non-pecuniary behavioral interventions, testing their efficacy in an environment devoid of complicating pecuniary motivations is ideal. Thus students in residence halls, who do not pay electricity bills, are the perfect subjects for such an experiment. In a nine-month long experiment, participants were given private information in the form of real-time feedback and social norms over their room's energy usage. The real time energy usage was decomposed by source: heating and cooling, lights and plug load. A subset of participants also had their energy usage made public in the form of posters that described their room as being an above/below average energy conserver. We found that private information alone was not sufficient to motivate statistically significant energy savings in our sample. However, when we combined private information with public information, we induced an average energy saving of 20 percent, with the majority of saving coming from high energy users. While public information has been shown to facilitate the decision to participate in energy conservation programs (Yoeli et al., 2013), to our knowledge, this is the first study to measure the effectiveness of public information on repetitive energy conservation behavior amongst individuals. Our empirical setting allowed us to observe energy conservation behavior at a highly granular level since we measure energy use at a high frequency for three main appliances. Our results show that conservation occurred through lower use of heating and cooling rather than of lights or plug load. When public information was removed, conservation behavior continued to persist, even three months later.

In a world where electricity is a small component of household expenditure[4] and price increases are politically difficult to implement, behavioral "nudges" are a useful tool to induce energy conservation.[5] The heterogeneity of consumers means

[1] www.ecolabelindex.com

[2] www.pge.com/smartmeter

[3] This is not surprising considering that residents of the United States spend more than 90 percent of their lives in buildings (Evans and McCoy, 1998).

[4] 2.8 percent of 2009 household expenditure for the United States as a whole, and 2.2 percent for the Western United States (Consumer Expenditure Survey online tables).

[5] Economists generally believe that electricity conservation socially optimal since electricity generation creates externalities (CO2 and other emissions) that are not internalized through the price mechanism. However, this may not hold true if consumers pay prices that exceed the marginal cost of provision. This is the case if previous fixed costs undertaken by a utility are lumped together with energy costs to reflect one electricity price. This "all-in" price may exceed the socially optimal marginal price of electricity (which internalizes all externalities). If this is the case and consumers do indeed respond to marginal prices rather than average prices, then consumers may be under-consuming electricity (Davis and Muehlegger, 2010). However, if consumers receive bills with separate marginal and fixed charges or if they respond to average rather than marginal electricity prices (Ito, 2014), then this is no longer the case and conservation is still optimal. Resolving this issue is beyond the scope of this paper.

that a one-size-fits-all solution is unlikely to be successful, and hence behavioral scientists need a varied toolkit that appeals to a variety of motivations. Compared to other policies such as pecuniary incentives, information policies are a relatively inexpensive way to encourage conservation, especially in this age of mass information and telecommunication technology. Our research advances our knowledge of effective non-price incentives beyond the role of social norms demonstrated in Allcott (2011). We show that public information, or "conspicuous conservation", can be an effective and valuable part of this toolkit. Public information is particularly useful in that it can motivate conservation behavior among all consumers, *including* those who are not intrinsically motivated to conserve energy.

This paper is organized as follows. In section 2 we provide a conceptual framework and testable hypotheses. In section 3 we discuss the experiment location and technology, as well as the experimental design. In section 4 we describe how we implemented the private and public information treatments for the experiment, as well as recruitment and randomization strategies. In section 5 we examine the experiment results, with a discussion of heterogeneous treatment effects and persistence. In section 6 we discuss the empirical results and limitations and also bring in some qualitative evidence from entry and exit surveys to support them, before our concluding discussion in section 7.

Information and motivation

This section develops behavioral hypotheses on the impact of public and private information on conservation behavior. A simple formalized model is presented in Appendix A.

Scholars have identified three main types of motivations to conserve (Bénabou and Tirole, 2006): intrinsic motivation, extrinsic motivation and reputation or image motivation. *Intrinsic motivations* consist of both warm-glow and pure altruism (Ariely et al., 2009). Pure altruism is motivated only by an interest in the welfare of others, whereas warm-glow altruism is motivated by a boost in self-esteem associated with improving the welfare of others (Andreoni, 1990). *Extrinsic motivations* usually entail pecuniary rewards, although some non-pecuniary rewards have been used to motivate conservation in terms of energy conservation competitions (Petersen et al., 2007) and personal goal setting (Van Houwelinger Jeannet and Fred Van Raaij, 1989).[6] *Reputation motivation* differs from extrinsic motivations as it occurs when visibly prosocial actions act as a signal of virtue, creating a positive reputation. In this paper, we focus on intrinsic and reputation motivations because of the relatively low extrinsic rewards currently associated with energy conservation at the residential level. We argue that private information can be an effective conservation tool for individuals with intrinsic motivations while public information can motivate individuals beyond their intrinsic motivations by appealing to their desire for social approval.

Private information can either consist of procedural information or social norms. Procedural information, such as giving customers more detailed feedback over their *own* energy use, provides "know-how" and can reduce the cost of conservation activities (Schultz, 2002). For example, real-time information over fuel economy can show drivers exactly which aspects of their driving style uses the most gas, thereby allowing them to conserve fuel far more easily than before. According to psychologists, more information results in learning about potential behavior and therefore enables individuals to perceive alternative actions (Stern, 1992). Changes in behavior can occur when a person is aware of an issue, thinks his or her actions can influence it, and feels capable of engaging in such action (Fischer, 2008). Under such preconditions, detailed feedback on how to perform conservation activities, and on the outcomes of these activies, can facilitate conservation behavior (Fischer, 2008). It is therefore conceivable that learning about the impacts of energy usage can lower barriers to conservation action.

Information about social norms, such as information about *aggregate* energy usage by others, can increase the moral benefit from engaging in conservation. Social norms influence warm-glow altruism by changing perceptions of what behaviors are immoral, antisocial, or at odds with one's own identity, thereby increasing the moral cost (or moral benefit) of an action (Levitt and List, 2007). For example, people may feel more guilty about not recycling when they are informed that all of their neighbors do so, compared to when they are informed that none do. Empirical work by psychologists and political scientists has shown social norms to be effective at inducing conservation behavior in a number of settings, including recycling (Schultz, 1999), towel re-use (Goldstein et al., 2008), litter reduction (Cialdini et al., 1990), water conservation (Ferraro and Price, 2013) and energy conservation, which was discussed previously.

In conclusion, by decreasing the costs of conservation, or increasing the moral benefit, private information about detailed energy use or aggregate energy usage by others will lead to an increase in the level of conservation. We therefore hypothesize the following:

Hypothesis 1:. *The level of conservation will increase when private information is provided.*

Public information will make conservation behavior visible to others, thereby influencing how others perceive the individual. Individuals wishing to obtain a socially desirable reputation for conservation may take this as additional motivation to decrease energy use. This may increase the level of conservation relative to when conservation activities were unobservable.

Psychologists find that a prosocial reputation is valuable, allowing consumers to obtain a number of non-market goods such as trust (Barclay, 2004), friends, allies, romantic partners (Griskevicius et al., 2007; Miller, 2009) and leadership

[6] Petersen et al. (2007) induced dramatic savings of 30 percent in dormitory energy competition (with real-time feedback at the dormitory level). However this was over a short duration and it is not clear how sustainable this conservation behavior would be in the long run.

positions (Hardy and Van Vught, 2006). Prosocial reputation has been shown to be a significant motivator for charitable donations (Ariely et al., 2009), volunteer firefighting (Carpenter and Caitlin Knowles, 2007), blood donation (Lacetera and Macis, 2010), solar panel purchases (Lessem and Vaughn, 2011; Dastrup et al., 2012) and hypothetical green purchases (Griskevicius et al., 2010). In the corporate world, Jin et al., 2003 found that mandatory hygiene cards positively affected restaurant quality and health outcomes, while Delmas et al. (2009) found that mandatory disclosure over utility electricity generation fuel mix percentages resulted in an increase in cleaner fuels. Observability of cooperative behavior has been shown to increase participation in demand response programs allowing the electric utility to remotely restrict the energy consumption during peak hours (Yoeli et al., 2013). However, reputational motivation unleashed through public information has not yet been used as a mechanism to induce individual energy conservation behavior.

By engaging in conspicuous prosocial behavior, consumers signal that they are pro-socially minded (rather than pro-self). If energy usage is made visible to the public, consumers may be motivated to conserve energy to gather the benefits of a "green" reputation (Griskevicius et al., 2010). We therefore hypothesize the following:

Hypothesis 2. *The level of conservation will increase when public information is provided.*

Both Hypotheses 1 and 2 describe an average treatment effect of public and private information. However, the effectiveness of both information treatments may vary with individual levels of intrinsic motivation and current energy usage.

First, the provision of private information might result in larger behavior changes by those individuals with higher levels of intrinsic motivation. The intuition behind this comes from examining the costs of conservation. Since each additional unit of conservation will be more difficult to attain than the previous unit (exhausting low hanging fruit), the marginal costs of conservation will increase with the level of conservation. Thus an individual who is already engaged in considerable amounts of green activity, will have a higher marginal conservation cost than an individual who is not engaged. The introduction of new procedural knowledge will proportionally reduce the cost of all conservation activities. Since the marginal cost of conservation is higher for those who are conserving more, any proportionate reduction in conservation costs, will lead to a greater absolute decrease in marginal conservation costs. This in turn will lead to a larger increase in conservation activities by individuals.

Second, social norms could cause heterogeneous responses depending on whether individuals are outperforming or underperforming relative to the norm. Schultz et al. (2007) showed that social norms could cause a boomerang effect, with below average energy users increasing usage and converging to the norm. This only held for descriptive social norms, which describe what behavior is commonly enacted in a given situation and include information over aggregate behavior (Cialdini et al., 1990). The boomerang effect occurs because while the moral benefit of conservation will increase for those agents who are underperforming relative to the norm, the opposite may occur for those who are outperforming the norm. These individuals will therefore be less motivated to conserve and will increase usage.

Third, individuals might only increase their participation in this activity when doing so has a positive effect on society's assessment of them. Reputation functions by acting as a signal of virtue. Conservation levels should only increase in response to public information if the marginal change in reputation from increasing the level of a prosocial activity is greater than zero. If increasing the level of the prosocial activity will have no beneficial effect on the reputation of an individual, then making that activity public information should have no effect on it. For example, if person x always recycles in her own home, putting person x on a publicly visible reality TV show, like Big Brother, may not motivate person x to recycle more. Therefore individuals will be more likely to participate in conservation if this improves how they are perceived by other members of society.

We were able to test these hypotheses over aggregate and heterogeneous behaviors using uniquely generated experimental data. The experimental design and context is described in the next section.

Methodology

Experimental design

We installed real-time electricity meters that gather electricity usage for the lights, heating and cooling system and plug load in 66 residence hall rooms on the UCLA campus for one academic year (September 2010 to May 2011). Residence halls are an ideal location for a study of this nature. First, the dormitory rooms are standardized so that there are no differences in energy efficiency or size in the housing stock. Second, students do not pay electricity bills, so there are no price effects to confound with our behavioral interventions. This is particularly relevant for reputation motivations, since pecuniary rewards (like saving money on your energy bill) can dilute the green signal given by conservation actions. Despite the direct financial benefits of saving energy, research indicates that providing information about the cost of energy use does not necessarily affect energy use behavior among households (Lindén et al., 2006). This is consistent with studies indicating that pecuniary incentives might be counterproductive for energy conservation because they might crowd out more altruistic or prosocial motivations (Bénabou and Tirole, 2006; Bowles, 2008; Gneezy et al., 2011). While our experimental context helps us to identify the pure impacts of private information on altruistic and prosocial motivators, it does not allow us to identify the impact of private information on pecuniary motivators. Since most US electricity consumers do pay electricity bills, our analysis of private information may understate the true impact of private information for the general population. Nonetheless, such a

Table 1
Experimental Design.

Baseline (6 weeks)	**Private Information** (5 weeks)	**Public Information** (7 weeks)	**Persistence** (5 weeks)	**# of rooms**
	Control	Control	Control	23
	Private Information	Private Information	Private Information	22
	Private Information	Private + Public Information	Private Information	21

context is not unusual in the United States, with most university students not paying for electricity separately from the other costs of living in the dormitory. Similarly, renters and residents of condominiums do not pay water usage, sewage and trash disposal independently from their rent or Home Owner Association monthly fees. Finally the students had adequate control of their environment (lights, thermostats, plug load, windows) to meaningfully engage in conservation.

Table 1 above outlines the basic experimental design. Participating rooms were randomly split into three different groups, which we designate: *control¸ dashboard and poster*. Initially, the baseline usage of all three groups was recorded over a 6 week period. During this period electricity usage was monitored by the experimenters, but the participants were given no information about their electricity usage. Following this was a 5 week period, during which the *dashboard and poster* groups were both exposed to the private information treatment, with the *control* group continuing to receive no information. Private information took the form of real-time feedback delivered through an online energy usage dashboard and weekly emails. Each room had its own customized dashboard.

The public information treatment, which lasted 7 weeks, involved exposing the *poster* group to both public and private information, while the *dashboard* group continued to receive only private information. Public information took the form of posters and emails, which publicly rated rooms as above or below average energy conservers. Those participants who had their energy usage in the public realm could cultivate (or preserve) a "green" reputation by conserving energy.

In the final stage of the experiment we tested whether the new behaviors inspired by the experimental interventions resulted in habits that persisted even in the absence of these stimuli. A habit is formed when a task is repeated to the point where it becomes mechanical and enacted without awareness of circumstances (Beach and Mitchell, 1978; Aarts et al., 1997; de Vries et al., 2011). To test for persistence of treatment effects, we removed public information as a motivational instrument and observed whether conservation behavior persisted in its absence.

Location and technology

The experiment took place in three residence halls on the UCLA campus. All three buildings were built at the same time, opening their doors in 2005/2006, and are variations on a common design. Rooms are standardized across the buildings, which are located within a few hundred feet of each other. Each occupant has a bed, desk and wardrobe. All rooms are equipped with a programmable thermostat, an operable window, and a florescent overhead light. Shared rooms have an additional florescent hall light. Bathrooms are shared between rooms and were not monitored by the experiment. More information on the technology is provided in Chen et al. (2014).

The electricity infrastructure of the UCLA residence halls made energy monitoring at the room level impossible given existing technology. Like most commercial buildings, including dormitories, office blocks and schools, wiring is done at the building level, rather than at the room level, making room level feedback impossible. To overcome this problem, new technology was developed that allowed for the rapid retrofit of the rooms selected for the experiment. The new technology involved augmenting off-the-shelf plug point energy meters (which measure plug load) with sensing technologies to measure light usage and heating/cooling; and radios to wirelessly communicate with an internet-enabled gateway. This equipment was installed during the summer vacation, so that students moved into a new room complete with electricity monitoring equipment.

Experiment implementation

Private and Public Information Treatments

Private information was given to participants through a custom built web interface which we called the UCLA ENGAGE dashboard, as well as weekly email reports. The dashboard gave users real-time information over their room's current electricity usage by source (heating and cooling, lights and plug load), as well as historical and social usage comparisons and a running average of electricity usage by source.[7] An example of the ENGAGE dashboard can be seen in Fig. 1, below.

The private information given in the dashboard and emails could potentially teach participants about when and how they were using electricity, therefore lowering the cost of conservation (Fischer, 2008). In addition the dashboard and emails enhanced social norms towards conservation with visual comparisons between a participant's energy usage and that of similar rooms. This descriptive social norm should increase the moral benefits of conservation for above average users,

[7] The information was updated every 60 seconds.

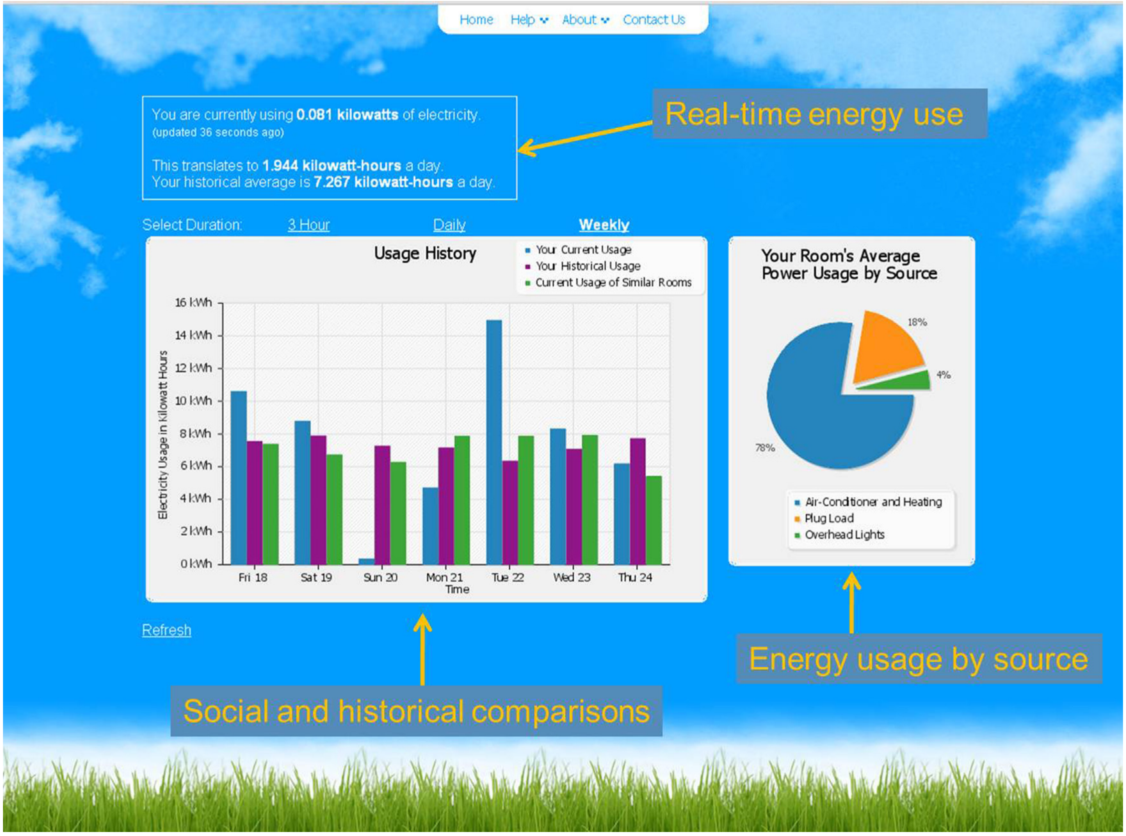

Fig. 1. UCLA ENGAGE Dashboard (blocked labels inserted).

increasing intrinsic motivation. It is also possible that the descriptive norm reduced conservation costs by benchmarking attainable conservation levels. Since social norms were built into the dashboard, we cannot separately identify the effects of feedback and social norms and have grouped them collectively under the label private information. Dashboard access was tracked using Google Analytics.[8]

Participants in the public information treatment were publicly rated as being above or below average energy conservers.[9] This relative rating system was used to protect the privacy of participants and prevent contamination of the control group with electricity usage information. Ratings were made public with large, prominently displayed posters, posted on each floor occupied by rooms participating in the public information treatment as shown in Fig. 2. The posters were placed on notice boards opposite the elevator, ensuring that all students on that floor would pass it several times a day. Ratings were determined on a weekly basis, where the weeks corresponded to the commonly known calendar weeks of the academic quarter. If a room used less electricity for the week than similar rooms ("an above average energy conserver") it was given a green sticker for the week. If the room used more electricity ("a below average energy conserver") it was given a red sticker for the week. The language on the poster was explicitly chosen to reflect positive behaviors – energy conservers as opposed to energy users.

Since the *poster* group only comprised one third of the entire group, it was possible for all rooms in the treatment to conserve energy and be awarded green stickers. This was made clear to the students through several emails as well as a note on the poster. To increase publicity and exposure, a copy of the poster was also emailed to each participant in the experiment (treatment and control). The public information treatment made the previously invisible prosocial action of conservation publicly visible. This created an additional motivation for participants to conserve – maintaining or creating a green reputation.

[8] Tracking took place at the room level. To facilitate ease of access to the dashboard, there were no logins. Rather each room had its own unique coded dashboard address. No identifying information was placed on the dashboard ensuring privacy. By tracking hits to the address, we can see how often rooms access the dashboard and which pages they were looking at (weekly, which was the default, daily or three hour). We cannot differentiate between roommates, since they have the same dashboard address.

[9] While the term 'average' was used for simplicity of exposition, rooms were actually rated as being above or below the median for their room type. Rooms were split into two types: single or shared. The use of the median and classification system were explained to students in the notes to the poster.

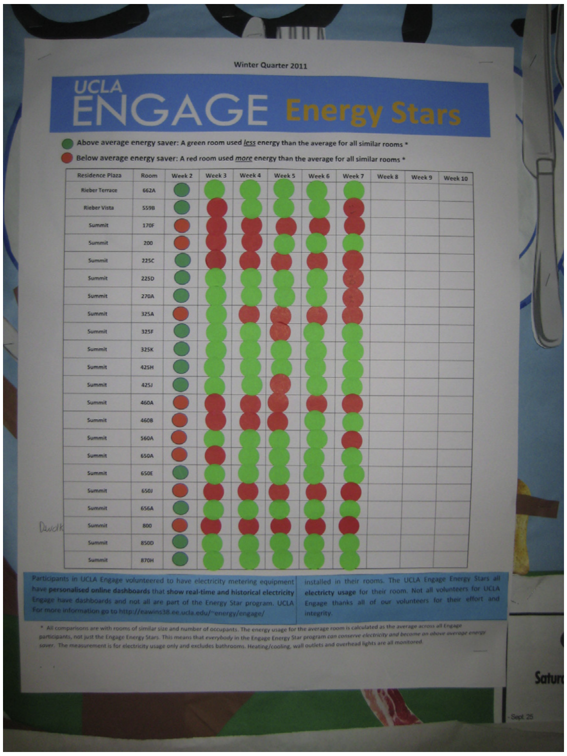

Fig. 2. UCLA ENGAGE Poster.

Experiment Recruitment

Several recruitment emails were sent to the 2,318 future residents of the three target residence halls. These were met with a high response rate, with 496 students completing an entry survey, of whom, 327 volunteered for the experiment (22 and 14 percent of the target population respectively). The final group of 102 experiment participants (from 66 rooms) was randomly selected from the group of volunteers, subject to room allocation constraints.

Table 2 below compares the randomly chosen experiment participants to the target residence hall population. Room allocation constraints led to us oversampling both single rooms (as opposed to shared rooms) and incoming students ($Pr(t<T)<0.001$ in both cases). Incoming students may care more about creating a good/green reputation than older more established students. This could potentially bias the public information treatment effect upwards. Alternatively, incoming students may have fewer community ties and less reason to invest in a green reputation, biasing the treatment effect of public information downward. We have no *a priori* reason to believe that single rooms will be more or less affected by either treatment.

The entry survey asked respondents about their energy usage habits, their beliefs about energy and the environment, as well as their beliefs about energy usage from different sources. We used the survey to construct environmental and altruism factors, using questions from the New Ecological Paradigm (NEP) Scale (Dunlap et al., 2000) and Altruism Scale (Schwartz, 1977). Although we cannot compare participants' attitudes with the general population, we can compare them with those students who completed the survey, but did not volunteer to participate. We find that experiment participants are significantly more altruistic and environmentally friendly ($Pr(t<T)<0.001$ in both cases). Self-selection along these criteria can potentially bias the effect of private information upward, since the effect of private information will increase with intrinsic motivation (see Hypothesis 1). However, since we do not find any significant effect of private information, this is not a concern. Likewise it is possible that the effect of public information could also be biased upwards by ideological self-selection. This would occur if "greenies" gained some non-reputational utility from advertising their internal beliefs. Such utility could be derived if consumers believed that their actions provided some form of demonstration or educational value.[10] We test this empirically (Table 6 regressions v and vi), and find no evidence that the effectiveness of public information on inducing conservation varies with an individual's own ideology.

[10] Alternatively, we could imagine that those who are identifying themselves as being green are in fact very brown in their private behavior. As such, they would be more motivated than browns to conserve by public information, since it exposes their private hypocrisy. Such behavior is at odds with the existing literature as well as our baseline period regressions, where environmentalists' behavior is consistent with their actions (see Clark et al., 2003; Kotchen and Moore, 2007, Kahn and Vaughn, 2009).

Table 2
Summary Statistics for Experiment Participants.

	Experiment Participants				Population	
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**
Age	18.50	1.167	17.00	24.00	20.090	1.362
Year of Study	1.48	0.941	1.00	4.00	1.790	0.959
Female	0.48				0.530	
Single Room	0.71				0.38	
Environmental Factor*	0.52	0.217	0.04	0.92		
Altruism Factor*	0.55	0.248	0.00	0.92		
Member Enviro. Org.*	0.12					
Observations	102 individuals				2318 individuals	

* These variables were derived from survey responses. Since not all experiment participants completed the survey, these variables only have 77 observations.

Randomization into Treatments

Randomization into the three treatment groups took place at the room level and was undertaken before the experiment began. We limited the public information treatment to only take place over half of the residence hall floors. These 'public information eligible' floors were randomly chosen. This was to increase possible peer effects and reduce the experimenter's effort costs involved in updating posters every week.

Regressing energy usage during the baseline period on dummy variables for the treatment groups and each of the randomization strata, we find that randomization was successful, with no significant differences found between the three groups for heating/cooling, lighting plug load or overall. These results can be seen in Appendix B.

Experiment Results

Baseline Usage

Table 3 shows that the average electricity usage over the entire period was 7.8 kWh per day. On a per capita basis this amounts to 198 kWh per month, which is comparable to the 2008 California monthly per capita *household* average of 210 kWh per household resident (US EIA, 2010). The majority of energy usage in all periods comes from heating and cooling, although there is substantial variation across rooms, with some rooms pumping the heater/AC all day, and others using it sparingly or not at all. Energy usage is lowest during the milder fall and spring seasons, which correspond with the baseline and persistence periods respectively.

Using the baseline period, where no one received any form of information, we can examine what factors influence energy usage. Since not all participants completed the entry survey, this investigation is limited to a sub-sample of 55 rooms.[11] The results of this analysis are presented in Table 4. Interestingly we can see that environmentalists (those with a higher score on the environmental factor) use substantially less heating and cooling than their peers (the difference between the most and least environmental participants would be almost 100 percent of the baseline period mean). Surprisingly, single rooms used significantly more heating/cooling (about 45 percent of the baseline mean) than shared rooms, although they do use less lights.

Main Results

After 6 weeks of baseline monitoring, the private information treatment began with both the *dashboard* and *poster* groups receiving real-time feedback over their energy usage through the UCLA ENGAGE dashboard. After 5 weeks of private information, participants in the *poster* group were informed about the upcoming public information treatment. The public information treatment lasted for seven weeks.[12] In all of the following analysis, we exclude data from university holidays and exam weeks yielding a total of 156 observation days taken over a 9 month period.

We ran the following econometric specification to test the effectiveness of public and private information:

$$\begin{aligned}\text{Usage}_{it} = \beta_0 + B_{1i}{*}(\text{roomFE}) + B_2{*}(\text{weather}_t)\\ + B_3{*}(\text{time}_t) + B_4{*}\text{private info}_{it} + B_5{*}\text{public info}_{it} + \varepsilon_{it}\end{aligned}$$

Where i is room and t is day. Treatments are designated by dummy variables in the periods that the treatments are operational. A significantly negative coefficient on the private info dummy would indicate that private information did

[11] In shared rooms, room level values are calculated by averaging those of the inhabitants.
[12] The intended treatment time was 9 weeks but ended two weeks early due to technical problems.

Table 3
Summary of Electricity Usage at the Room Level.[a]

	Total Usage (Daily Wh)			
	Mean	**Std. Dev.**	**Min**	**Max**
Entire Period	7834.19	4645.93	1362.06	20836.94
Baseline Period	6160.69	4485.23	519.02	20972.34
Private Info Period	9440.91	5953.02	1601.70	26987.78
Public Info Period	8027.09	5425.02	1450.84	26462.03
Persistence Period	7499.34	5339.63	687.92	21677.60
Baseline Usage by Source (Daily Wh)				
Lights	288.37	164.80	0.00	673.61
Heating/Cooling	4433.37	4298.17	0.00	20165.35
Plug load	1438.95	1184.11	93.82	6336.00

[a] There are 66 rooms in the baseline period, 65 in the public and private information periods and 62 in the persistence period. Attrition is due to student room changes.

induce conservation, validating Hypothesis 1; while a significantly negative coefficient on the public info dummy would signify that public information did induce energy savings, validating Hypothesis 2.

To remove any baseline differences between rooms we include a room level fixed effect. We account for changes in weather across time by including heating and cooling degree days, which measures the potential need for heating or cooling with respect to a baseline temperature.[13] We interact these degree days with a dummy for female, since research on thermal comfort has found that women are more sensitive to temperature changes than men (Parsons, 2002; Karjalainen, 2007). Changes in usage patterns across time are captured by the inclusion of a cubic of a daily time trend, weekly fixed effects, and day of the week fixed effects. The cubic time trend is intended to measure long term patterns, such as the slow adoption of electronics (or unpacking) after moving in to a new residence hall room. Weekly fixed effects on the other hand capture short-term time trends. These weeks correspond to the academic calendar and will capture common events such as a midterm week or a public holiday. Finally, day of the week fixed effects capture habitual behavior like spending less time in rooms over weekends. To account for the non-asymptotic nature of our sample size and possible error clustering at the room level, we bootstrap all standard errors (Bertrand et al., 2004).

The public information treatment is incremental to the private information treatment, meaning that participants receiving public information, continued to receive private information. The marginal effect of public information is identified since there was a period when participants in the public information treatment group (the poster group) received private information only. Our estimation results, with usage broken down by source, are shown in Table 5 below.

The effects of private information on total energy usage are negative, but not statistically significant. There is a statistically significant effect of private information on overhead light usage, which was reduced by 78 watt hours a day. This is equivalent to turning off the main room light for 80 minutes a day, or represents a 20 percent reduction in light usage from the private information period average.[14] Light usage during this period constituted less than 5 percent of total energy usage. This focus by minimally motivated participants on light usage is similar to those found in our pilot study and Petersen et al. (2007). This can possibly be explained by habits or ideas ingrained during childhood. In our entry survey nearly 90 percent of respondents agreed with the statement that "While growing up, I was told repeatedly to turn off the lights when leaving a room." When asked about a similar statement for heating/cooling behavior, only 40 percent of respondents agreed with it. Apart from the effect of lighting, we find little support for Hypothesis 1 that private information can induce conservation. This failure could occur because participants do not view or understand the dashboard, or because descriptive norms cause a boomerang effect, resulting in convergence to the norm. This is investigated further in Section 5.3.

Public information by contrast, had a very large and statistically significant effect on total energy usage. Participants placed in the public information treatment reduced their heating/cooling by 25 percent of the period average. Plug load and lighting were also reduced by 7 and 5 percent respectively, although these reductions were not statistically significant. This amounted to a total reduction of 1,500 watt hours or 20 percent of the period average. This result is robust to alternative specifications such as random effects with individual level controls and daily fixed effects models (not shown). These results support Hypothesis 2, which conjectured that public information would induce conservation.

[13] We approximate heating and cooling degree days as the number of degrees the daily maximum is above, or the daily minimum is below 65 degrees Fahrenheit, respectively. Daily temperature data was collected from an on campus weather station (with special thanks to James Murakami for providing this data).

[14] We obtain similar results when restricting our analysis to the baseline and private information periods only (not shown).

Table 4
Room Level Regression on Baseline Usage.

	Total Usage	Heating/Cooling	Overhead Light	Plug Load
Female	−1,155.393	−779.824	−91.465*	−276.634
	(1,191.295)	(1,140.997)	(48.647)	(252.255)
Age	−35.690	−378.962	−44.267	392.903*
	(686.667)	(573.087)	(32.735)	(236.998)
Year of Study	−75.823	−129.976	60.703**	−18.962
	(670.274)	(631.560)	(29.732)	(169.413)
Environmental Factor	−5,248.328*	−5,486.787*	135.806	119.065
(0.04 < Env. Factor < 0.92)	(3,018.645)	(2,958.568)	(99.505)	(569.348)
Altruism Factor	1,953.077	2,593.734	−56.074	−539.914
(0 < Altruism Factor < 0.92)	(2,725.658)	(2,561.553)	(99.565)	(506.736)
Member of Enviro Org.	−518.500	−230.534	−23.876	−267.277
	(1,226.459)	(1,151.134)	(54.841)	(409.090)
Single Room	1,955.991	2,561.988**	−141.073**	−477.056
	(1,351.889)	(1,191.548)	(60.628)	(354.920)
Observations	1879	1879	1879	1879
Number of rooms	55	55	55	55
R−squared	0.0851	0.1042	0.209	0.1725
Mean for baseline period	5929.241	4231.889	291.6913	1405.661

Bootstrapped standard errors are reported in parentheses and are clustered at the room level. *p < 0.10, **p < 0.05, and ***p < 0.01. Variables not reported: heating and cooling degree days, heating and cooling degree days*female, residence hall dummies, day of the week fixed effects, week fixed effects, constant and cubic time trend.

Private Information

Dashboard Views

Private information yielded no significant average treatment effect. This could be because the intention to treat did not translate into actual treatment received. A successfully administered treatment under private information would have involved a participant receiving information and finding that this information was useful.

Using Google Analytics, we were able to track which rooms viewed the ENGAGE dashboard and when. Of the 43 rooms which were given access to the dashboard, 39 viewed it at least once, with the median number of views being 7 and several rooms viewing it almost every day.[15] Since more than 90 percent of rooms viewed the dashboard (and non-viewers may still have seen the email reports), it seems reasonable to conclude that participants did receive the information. In a separate analysis (not shown) we examined whether conservation from private information occurred for frequent dashboard viewers or increased with incremental dashboard views. Neither hypothesis yielded statistically significant results. Interestingly, none of our attitudinal measures have any predictive powers for dashboard views (including the environmental and altruism factors).

The next question is whether the participants' prior knowledge about their energy usage was correct, with the information treatment then providing no new information. We compared participant actual energy usage by source from the baseline period, with the energy usage that they predicted for an *average room* before the experiment.[16] The results show that respondents overestimated how much of their energy usage was constituted by lighting, and underestimated how much was constituted by heating and cooling (this also occurred in our pilot study). On average, participants predicted that lights would constitute 29 percent of their energy usage while the average usage for lights was 5%. Compared to respondent estimates of roughly equal usage, experiment participants used on average 15 times more electricity for heating and cooling than overhead lighting during the baseline period.[17] It is possible that participants overestimate the energy use from lights because they have not been paying the bills in their home. However, previous research suggests that consumers have little awareness of the energy efficiency of appliances and of the price of the services produced by electrical appliances (Dennis et al., 1990; Mansouri et al., 1996; Yamamoto et al., 2008). Moreover, Attari et al. (2010) found similar results in a national survey, with survey respondents underestimating "*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*. These results indicate that there is ample room for private information to correct erroneous beliefs and thereby lower the cost of conservation actions.

[15] The four rooms who never viewed the webpage were equally split between the *private* and *public information* groups. Similarly, Allen and Janda (2006) found that half of their sample never touched their real-time energy meters despite having requested them.

[16] This was to ensure that we captured respondents' perceptions of energy usage rather than their own idiosyncratic energy usage behavior.

[17] In order to select percentages, respondents had to slide a cursor for each of the three energy usage sources until the total for all three added up to 100 percent. This eliminated default bias since the default for all three was zero. However, it is possible that the equal magnitudes between sources is the result of the 1/n bias witnessed in portfolio allocations, in which allocations are evenly split between n options (Benartzi & Thaler, 2007).

Table 5
Basic Treatment Effects.

	Total Usage	Heating/Cooling	Light	Plug Load
Private Information	−441.692	−361.578	−78.391*	−1.723
	(1,142.924)	(892.152)	(45.810)	(216.695)
Public Information	−1,504.371**	−1,330.889**	−24.221	−149.261
	(626.157)	(650.205)	(26.033)	(166.929)
Heating degree days	96.945**	92.534*	2.502**	1.909
	(48.439)	(47.735)	(1.239)	(4.734)
Cooling degree days	121.808***	122.161***	0.801	−1.154
	(40.218)	(43.503)	(1.139)	(2.688)
Heating degree days × female	76.181	64.929	0.910	10.342
	(68.736)	(66.659)	(1.750)	(9.697)
Cooling degree days × female	42.242	38.245	−1.769	5.767
	(58.360)	(70.537)	(1.633)	(5.145)
Observations	7120	7120	7120	7120
Number of rooms	66	66	66	66
R − squared	0.11	0.08	0.11	0.19
Mean for entire period	7772.045	5443.149	372.3732	1956.523

Bootstrapped standard errors are reported in parentheses and are clustered at the room level. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$. Variables not reported: day of the week fixed effects, week fixed effects, average room level fixed effect and cubic time trend.

Convergence to Norm

An alternative explanation for private information's low average treatment effect could be a "boomerang effect" caused by descriptive social norms. The dashboard and email reports created a descriptive social norm by informing participants about whether they were using more or less electricity than other users. It is possible that this information weakened the norm towards conservation for below average energy users, whilst strengthening it for those who used more than average. This would cause convergence to the norm and a zero average treatment effect.

In Table 6 equation i, we interact a dummy variable indicating that consumers are above median users in the baseline with the private information treatment dummy. This means that the coefficient on private information applies only to below median users. Since the coefficient on private information is positive and insignificant we conclude that there is no evidence that below median users increased their usage in reaction to private information. Similarly, there is no effect of private information on above median users.[18] While not statistically significant, these point estimates suggest that instead of a boomerang effect with below average users increasing their usage, we see the opposite with these participants further decreasing their energy consumption![19] This seemingly paradoxical result can be explained by examining the interaction between ideology and usage.

Environmental Ideology and Conservation

In our baseline period regressions we found that environmentalists used significantly less electricity than non-environmentalists (see Table 4). We conjectured that these participants, who had greater levels of intrinsic motivation, would be more responsive to private information than their browner counterparts. We test this in Table 6, regressions *iii* and *iv*, by interacting private information with an environmental and altruism factor, respectively. Although not statistically significant, the point estimates indicate that greener, more altruistic participants are more responsive to private information, with those in the top decile of environmentalism and altruism reducing usage by 1,000 and 1,600 watt hours respectively, while those in the bottom decile did not conserve.

Public Information

Large Energy Users and Conservation

The results on who conserves under public information are strikingly different from that of private information. Table 6, equation *ii*, which interacts above median baseline usage with the public information treatment, shows that the entire effect of public information is coming through those participants who were above average electricity users in the baseline period. These large users reduce their electricity usage by about 20 percent compared to the average usage for other large users during this period. Due to the binary nature of the reputation mechanism, only those participants who were rated as below average conservors could improve their reputation. Those particpants who already rated above average conservors could not gain any further repuational benefits by conserving more. The results above confirm that public information is only effective in inducing conservation when the marginal change to reputation from conservation is positive.

[18] The net effect of private information + private information ∗ above median user is zero.
[19] Similarly, Ferraro and Price, 2013 found no evidence of a boomerang effect from descriptive norms.

Table 6
Heterogeneous Treatment Effects – User Type and Ideology.

	User Type		**Ideology**			
	i	**ii**	**iii**	**iv**	**v**	**vi**
Private Information	−1120	−453.6	583.8	1277	−336.0	−354.6
	(938.1)	(1132)	(1584)	(1900)	(1072)	(995.2)
Public Information	−1590**	37.34	−1392**	−1352**	−1862	−2029*
	(626.4)	(812.5)	(666.1)	(609.1)	(1132)	(1172)
Private Info × Above Median User	1242					
	(1208)					
Public Info × Above Median User		−2330**				
		(998.9)				
Private Info × Environmental Factor			−1775			
(0.04 < Env. Factor < 0.92)			(2601)			
Private Info × Altruism Factor				−2747		
(0 < Altruism Factor < 0.92)				(2974)		
Public Info × Enviromental Factor					994.1	
(0.04 < Env. Factor < 0.92)					(2368)	
Public Info × Altruism Factor						1227
(0 < Altruism Factor < 0.92)						(1680)
Observations	7120	7120	7120	7120	7120	7120
Number of rooms	66	66	66	66	66	66
R − squared	0.109	0.111	0.108	0.108	0.109	0.108

Bootstrapped standard errors are reported in parentheses and are clustered at the room level. * $p < 0.10$, ** $p < 0.05$, and ***$p < 0.01$. Variables not reported: day of the week fixed effects, week fixed effects and cubic time trend, average room level fixed effect, heating and cooling degree days, heating and cooling degree days interacted with female, constant.

This is a powerful result since these above average energy users were the least intrinsically motivated to conserve in the first place, and were unaffected by the provision of private information. Public information successfully motivated them to conserve out of a desire to obtain the benefits of a "green" reputation, rather than any intrinsic motivation. Equations *iv* and *vi* reiterate this point, showing that there is no significant and negative interaction between ideology and the public information treatment.

Persistence

The public information treatment induced large behavioral change with above median users reducing their energy usage by 20 percent. But did this motivational mechanism inspire unsustainable actions that would end with the treatment, or were new and lasting habits formed? Behavioral decision theorists view habits as a rational response to frequently occurring tasks, since they allow individuals to forego having to undertake the entire decision process each time that the task occurs. A habit is formed when a task is repeated to the point where it becomes mechanical and enacted without awareness. Habitual behaviors may be the result of an earlier, more reasoned decision, but may be non-optimal given changing circumstances (Beach and Mitchell, 1978; Aarts et al., 1997; de Vries et al., 2011). Thus we may expect that the withdrawal of public information is not a disruptive/salient enough event that participants will re-optimize their habitual behaviors.

To evaluate this, we ended the public information treatment while continuing to supply participants in both the *dashboard and* poster groups with private information over their energy usage. The persistence period lasted for 10 weeks after the public information treatment ended. Treatment effects have been shown to wane significantly over similar time periods in other conservation experiments (Nolan et al., 2008; Allcott, 2011; Allcott and Rogers, 2012; Ferraro and Price, 2013, Hayes and Cone, 1977). Due to technical problems, exams and spring break, we only examine the last 5 weeks of this period. This later time period, plus the disruption of examinations and a vacation period, ensure that we are catching lasting habits. We run the same specification as the main regression, but extend the time period to include the persistence period. We also add in an extra term called persistence, which is a dummy for being in the *poster* group, but no longer receiving the public information treatment.

$$\text{Usage}_{it} = \beta_0 + B_{1i}*(\text{roomFE}) + B_2*(\text{weather}_t) + B_3*(\text{time}_t) + B_4*\text{feedback}_{it} + B_5*\text{reputation}_{it} + B_6*\text{persistence}_{it} + \varepsilon_{it}$$

Table 7 shows that the effects of persistence are significant and large. Although the magnitude of persistence is seemingly larger than that of the public information treatment, it is actually statistically indistinguishable. This holds for total usage, as well as usage by all three constituent sources (although the effect on plug load and light use is again statistically insignificant). In a separate regression we find that the persistence effect is operating completely through above median users, as with public information (regression not shown).

Table 7
Persistence of the Reputation Treatment.

	Total Usage	Heating/Cooling	Light	Plug Load
Private Information	−504.530	−443.706	−82.437*	21.614
	(977.654)	(876.920)	(49.822)	(228.022)
Public Information	−1,516.046**	−1,338.582**	−20.537	−156.928
	(615.887)	(582.851)	(23.818)	(166.748)
Persistence of Public Info	−1,921.633*	−1,764.047*	−33.975	−123.611
	(1,131.868)	(990.326)	(40.681)	(199.500)
Heating degree days	94.848**	94.151**	0.792	−0.094
	(43.342)	(45.459)	(1.304)	(4.546)
Cooling degree days	139.166***	137.914***	0.279	0.973
	(34.450)	(40.429)	(0.884)	(3.262)
Heating degree days × female	62.581	51.248	0.747	10.586
	(54.347)	(66.316)	(1.779)	(9.211)
Cooling degree days × female	13.995	10.460	−1.368	4.902
	(49.870)	(61.591)	(1.324)	(5.362)
Observations	8917	8917	8917	8917
Number of rooms	66	66	66	66
R−squared	0.09	0.07	0.09	0.16
Mean for entire period	7762.262	5422.693	371.0645	1968.504

Bootstrapped standard errors are reported in parentheses and are clustered at the room level. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$. Variables not reported: day of the week fixed effects, week fixed effects and cubic time trend, average room level fixed effect.

Discussion of results

In our empirical analysis we found no effect of private information on conservation behavior, while public information induced a reduction in electricity use of 20 percent. Since we observed energy usage at the appliance level, we were able to see that the majority of the impact from public information came from reductions in heating and cooling. We interpret all results as coming from behavioral change since the participants have no incentive/ability to invest in new energy efficient capital stock. This was further verified by surveys and focus groups..

This analysis is supported by qualitative data gathered during focus groups and exit surveys at the conclusion of the experiment. Students in both the *dashboard* and *poster* groups remarked on being astonished at how much of their energy usage came from heating and cooling. Nonetheless, private information only helped those students who were already motivated to conserve. By way of example, one student in the *dashboard* group said, "*I feel that having access to my power usage made me more aware and considerate of the amount of power I used.*" While for those students who were not intrinsically motivated, private information just wasn't enough: "*The amount of energy that I consume compared to other rooms wasn't a great enough incentive to cut back.*"

This reaction stood in stark contrast to that of participants in the *poster* group, where reaction to the public information treatment (poster) was far less equivocal:

"*Once the poster got up, it became serious…*"
"*I liked the poster, it made us want to get green dots.*"
"*We want to make it green because red looks bad.*"
"*I thought the posters were pretty crucial to the whole process. It gets everyone else involved.*"
"*We did not want to attract attention because we were red.*"
"*I turned off all the lights and wear a lot of sweaters so I could get a green dot.*"
"*When I got a green dot, I received high 5.*"

Our results are consistent with previous research on self-image considerations describing how individuals derive utility from prosocial behavior as a signaling mechanism (Gneezy et al., 2012). While previous research has described this mechanism in the context of green products or charity, our study demonstrates empirically the effectiveness of signaling mechanism and reputation in the context of energy conservation behavior. This is particularly interesting because electricity is a non-differentiated product that is usually invisible to most users. Our work builds on Yoeli et al. (2013) who have demonstrated the role of behavior observability on a one-time decision to participate in electricity demand response program. We show the value of public information for energy conservation behavior, which consists of repetitive behavior where consumers form a new stock of consumption habits leading to persistent changes (Allcott and Rogers, 2012). In addition, we were able to observe conservation behavior at a highly granular level, recording energy use for three main appliances. This allowed us to understand how the conservation impacts occurred, i.e. which appliance participants decided to turn off or on. This is important, because people do not consume electricity directly; instead, they consume services powered by electricity. These include lighting, heating and cooling and plug-load (such as computing). To understand electricity consumption, it is therefore important to study electrical appliance use. Thus, our paper aims specifically to clarify participants' decision-making in electricity consumption through electrical appliance use. Our study expands the realm of use of public information strategies to the new context of energy conservation behavior.

Our experiment did not allow us to investigate the finer points of reputation as a mechanism, such as whether people were really seeking public recognition and status or avoiding shame or symbolic punishment (Fehr and Gächter, 2000; Gächter et al., 2008). Some of the comments shown above do seem to indicate the latter, although shaming is at odds with the incredible amount of positive comments we received about the public information treatment. Not only did we not receive a single negative comment or complaint about the posters, but some students even reported missing having the posters up. Further research on this topic would be beneficial, particularly with regard to asymmetric responses between the two mechanisms and how these evolve over time (Gächter et al., 2008).

Another potential motivational mechanism that could explain the strong result of public information is competitiveness between participants. This seems unlikely since participants were given their relative usage in the private information treatment. If they merely desired to "beat" other participants, they would have reduced consumption in the private information treatment. If they only started competing in the public information treatment, then it is because they wanted to acquire a reputation for being a better energy conserver than others. Moreover, in all of the surveys and focus groups, the word competition was only mentioned once.

Our study shows that public information can effectively induce energy conservation, but it is not without limitations. First, our experiment population is somewhat younger and lives in a more environmentally aware community than most U.S. residents. The effectiveness of public information might vary with the greenness of others in the community. For example, while driving a Prius may earn you the respect of your peers in Berkeley, California, it is unlikely to do the same in Lubbock, Texas. This raises questions about the external validity of our experiment, since purely green signals may not work in non-green areas. However, there are a broad range of prosocial signals out there that can possibly be harnessed to appeal to heterogeneous communities. Further research is warranted to compare the effectiveness of alternative public information signals in different contexts. Second, our population is relatively cohesive with strong social ties. Social ties have been shown to influence cooperation, altruistic norm behavior enforcement (Goette et al., 2012). Further research could investigate the effectiveness of public information in contexts with lower level of social interactions. Third, we have no monetary rewards in our experiment. In practice, monetary rewards such as a reduced electricity bill may increase the impacts of private information, while simultaneously diluting the reputational signal of conservation, since agents may be perceived as conserving purely to save money. However, if agents do not mentally place conservation efforts in the pecuniary realm (since saving money on bills is not an explicit incentive), financial rewards may operate alongside reputation, boosting the effectiveness of public information. Finally, our public information mechanism did not encourage further conservation by environmentalists, since it only provided positive marginal reputational benefits to those large electricity users who were not already conserving. Future mechanisms should incorporate levels that encourage all consumers to conserve. These limitations provide ample opportunity for future research by changing both the experiment context and public information mechanism.

Conclusion

Private information such as real-time feedback over energy usage allows consumers to be better informed and hence make better decisions. But without sufficient motivation, consumers will not incur the costs of gathering, interpreting and utilizing this information. Public information can motivate consumers to engage in green behaviors so that they obtain the benefits of a green reputation. Psychologists have shown that a reputation for being pro-social (as opposed to pro-self) can lead to a number of rewards such as mates, leadership opportunity and friends. By making previously unobservable pro-social behavior such as energy conservation visible, consumers have an additional motivation to engage in such a behavior, that of a socially beneficial reputation.

In a unique field experiment we outfitted residence hall rooms at UCLA with real-time energy metering equipment and provided a number of these rooms with real-time feedback about individual and aggregate electricity usage. We found that those participants receiving private information in the form of feedback and social norms were only minimally motivated to conserve, and thus there was no significant effect of private information on energy conservation. By making energy usage public for a subset of participants, we were able to engage reputational motivations for conservation and induced a 20 percent reduction in energy usage among above median electricity users. Moreover, after two months of the public information treatment, these previously large energy users had formed substantially better energy usage habits, which persisted until the experiment ended three months later. We were also able to observe the actions taken by participants to reduce their energy use. While most participants learned how much energy usage came from heating and cooling via our dashboard, only participants in the public information treatment reduced the use of their heating and cooling system.

In a world of heterogeneous consumers, social scientists need a number of tools in their behavioral toolbox to appeal to a variety of motivations. Compared to other policies, such as pecuniary incentives, information policies are a relatively inexpensive way to encourage conservation, especially in this age of mass information and telecommunication technology and have the potential to reduce the high cost of energy efficiency demand-side management programs (Auffhammer et al., 2008). Public information in particular has a potentially important role to play since it can motivate both those who are *and* those who are not ideologically green to conserve.

Public information has already become a valuable tool in encouraging corporations to behave in a more environmentally friendly manner (see for example Delmas et al., 2009), but it has also been abused in this environment with firms engaging in "green-washing", by reporting only selective information in voluntary disclosure programs (Delmas and Burbano, 2011; Lyon and Kim, 2011). This is a particularly salient issue for the implementation of any consumer-orientated public information program. Consumers are unlikely to find any sort of mandatory public disclosure program palatable, while any voluntary public information policies may lead to adverse self-selection into only those programs that reflect current behaviors in a good light. To overcome this, any voluntary program needs to be designed in such a way so as to ensure a positive marginal reputational benefit to conservation for targeted consumers, encouraging both participation and conservation. For example, the reputation mechanism can combine absolute measures with changes from baseline, to reward both those beginning and those continuing to conserve. Credible public information mechanisms can be employed in a variety of creative ways to encourage consumers to conserve: from car window displays showing fuel efficiency; to social media applications that show the environmental impact of your shopping cart. Intelligently designed public information mechanisms can encourage conservation, while allowing people to communicate their greenness to the world.

Appendix A. Model

In this section we formalize the interaction between information, motivation and costs with a simple model that allows us to develop testable behavioral hypotheses. To this end we build on Bénabou and Tirole, 2006 model of prosocial behavior. In this framework, an individual's incentives to engage in prosocial behavior, such as performing conservation action a, is divided into three basic motivations, intrinsic (nv_a), extrinsic (yv_y) and reputation, $R(a,y)$. Formally an agent's utility is:

$$U(a) = (nv_a + yv_y)a + R(a,y) - C(a,k,\theta) \tag{1}$$

Where v_a is an agent's own ideology and n is the perceived saliency of the set of social norms that pertain to a particular action. In contrast to Levitt and List (2007), who model social norms as increasing the moral cost of undertaking an anti-social action, we model social norms as increasing the moral benefits of acting prosocially. Thus a greater value of n is associated with a stronger norm for conservation. We allow the effect of social norms to vary positively with own ideology by interacting the social norm with personal ideology in accordance with the empirical results obtained by Costa and Kahn, 2013. Extrinsic motivations are a combination of the monetary reward, y, and its valuation by the agent, v_y. The cost of behaving prosocially $C(a,k,\theta)$ depends on an individual's procedural knowledge, k, and cost shifter, θ. We will initially assume that the state of procedural knowledge, k, is constant across individuals. Personal ideology (v_a, v_y) is determined by an independant draw from a bivariate normal distribution, while costs $C(a,k,\theta) = \theta k^{-1}(a^2/2)$.

The provision of private information to an agent can influence behavior by increasing procedural knowledge, k, strengthening the social norm, n, or both. Increasing knowledge will decrease the cost of conservation, whereas strengthening the social norm will amplify intrinsic motivation.

Reputation, $R(a,y)$, depends on whether conservation actions are public information or not $(I: x \to 0, 1)$, the degree to which agents care about their reputation, γ (which we assume is constant across all agents), and the expectation that others have of their (unobservable) attitudes (nv_a), based on their observable behavior and rewards, hence:

$$R(a,y) = I(x)\gamma E(nv_a|a,y) \tag{2}$$

Substituting in the cost and reputation terms and taking the first order condition to determine the optimal level of the prosocial action a, we are left with

$$a^* = \frac{1}{\theta k^{-1}}\left[nv_a + yv_y + r(a,y)\right] \tag{3}$$

where $r(a,y) = I(x)\gamma(dE(nv_a|a,y)/da)$ is the marginal reputational return to a change in the level of the prosocial activity.

Following Bénabou and Tirole, 2006 we are able to to solve for the optimal level of conservation using standard results from the normal distribution and the fact that the level of a informs us about the agent's intentions. This yields the optimal level of the conservation activity a^*, such that:

$$a^* = \frac{nv_a + yv_y}{\theta}k + \gamma I(x)\rho \text{ where } \rho = \frac{\sigma_{nv_a, nv_a+yv_y}}{\sigma^2_{nv_a+yv_y}} \tag{4}$$

To solve for this conditional expectation, we can follow Benabou and Tirole in exploiting the fact that the level of a tells us something about an agent's intentions. Since v_a and v_y are jointly distributed and y is exogeneously given, we have

Following on standard results for the normal distribution we have[20]

$$E[nv_a|nv_a + yv_y] = n\overline{v_a} + \rho(nv_a + yv_y - n\overline{v_a} - y\overline{v_y})$$

[20] If $(x_1, x_2) \sim N\left(\upsilon_1, \upsilon_2; \begin{matrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{21} & \sigma_2^2 \end{matrix}\right)$ then $E(x_1|x_2) = \overline{\upsilon_1} + \frac{\sigma_{12}}{\sigma_2^2}(x_2 - \upsilon_2)$.

where $\rho = (\sigma_{nv_a, nv_a + yv_y}/\sigma^2_{nv_a + yv_y})$. We can then substitute in the first order condition, yielding

$$E\left[nv_a | nv_a + yv_y\right] = n\overline{v_a} + \rho(a\theta k^{-1} - \gamma I(x)\frac{dE(nv_a|a,y)}{da} - n\overline{v_a} - y\overline{v_y})$$

Taking the derivative with respect to a gives us a linear differential equation $(dE(nv_a|a,y)/da) - \rho\theta k^{-1} + \rho\gamma I(x)(d^2E(nv_a|a,y)/da^2) = 0$, which has the general solution

$$\frac{dE(nv_a|a,y)}{da} = \rho\theta k^{-1} + \xi e^{(-a/\rho\gamma I(x))}$$

Where ξ is the constant of integration. Benabou and Tirole show that an interior solution exists only in the case where $\xi = 0$.

We can then subsitute this marginal value of reputation into eq. 3 of the main text. This yields the optimal level of the prosocial activity a to be:

$$a^* = \frac{nv_a + yv_y}{\theta}k + \gamma I(x)\rho$$

Appendix B:

See Table B1.

Table B1
Random effects regression of daily electricity usage by source to test randomness across the treatments in the baseline period.

	Total Usage	Heating/Cooling	Light	Plug Load
Private Info Only Group	1,723.835	1,370.969	−32.878	420.753
	(1,151.216)	(1,156.347)	(45.359)	(365.139)
Public Info Group	181.978	469.453	−50.877	−225.329
	(1,663.754)	(1,689.876)	(48.463)	(386.289)
Strata 1	−636.093	253.770	−209.282***	−689.802
	(1,907.022)	(1,766.687)	(51.684)	(631.715)
Strata 2	1,231.028	1,458.383	−236.480***	17.415
	(1,752.547)	(1,662.565)	(41.389)	(635.880)
Strata 3	−2,058.146	−878.346	−236.491***	−846.546
	(2,136.197)	(1,926.735)	(74.350)	(603.978)
Strata 4	−1,128.724	127.796	−243.396***	−1,012.009**
	(1,571.345)	(1,407.052)	(38.589)	(513.417)
Strata 5	−2,282.704	−1,797.416	−76.478	−405.147
	(1,901.976)	(1,656.015)	(78.100)	(582.208)
Strata 6	−3,467.035**	−2,625.189**	−5.490	−840.397*
	(1,414.093)	(1,225.290)	(125.155)	(510.746)
Strata 7	−4,439.352***	−3,291.717**	−203.099**	−941.687
	(1,672.599)	(1,465.653)	(85.813)	(625.297)
Constant	6,321.588***	3,910.774**	498.822***	1,897.264***
	(1,727.971)	(1,566.083)	(43.394)	(509.006)
Observations	2207	2207	2207	2207
Number of rooms	65	65	65	65

The sample was stratified by gender, room type and floor/building. Bootstrapped standard errors are reported in parentheses and are clustered at the room level. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

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