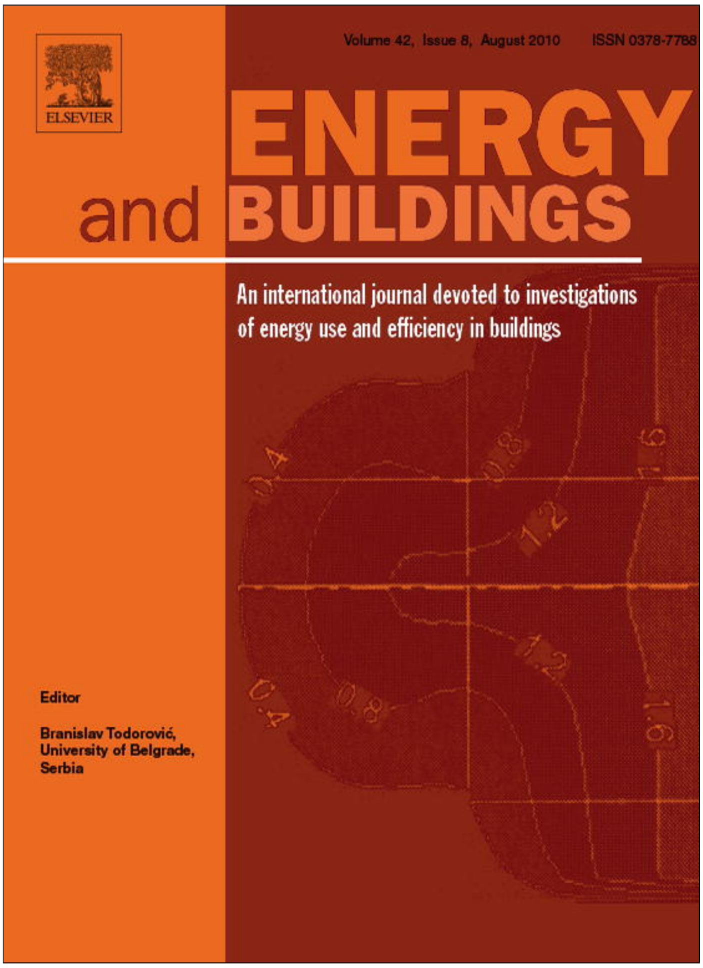
Volume 42, Issue 8, August 2010 ISSN 0378-7788
ELSEVIER
ENERGY
and BUILDINGS
An international journal devoted to investigations of energy use and efficiency in buildings
Editor
Branislav Todorović,
University of Belgrade,
Serbia

Energy and Buildings 42 (2010) 1329–1336

Contents lists available at ScienceDirect

Energy and Buildings

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

Response–relapse patterns of building occupant electricity consumption following exposure to personal, contextualized and occupant peer network utilization data

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ARTICLE INFO

Article history:
Received 1 August 2009
Received in revised form 11 January 2010
Accepted 1 March 2010

Keywords:
Behavior
Building occupant networks
Energy efficiency
Energy monitoring

ABSTRACT

Behavior can account for significant differences in building energy use. Monitoring and reporting of building energy use may induce occupants to conserve energy. The goal of this study was to assess the behavioral impact of providing building occupants with personal electricity utilization data contextualized with different social frames of reference. We installed monitoring equipment on the electrical meters for 83 rooms of a six-floor residential dormitory building and formulated three study groups and a control group from the building occupants. One study group was provided with their own electricity use, a second group was provided their own electricity use contextualized with average building occupant utilization, and a third group was provided with their own electricity use contextualized with both average occupant utilization and the electricity use of their peer network in the building. The only group that significantly reduced their electricity use when compared to the control group was the study group that could view peer network utilization. All three study groups exhibited response–relapse patterns after viewing their electricity consumption raising important questions about the sustainability of energy conservation and monitoring efforts.

1. Introduction

Concerns about greenhouse gasses have brought energy use to the forefront of policymaking in many countries. Countries seeking to curb emissions are focusing efforts on reducing energy use in buildings since the built environment accounts for a significant percentage of total consumption. In the United States, for example, buildings are responsible for approximately 40% of total energy use [1]. The current presidential administration in the United States has pledged that all buildings reduce their energy use more than 80% by 2050 and plans to strategically invest $150 billion over the next 10 years in order to catalyze efforts to build a clean energy future [2]. Many urban municipalities are also committed to reducing their carbon footprint sooner. As an example, the Mayor of New York City is committed to reducing 30% of its greenhouse gas emissions by 2030 and much of this improvement will have to come from making buildings more energy efficient [3].

Most efforts to reduce energy use in buildings focus on improving building infrastructure through steps such as upgrading boilers, adding insulation, replacing windows, and replacing lighting, office equipment and appliances. While these measures are often effective, they require substantial investment, are not necessarily readily adaptable to existing buildings, and require ongoing operations and maintenance to achieve their full potential. Besides being expensive, the positive effects of building improvements can be negated by profligate personal energy use. Despite advances in energy efficient building practices (i.e., LEED Green Building Rating System™ [4]) and the proliferation of energy efficient appliances, the intensity of electrical use actually continues to increase [5]. It has even been demonstrated that a "take-back" effect exists where energy use tends to *increase* after conventional efficiency measures are implemented [6].

2. Background

There is tremendous potential for reducing greenhouse gas emissions by motivating energy efficient behavior. One study found a 5-to-1 variation in energy use across identical build-

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doi:10.1016/j.enbuild.2010.03.001

ings and attributed the difference in consumption to behavior [7]. Another reviewed electricity shortages from around the world and reported 4–20% short-term energy-saving behavior changes from building occupants when appropriate marketing approaches were aggressively employed [8]. Studies in commercial [9] and residential buildings [6,10–12] report energy savings resulting from behavior change can even exceed those associated with more conventional energy conservation measures (i.e., improved boilers, added insulation). The impact that changes in personal behavior can have on energy use in buildings makes determining the most effective ways of motivating energy-saving practices a high priority.

Researchers have recently begun exploring how sharing energy use information with building residents can increase energy efficiency. This is particularly important when there is no financial incentive for participants to conserve, as is often the case in dormitories as well as institutional, hospitality, and many commercial buildings. Petersen et al. [12] investigated how providing near real-time energy use information to dormitory occupants would affect consumption. The results from this study were encouraging; the 16 buildings whose residents received weekly updated data reduced their total consumption by 31% over the 2-week study period while the 2 buildings whose occupants had access to real-time data showed a 55% reduction over the 2-week period. Based on these two figures, Petersen and colleagues concluded that real-time data on electricity utilization is more effective than weekly consumption reports in allowing building occupants to adapt and learn how to be more energy efficient.

Another recent study on resource use demonstrated that hotel guests reuse their towels more frequently when informed that 75% of other guests in the hotel have also reused their towels [13]. Incidence of towel reuse was even higher among guests who were told that 75% of former guests in their particular room reused their towels. Subjects who were given messages not associated with the hotel or other guests reused their towels less than those who received hotel-specific or room-specific messages. This study showed that information contextualized by the invented statistic (the 75% figure was arbitrarily selected by the researchers) had a significant impact on environmental conservation practices.

From the findings of the hotel towel study [13], it is evident that social pressure can be leveraged to induce conservation behavior. Staats et al. [10] investigated how awareness of peer behavior as well as group discussion and feedback can induce pro-environmental behaviors that reduce waste created and gas, water and electricity used. However, the Staats et al. study did not compare the difference in improvement between households who received socially contextualized electricity usage feedback and did not provide participants with a reference point to contextualize their behavior other than previous consumption. The question then is how the awareness of behaviors of others can impact energy conservation behaviors among individuals where directly measured information (the data in [10] are survey-based) about social system performance is shared with building occupants. The Petersen et al. [12] energy monitoring experiment had an element of social pressure in that students were viewing the consumption of other dormitories and may have felt they were disappointing other building occupants in the competition if they did not conserve. However, it is difficult to imagine strong social accountability when the vast majority of consumption occurs in private rooms and the study did not have room-level energy use monitoring. Even if a resident was inspired to use less energy in order to support his or her building in the competition, this improvement would be unlikely to be discernable within the performance of an entire building.

3. Methodology

3.1. Study design and hypotheses

To examine how contextualizing personal electricity use information may impact electricity use behavior within a residential building, we instrumented 83 of the 89 rooms in a 6-floor dormitory building in New York City on the Columbia University campus. The dormitory is occupied by Columbia University undergraduate juniors and seniors. These students leave the dormitory to attend classes intermittently Monday through Thursday 9 a.m. to 10 p.m. with a small number of classes also taking place on Fridays. Therefore, the students are generally in and out of their rooms throughout the week. Of the 89 rooms, 77 are doubles (two-person suites). Doubles and singles both have kitchens and private bathrooms. The size of doubles ranges from 18.0 to 44.6 m^2 while singles are between 15.9 and 17.2 m^2. Roughly 40% of the rooms have a southern street-side exposure while the rest benefit from natural light from windows that face a large central courtyard. Electrical loads in the rooms vary, but typically include computers, entertainment equipment (televisions and stereos), lighting, a small refrigerator/freezer, and an electric stove and oven.

We were interested in examining how response varies if residents only review personal electricity utilization information as opposed to receiving information on average occupant utilization or the utilization of an occupant's peer network to contextualize their personal utilization. The central research question of this investigation is whether personal electricity use information, as opposed to floor or building level (as in Petersen et al. [12]), motivates electricity-saving behavior. Furthermore, we were interested in how the contextualization of this information with real information on utilization by others, as opposed to arbitrarily defined contextualized information (as in Goldstein et al. [13]), affected any changes in electricity use.

To examine these questions, we formulated the following study groups based on the conditioning of each group:

- *Study Group A*—Able to view individual past vs. individual present electricity utilization.
- *Study Group B*—Able to view individual past vs. individual present electricity utilization as well as individual vs. average personal electricity utilization of all occupants in instrumented suites in the building.
- *Study Group C*—Able to view individual past vs. individual present electricity utilization, individual vs. average personal electricity utilization of all occupants in instrumented suites in the building, and individual vs. that individual's peer network electricity utilization.
- *Control Group*—Unable to view electricity utilization information.

Based on these study groups, we posed the following three hypotheses on the relative response of each group to electricity consumption information:

Hypothesis 1. All three study groups will exhibit greater electricity use reduction than the control group.

Hypothesis 2. If building occupants are exposed to personal electricity use data contextualized by the building average (Study Group B) then they will reduce their electricity usage more than occupants exposed only to their own personal electricity use data (Study Group A).

Hypothesis 3. If building occupants are exposed to personal electricity use data contextualized by peer network as well as the building average consumption (Study Group C) then they will reduce their electricity usage more than; (i) occupants exposed to personal electricity use data contextualized only by the building average (Study Group B) or (ii) occupants exposed only to their own personal electricity use data (Study Group A).

3.2. Recruitment

Recruitment posters were posted on every floor of the building as well as in the elevator approximately 1 month prior to the beginning of the study period in order to raise awareness of the study and recruit participants. The posters were checked every week to make sure they were not removed or damaged. The emphasis of the poster was that participants would get the opportunity to view their electricity consumption and possibly the electricity consumption of their friends. No attempt was made to describe the potential environmental benefits associated with saving electricity. The posters advertised the opportunity to win an Energy Star high definition television in a raffle for participating in the study. The television was not an incentive for energy use reduction as it was specifically announced that it would be given to a participant selected at random. This differs from Petersen et al. [12], who offered a prize for the largest reduction, as we were interested in isolating the specific influence of the contextualized information on electricity conservation performance as much as possible. Additionally, two recruitment emails were sent to every resident in the building. The recruitment effort was also supplemented by an in-person recruitment process. Research assistants set up a recruitment table in the building lobby. This effort took place 2 weeks prior to the study start date and again 1 week in advance of the study.

Building occupants who consented to participate in the study completed a survey on their peer network in the building. Only one person in each double suite was allowed to participate in the study to avoid having some suites with two people in the study and others with only a single participant. This was an important issue because the maximum granularity possible for electricity monitoring was at the level of individual suites. In the initial survey, participants were asked to identify occupants in the building with which they were friends. Of the 37 participants eight lived in single rooms without a roommate, while the remainder had a single roommate. We utilized the responses to this survey to identify the building occupant networks. If a peer nomination by the surveyed building occupant was reciprocated, then the building occupant dyad was considered to be part of the same peer network. Of the 37 participants 9 only received their own electricity use (Study Group A), 9 received their own electricity use as well as the building average electricity use (Study Group B), and 19 received their own electricity use, the building average use, and the electricity utilization of those individuals in their building occupant peer network (Study Group C). The reason a comparatively larger number of individuals were included in Study Group C was to accommodate peer networks of up to three building occupants.

Electric current data were also logged for 46 suites not participating in the study which served as the control group. Although data from non-participants could have been affected by general awareness of the study due to the recruiting process, as well as possible influence from participants in the study, it is still a valuable way of accounting for overall building trends in order to focus on changes in behavior deriving from awareness of personal and contextualized electricity consumption information. A control group was important in our study to ensure that performance due to electricity use information sharing is not skewed by cross-cutting external pressures on occupant consumption. For example, during the three hottest days between April 1st and May 7th (April 26th, 27th and 28th had an average daily high temperature of 31 °C) the building, which does not have air conditioning, saw a statistically significant 30% jump in average room consumption relative to the average of every other day in that period.

3.3. Monitoring

Onset Computing HOBO U30 Data loggers connected to 0–20 A Continental Control Systems current transducers monitored electric current for each suite in the study every 5 min. Six data loggers were installed in the basement of the building on the suite electrical subpanels, each reporting electric current usage for approximately 15 suites. This building was selected for the study because each suite also had an existing electrical meter. Data from the existing meters was used at the beginning of the study to calibrate the current transducer to take into account typical voltage fluctuations and power factor issues. 77 of the 89 suites in the building were doubles. For these suites, half of the power draw was assigned to each roommate when producing the personal electricity consumption reports as well as when conducting the data analysis.

3.4. Study procedure

The study period began on April 1, 2009. Participants were informed upon consenting to participate in the study that their electricity use reports would include data starting on this date. On the morning of April 10th emails were sent to Study Groups A, B, and C explaining how to access their electricity consumption reports posted on a secure, password-protected website (reports were not available until this day). In addition to receiving instructions on how to access their electricity consumption reports, participants from Study Groups B and C were told the percent difference between their average power draw over the previous 7 days and the average building occupant power draw over the same period. Participants in Study Group C were also told the percent difference between their average power draw over the previous 7 days and that of their occupant peer network over the same period. Notification emails with a link to the site were also sent on the evenings of the 16th and 23rd of April and included the same percent difference summary information previously mentioned.

Fig. 1 contains an example of an electricity consumption profile report provided to a participant in Study Group C. The graph on the top left of the profile shows average daily power draw for the previous 7 days. The color of each bar depends on the difference between the peer network average and the individual. A red line would indicate >20% above the peer network average, a yellow line would indicate within 20% of the peer network average, and a green line would correspond to >20% below the peer network average (For interpretation of the references to color in this sentence, the reader is referred to the web version of the article.). The average building occupant power draw is also included on this graph (black line). The graph at the top right of the consumption profile shows average power draw for each day from the beginning of the study and was designed to allow Study Group C participants to view their performance over time relative to the building average and their peer network average. The lower graph indicates instantaneous current measurements over the course of the previous day. This last graph was provided so that participants could better understand their own electricity utilization patterns and thus identify times of the day when they tended to use more or less electricity. The reports for participants in Study Groups A and B differ only in the content of the top two graphs and a general explanatory statement just below the title of the report.

3.5. Data analysis

To compare the electricity consumption between the study groups and the control group, we utilized the following equation to

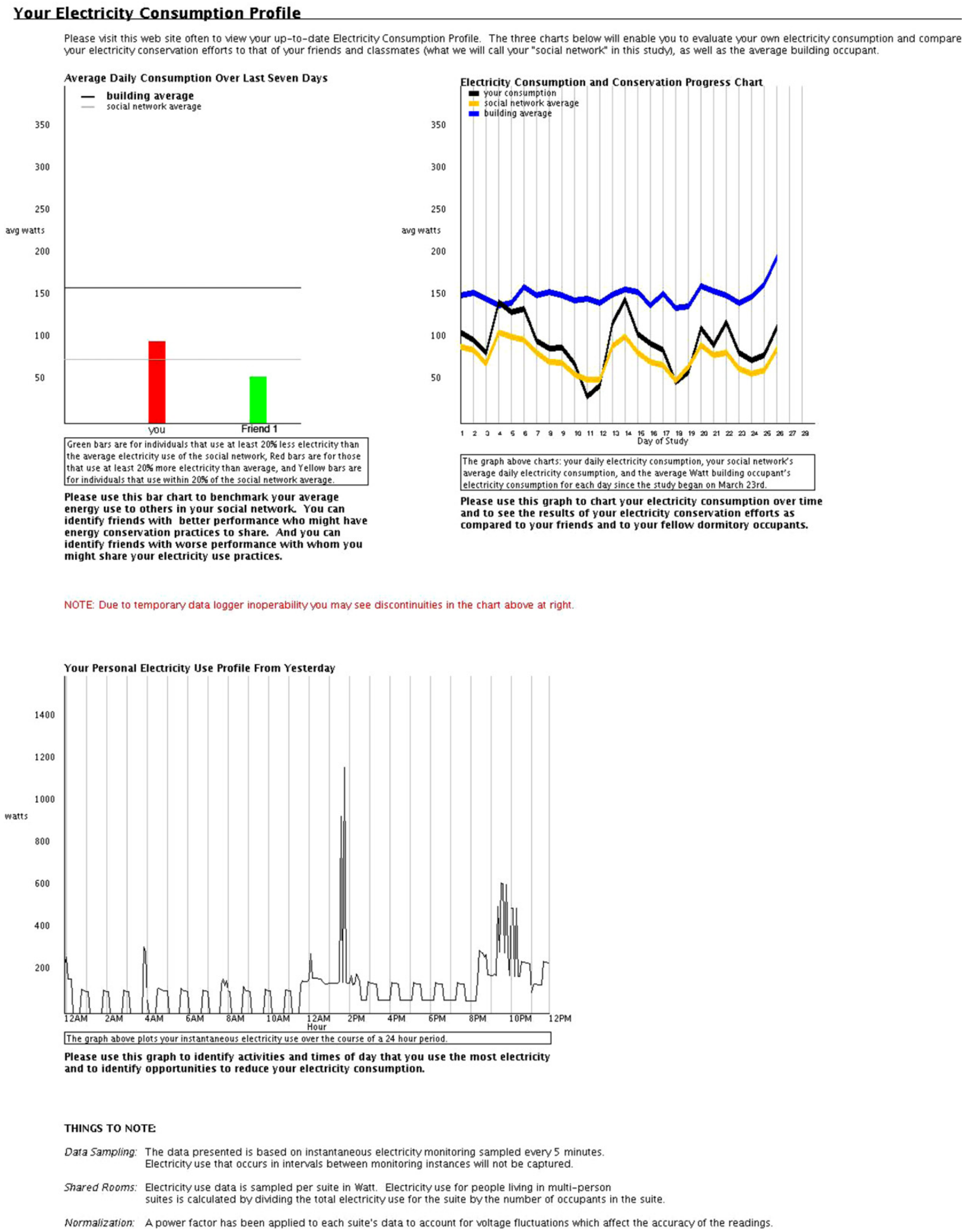

Fig. 1. Example electricity consumption profile for Study Group C.

identify the percent difference between the average power draw of an individual and the average power draw of non-participants on a given day.

$$D = \frac{(PS/NO) - PC}{PC} \times 100 \qquad (1)$$

where

D = percent difference between daily average power draw of an individual and the average power draw of the control group;
PS = average daily power draw for a given suite;
NO = number of occupants in the particular suite (1 or 2);
PC = average daily power draw of control group.

Table 1
Overall performance of all participants during study period relative to pre-study performance.

Comparing	95% confidence interval		p
	Upper bound	Lower bound	
DP_{before} mean = −14 to DP_{during} mean = −20	13	−1	0.1
DP_{before} mean = −14 to DP_{2weeks} mean = −26	20	5	0.001*
DP_{before} mean = −14 to $DP_{lastweek}$ mean = −10	6	−15	0.4

* Statistically significant ($p < 0.05$).

Comparisons between *D*-values for different days and different groups were accomplished using the Welch Two Sample *t*-test. Statistical significance for all tests was assessed at $p < 0.05$. In assessing behavioral responses following exposure to electricity consumption profiles we chose to focus on the 3 days following the day a notification email was sent. The upper limit on the number of days we could examine to assess behavioral response following a notification was 6 days since the sample would then begin to incorporate response to the following email notification. By utilizing 3 days of data instead of 1 or 2 days after notification emails were sent we could accommodate the fact that some individuals would view and respond to the electricity consumption profile with an immediate behavior change while others may have viewed the email a day later or delayed their behavioral response to the email by a day or both. Additionally, by utilizing a 3-day period we were able to examine a period that included both weekends and weekdays during which participants could apply conservational techniques over different kinds of daily schedules.

4. Results

Table 1 contains electricity utilization percent differences of all participants in all study groups compared to the control group. In all tables, the second letter denotes the study group (*A*, *B*, or *C*) or whether the analysis includes all participants (*P*). The subscript indicates the time period (*before*, *during*, 2*weeks*, *lastweek* or 3*DP*, described below) or the particular email communication to which we are measuring a response pattern (1, 2 or 3). For example, DC_1 stands for the percent difference between the daily consumption of members of Study Group C and the average of the control group over the 3 days following the first notification email. Other time periods are denoted by the following subscripts:

- *before* = subset of *D*-values for a given group from the 1st day of the study (April 1) until the day participants were sent the first email (April 10);
- *during* = time period after the first email during the study (April 11–30);
- 2*weeks* = time period from April 11 to 23, selected for reasons described below;
- *lastweek* = time period from April 24 to 30;
- 3*DP* = the 3-day time period leading up to the distribution of an email.

Overall, participants showed the greatest improvement in electricity utilization when compared to the control group over the first 2 weeks of the study (a statistically significant 26% difference). However, in the third week we observed that participants were only 10% below the non-participating control group in the last week of the study. Considering that average daily power draw for participants was 14% below non-participants before the first email notification was distributed, the participants were actually performing worse than before the study. These results are contained in Table 1.

Examination of survey data and analysis of the all participants' performance revealed that participants tended to view their electricity consumption profiles only when they were notified that profiles were available. Only 2 of the 17 survey respondents indicated they checked their electricity consumption profiles more than once a week in the first 2 weeks after the first email notification and the average number of visits to the site with the

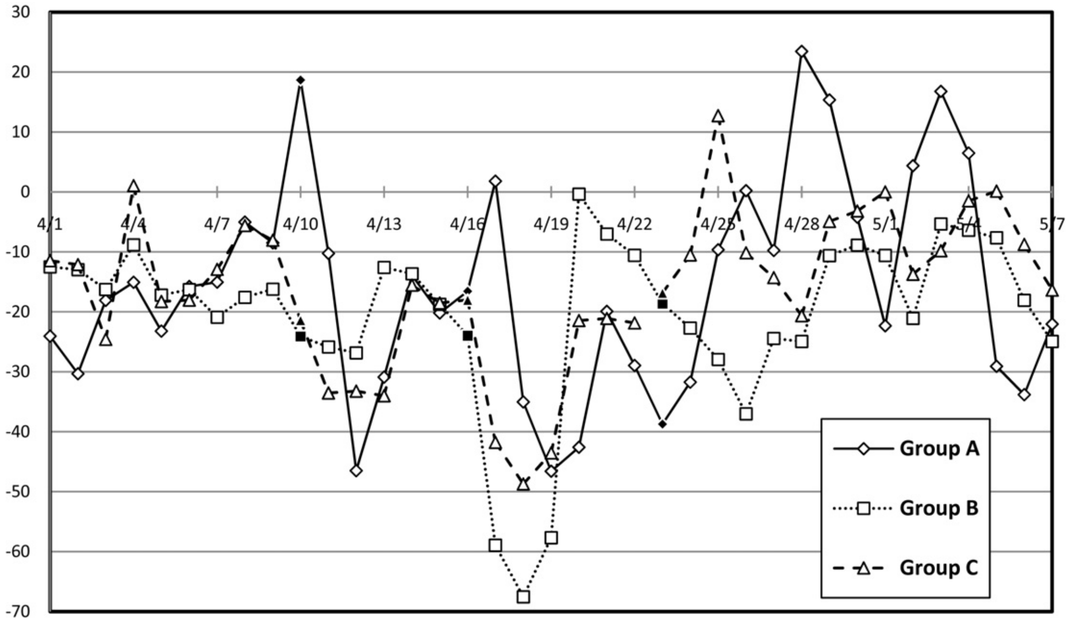

Fig. 2. Average percent difference in electricity use between study groups and control group.

Table 2
Responses to notification emails relative to pre-study performance for all participants.

Comparing	95% confidence interval		p
	Upper bound	Lower bound	
DP_{before} mean = −14 to DP_1 mean = −30	26	5	0.003*
DP_{before}[a] mean = −13 to DP_2 mean = −45	40	21	1E−9*
DP_{before} mean = −14 to DP_3 mean = −12	−18	13	0.8

* Statistically significant (p < 0.05).
[a] Subset does not include data during given period from suites for which no data was logged on the 18th and 19th of April (there were technical issues for some rooms during the 3 days after second email) and thus has a different mean from the same subsets used in the 1st email comparisons.

electricity consumption profiles per week over this period was 0.97 despite the fact that the profiles were updated daily and always available. Fig. 2 graphs the percent difference for each study group compared to the control group over time. The date that email notifications were distributed are indicated with solid black data points (April 10th, April 16th and April 23rd). The electricity utilization comparisons for the study groups in the graph exhibit a response pattern that coincides with the notification emails in the 2 weeks where overall electricity conservation was significant.

Examining the performance in the 3-day periods after email notifications more closely we observed that the first two notification emails produced significant reductions in all participants with their consumption falling to 30% below non-participants after the first notification email was distributed and 45% below non-participants after the second notification email representing improvements relative to *before* period *D*-values of 16 and 31%, respectively (Table 2). The third week did not result in any significant reductions.

Given that survey and performance data indicate exposure to electricity use profiles occurred principally after the first two email notifications and overall participants did not show a behavioral response to the third email our comparison of the performance of the three groups relative to the control group focused on the response to the first two notification emails or, more accurately, first notification of availability of electricity use profiles and a reminder of such availability a week later. Table 3 contains the results of each study group compared to the control group after each of the first two email notifications. Examining the study groups and time periods separately revealed that only Study Group C had a statistically significant reduction in electricity use relative to the Control Group over the course of the 3 days following initial access to electricity use profiles (see DC_{before} vs. DC_1 in Table 3). The average power draw for Study Group C the 3 days after the first email was 34% below the Control Group, or 20% less than during the *before* period.

The second electricity consumption notification email elicited another statistically significant response from Study Group C in which the average power draw dropped to 45% less than the Control Group, or 28% less than during the *before* period. Study Group B also showed a statistically significant change in behavior after the second email notification falling to an average *D*-value 24% less than during the *before* period. It should be noted that data for some of the suites is missing due to technical problems with the wireless router used to transmit the data for the 3 days after the second email. However, these suites were also eliminated from other sets used in comparison in order to generate reliable *p*-values. In this way, results were not biased by having individuals that may have drawn significantly more or less power than average included in the *before* period then cut out in sets of *D*-values after the second email notification. Group A did not show a statistically significant change in consumption after either of the first two notification emails.

In order to assess how these improvements after email notifications were maintained the days after 3-day periods following an email notification but before the next email were compared to the *before* study period. Just as a 3-day period was used to assess response after an email, a 3-day period after the response but before the next email was used to examine how significant reductions in electricity use were maintained. Table 4 includes results demonstrating how conservation behavior relapses by comparing *before* period *D*-values for a given group to those of the 3-day period before the next email, but after a significant improvement. Examining the period in the 3 days prior (3*DP*) to the second and third email we observe that for each instance of a statistically significant response after an email (Group C after emails 1 and 2, Group B after email 2) the statistically significant improvement relapses and levels of consumption return to approximately those of the *before* period (Table 4). For example, the fact that Group C is only 17% below non-participants in the 3 days leading up to the second email is not a statistically significant difference relative to the pre-study utilization for the group (DC_{before} = 13%). A *D*-value of −20% in the 3 days leading up to the third email for Group C is also not statistically significant different compared to pre-study consumption. Similarly, after the instance where Group B shows a statistically significant reduction in power draw (the 3 days after the second email or DB_2) its average power draw goes back up to only 12% less than non-participants which is actually worse than the −16% *D*-value in the *before* period.

In summary, comparisons between the *before* period performance and the 3 days after each of the first two email notifications demonstrate that Group C exhibited the strongest response while comparisons between the *before* period and the 3*DP* demonstrate that the two groups (B and C) that showed significant improvement after email notifications reverted to electricity utilization statistically indistinct from the *before* period 3 days after the first two email notifications.

Table 3
Responses to notification emails relative to pre-study performance for each study group.

Comparing	95% confidence interval		p
	Upper bound	Lower bound	
DA_{before} mean = −14 to DA_1 mean = −30	37	−6	0.2
DB_{before} mean = −16 to DB_1 mean = −22	30	−19	0.7
DC_{before} mean = −13 to DC_1 mean = −34	34	7	0.004*
DA_{before}[a] mean = −15 to DA_2 mean = −28	36	−21	0.6
DB_{before}[a] mean = −38 to DB_2 mean = −62	35	6	0.007*
DC_{before}[a] mean = −17 to DC_2 mean = −45	26	4	0.008*

* Statistically significant (p < 0.05).
[a] Subset does not include data during given period from suites for which no data was logged on the 18th and 19th of April (there were technical issues for some rooms during the 3 days after second email) and thus has a different mean from the same subsets used in the 1st email comparisons.

Table 4
Relapses after significant improvements in performance following notification emails relative to pre-study performance.

Comparing	95% confidence interval		p
	Upper bound	Lower bound	
DC_{before} mean = −13 to DC_{23DP} mean = −17	23	−14	0.7
DC_{before} mean = −13 to DC_{33DP} mean = −20	24	−10	0.4
DB_{before} mean = −16 to DB_{33DP} mean = −12	22	−30	0.7

5. Discussion

The survey data regarding visits to the web site where personal electricity use profiles were made available is in contrast to Petersen et al. [12] findings that building occupants will take advantage of electricity use information without prompting. They reported an average of 4.8 visits per week among residents who lived in the two buildings that received real-time energy use data and an average of 2.5 visits per week among residents of the other 16 buildings in their study that received only weekly updated energy use data. The participants in our study accessed energy use data only 0.97 times per week in the first 2 weeks after access was made possible. This difference may be a result of the fact that participants in the Petersen et al. study were competing for a prize, or possibly that they were provided with educational material on the environmental impact of their conservation.

Our participants only accessed their electricity use profiles about once per week and the trends in Fig. 2 suggest that this occurred when email notifications were distributed. Therefore, our discussion of consumption trends and analyses of results largely takes the form of a perturbation-response analysis even though exact access times for each participant were not known. Ideally, specific information about when consumption profiles were visited would have been stored by the website with each participant's electricity use profile to support the observation that our study participants only checked their electricity use when prompted.

By comparing responses to the first and second notification emails we can begin to assess the impact that contextualizing energy use information had on behavior. Study Group A showed no significant reduction in electricity use following either of the first two notifications. This suggests that merely sharing electricity use information is not sufficient to induce a consistent electricity conservation response and does not allow the rejection of the null hypothesis for Hypothesis 1. Participants in Group B showed a statistically significant response after only the second notification, 24% less than *before* study period. This suggests some promise for including building-level information to contextualize personal electricity consumption but does not provide strong support to reject the null hypothesis for Hypothesis 2. Further research should investigate the impact of contextualizing electricity consumption using values that represent an impersonal but physically proximal social system electricity utilization average. Study Group C showed statistically significant improvement relative to the *before* period after each of the first two email notifications. The fact that these reductions were also 20 and 28% less than the average *D*-values from the *before* period (respectively) while Study Group B only saw a significant reduction after the second email (still 4% less than that of Group C) and Group A did not show significant improvement after either of the first two emails provides evidence against the null hypothesis of Hypothesis 3. The larger sample size of Study Group C (19 vs. 9 for each of the other groups) also decreases the size of the confidence bounds for this group. These results emphasize the value of integrating electricity use data from peer networks in future similar efforts to induce collective behavioral responses to reduce electricity consumption.

Conspicuously, the third email notification had no significant effect on behavior (Table 2). Indeed, in terms of participants overall, the *lastweek* period of the study was statistically similar to the *before* period (Table 1). This lack of response can be explained by the fact that the study was completed in a college dormitory and the last week of the study overlaps with end-of-semester due dates of final papers and projects as well as with preparation for final exams. It is likely then that consciousness of electricity consumption eroded under end-of-semester stress. One participant in the final survey even suggested that the study be completed earlier in the semester when "people aren't stressed with finals and papers." Future researchers may opt to examine more closely the typology and relative impact of external social system pressures on inducing electricity conservation behaviors.

From our survey data we learned that the study did not appear to become a topic of conversation within the building. The relapses in consumption we observed may have been symptomatic of the fact electricity conservation practices did not enter into the social discourse among the building occupant networks. Of the 17 surveys submitted, only one participant indicated that they talked to someone else besides their roommate about electricity conservation practices. Two others shared tips on how to save electricity with their roommates. This suggests that, although participants in Study Group C may have felt social pressure to conserve, the study did not bring electricity use into the realm of social discourse. Conducting this kind of study in a setting where participants are more likely to interact (such as in the competitive environment in Peterson et al. [12]) would perhaps increase the discourse on energy efficiency and be more productive for testing the capacity for social networks to influence behavior. Conducting the investigation over a longer period may also produce similar results. Future researchers should consider research designs that include measures to introduce and measure discussion of energy conservation practices across building occupant social systems.

It is important to list some of the major limitations of this investigation. The small sample sizes coupled with the fact that visits to the energy use profiles online were not tracked were the principal limitations. However, survey data showed that participants visited electricity consumption profiles essentially once per week and that no study group visited significantly more than any other. This suggests that no study group was populated with a more energy conservation interested group of participants. Still, larger groups, even at the expense of the size of the control group, are warranted in order to reduce the probability of initial group bias. Another limitation was the short duration of the study as well as the coincidence of the final exam period in the third week of monitoring. A longer period of monitoring would allow us to separate short-term and longer term sustainability issues. Decades of social marketing research have made it clear that the way that information is presented to an individual has a strong impact on the effect of that information. Further research is needed to ascertain whether providing detailed information about the impact of electricity use may provide an additional incentive for conservation. The use of kiosks in the lobby of the building or other public reminders of the study (as in [12]) would likely bias the control group, but may enhance the sustainability of energy savings by reminding participants of the monitoring on a more frequent basis. Further exploration of this issue is warranted. One of the benefits of conducting this study in a large dormitory, especially one that allows calibration of the current sensors, is that the group of occupants is relatively homogenous and changes every year. This will allow us to conduct academic year-long investigations in the future as well as avoid issues with subject fatigue that can occur with this kind of research.

6. Conclusion

This study demonstrated that giving building occupants information that enables them to compare their electricity use to others can result in a more reliable improvement in electricity utilization than simply providing the raw values of average daily power draw to individuals. Future efforts to understand and induce electricity conservation in buildings should consider incorporating building level and/or peer network level utilization information sharing among building occupants. Leveraging peer networks to encourage electricity conservation has the potential to produce more consistent electricity conservation results than allowing residents only to view their own electricity utilization. In order to consistently reduce electricity consumption people may need benchmark information to contextualize their conservation efforts. A very important finding of this study is the response–relapse behavioral pattern observed. In every instance that a group showed significant improvement after receipt of an electricity consumption profile, 3 days later behavior would essentially relapse to pre-study utilization levels. Investigating electricity conservation performance following specific communications rather than only examining total electricity savings over the study period enabled us to identify this response–relapse pattern. We need further research to better understand patterns of responses and relapses in behavior. Moreover, we need research that clarifies the impact of external factors on energy conservation such as the lack of response we observed in the final week of the study. Such research would require more accurate information about when electricity consumption information is viewed by participants and should be examined over longer time periods than this or previous studies. To meet the ambitious greenhouse gas emissions goals currently being set in countries around the world, we need to improve our understanding of how to achieve sustained electricity conservation in buildings which are responsible for a substantial proportion of such emissions. A more thorough understanding of response–relapse tendencies and how to mitigate relapses in electricity conservation may be critical to achieving sustained electricity conservation in buildings.

Acknowledgements

This material is based upon work supported by the Columbia University Earth Institute under Grant No. 4-10552. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Earth Institute. The authors also wish to thank Nilda Mesa, Patricia Culligan, Morgan Whitcomb, and Richard Plunz for their support in the development and execution of this project.

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