Short Paper: Comparing Energy Feedback Techniques for Dormitory Students in India

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ABSTRACT
Recent research work has explored solutions to address the problem of increased energy consumption by providing feedback to individuals about their consumption patterns, thus motivating them for conservative actions. In particular, university dormitory setting provides an excellent venue to explore effectiveness of energy feedback mechanisms. Most of such dormitory studies used a web-based portal for enabling competition among students as motivation for energy saving. Moreover, the majority of them have been conducted in the developed world. In this paper, we report a 6-week study conducted in an Indian university with 432 students (18 groups), comparing five different eco-feedback techniques. The results show that *Daily Individual Paper Feedback* encourages more conservation, both among males and females, with 19.4% and 7.6% reduction, respectively. We conclude with a discussion on the importance of easy and regular availability of information, effectiveness of paper-based feedback, and role of gender in eco-feedback.

Categories and Subject Descriptors
H.5.m [**Information interfaces and presentation** (*e.g.*, HCI)]: Miscellaneous.

General Terms
Design, Experimentation, Human Factors.

Keywords
Energy; Sustainability; Eco-feedback; India; Dormitory; Students

1. INTRODUCTION
Global energy consumption has been increasing rapidly. The supply cannot always be increased fast enough to meet the demand, and resources such as fuels are non-renewable. An alternative solution is to decrease the demand and the wastage. Many eco-feedback techniques [8] – *technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact* – have been proposed and evaluated in residential [1,5,7] and workplace [4,9] settings. Typically, in residential settings, individuals (or their relatives) directly pay for the consumed energy, whereas in workplace settings, employees consume and the organization pays for it, resulting in minimal participation by employees towards energy conservation [9].

Student dormitories lie somewhere in between, wherein the energy bill is split equally among all students sharing the dormitory in spite of unequal consumption by the dorm-mates. This can result in excessive electricity usage behavior, as there is no direct financial repercussion. Interestingly, unlike office spaces, dormitory students have a high degree of control over the appliances consuming energy, *e.g.*, operation of computer, lights (personal room light and common area shared lights), water heater, *etc*. Embedding conservation habits as students can have lasting impact. For many such reasons, dormitories make up an excellent place to study the impact of giving the energy consumption feedback to the students. Recently researchers have explored eco-feedback techniques in dormitories [2,3,6,10,11]. However, most have focused on developed countries. As a result, there is little information about whether or how those results might be applicable to other geographies and cultures, especially developing regions, which are significantly different from the developed nations.

With 682 universities and 35,539 colleges [13], the higher education sector constitutes a significant share of Indian energy consumption. Hence, there is great value in understanding the effectiveness of eco-feedback techniques in an Indian dormitory. There are significant differences between Indian dormitories and the dormitories in the developed nation. First, appliances usage in Indian dormitories is limited to heating water for shared usage, heating and cooling room (few months of the year), powering lights, fans and computer, and powering washing machine with dry spin for shared usage. In developed regions, centralized heating and cooling system consumes a bulk of energy, along with clothes dryer, television, coffee maker, *etc*. Second, social and cultural differences result in significantly different approach towards energy usage and conservation by Indians when compared to developed regions, both in residential [15] and workplace [9] settings. Shrinivasan *et al.* [15] studied middle and high-income urban Indian residential consumers and observed deep conservation practices, which are *contextually imposed, habitual (to the point of being natural and unnoticed), and deeply integrated into daily activities*. Third, Indian students living in the dormitory are usually from family background with limited resources. Moreover childhood habits play a significant role in learning and practicing energy conservation in India [9,14,15].

We conducted a 6-week study in an Indian university with 432 students, divided in 18 groups, comparing the effectiveness of five different eco-feedback techniques. Gender-based comparison showed that female consumed less than male throughout the study. However, the energy consumption gap between males and females decreased during the study, hinting that the males more actively participated in the study. Among the different eco-feedback, *Daily Individual Paper Feedback* achieved maximum conservation, both among males and females, with 19.4% and

BuildSys'15, November 4–5, 2015, Seoul, South Korea.

ACM 978-1-4503-3981-0/15/11…$15.00.
DOI: http://dx.doi.org/10.1145/ 2821650.2821678

7.6% reduction, respectively. The group discussion with the participants revealed that majority of conservation was achieved by reducing usage of shared resources, such as switching off lights of common area and corridors, and reducing hot water showers in shared washrooms.

2. RELATED WORK

A comprehensive review of 38 household energy studies conducted over last 25 years concluded that consumption related feedback increases awareness and motivates conservation [5]. More recently researchers started studying the effect of energy feedback in university dormitories.

University of Hawaii conducted a floor-level dormitory energy competition with online real-time visualization of energy data and prizes for participation [3]. Similar competition based approach was adopted by Indiana University as Energy Challenge [10] and Wellesley College as Green Cup [12]. Bekker *et al.* [2] conducted a 3-week study providing feedback, incentives, and education to encourage reduction of electricity use. They found mean savings of 16.2% (daytime) and 10.7% (nighttime).

Other research studies explored the effect of varying a particular factor in dormitory energy conservation. Petersen *et al.* [11] compared different resolutions of energy feedback data in a two-week dormitory energy competition, and found that dormitories receiving real-time feedback reduced consumption by 55%, compared to 31% for dormitories receiving weekly feedback. Though the reduction is significant, the study was over a short duration and it is not clear how such reduction are sustainable. At University of California Los Angeles, researchers compared private and public information as motivators [6]. They found that private information in the form of real-time online feedback has no effect, while public posters resulted in a 20% reduction.

Liu *et al.* [16] is the only work we found studying energy consumption in a dormitory setting in a developing nation. They designed and deployed an electricity feedback system (with a prepaid electricity system) in a Chinese University, to understand how students adopt digital feedback systems and make them work as part of their daily lives. The user study did not compared eco-feedback techniques, instead based the design of the interface on the findings from a preliminary study. All these studies deploy energy-monitoring devices, collect data, and provide web-based feedback, with incentives and competition among students. Also, all these deployments and evaluations are limited to developed nations. In this paper, we report a study conducted in an Indian university dormitory comparing different energy feedback.

3. SYSTEM AND STUDY DESIGN

As part of an energy conservation program, the University installed smart electricity meters in each floor of female and male dormitory. The installed smart meters collected data every 30 seconds. Multiple meters were connected over a common RS485 serial communication bus and the energy consumption data was pulled using a single board computer, Raspberry Pi. Our system used sMAP [17] for transmitting and storing data. While we used the existing sMAP open source architecture, we have to develop custom drivers (in Python) to pull data from the energy meters, as well as develop the frontend for data visualization.

3.1 Participants

432 participants (63.9% male, 36.1% female) participated in the study. All were Computer Science students (as the university only offered specialization in CS) – 69.9% BTech, 18.9% MTech, and 11.2% PhD program. Among male, 144 rooms were singly occupied and 66 were shared between two students, while for female, 78 rooms were singly occupied and 78 were shared between three students. Note: Participation in the study was optional. A participant could opt out by emailing the study coordinator. We did not receive any opt out emails.

3.2 Methodology

Energy consumption data was collected at the floor level – 18 floors in total, with 10 all male floors and 8 all female floors. Some of the floors were excluded from the study, since they included other shared consumption devices (*e.g.*, recreation room) and only the room level electrical distribution could not be separated. The energy bill of a floor is split equally among students residing on that floor in spite of unequal consumption by the floor-mates. Hence, each floor can be safely assumed to be a '*dormitory*'. Based on the floor level, participants were divided in 18 *groups* – 10 male groups and 8 female groups. Among male, the number of participants per group varied from 22 to 36 (m=27.4, sd=6.5), and for female from 17 to 24 (m=19.4, sd=2.7).

The six-week study was conducted during Dec'14-Jan'15 in New Delhi. Initial two weeks were for baseline data collection (*Baseline Phase*), followed by two weeks of the deployment of energy feedback techniques (*Deployment Phase*), and last two weeks data were to analyze for sustained conservation practices (*Post-Study Phase*). During the baseline and post-study phase, the participants were not aware that energy consumption data was being collected. At the end of post-study phase, two group discussions of ~2 hours each were conducted to understand their energy conservation pattern and discuss the effectiveness of various methods.

For the deployment phase, 6 *clusters* consisting of 3 randomly selected groups were formed, with each cluster having at least 1 male and female group. Feedback mechanisms were selected based on previous work [2,3,6,11], to understand the impact of medium (paper versus online), frequency (daily, weekly, versus anytime), and display (public versus private) of information.

A. *Baseline*: Groups in the baseline cluster did not receive any feedback. They were not even aware that they were part of the study. The baseline groups accounted for external changes (including weather) during the course of the study.

B. *Only Education*: Participants in this cluster have to attend weekly meetings with the study coordinator, discussing ways to conserve energy. This condition takes its inspiration from the importance of energy literacy [2,11].

C. *Weekly Individual Paper Feedback*: Participants in this cluster received weekly energy consumption data printed on an A4-sheet, slipped into their room (every Sunday morning, thrice in two weeks). The sheet contained information on the last week's total consumption by their group (in energy and monetary units), daily consumption information, and comparison of their last week consumption with the lowest-, median- and highest-consuming groups using a bar graph.

D. *Daily Individual Paper Feedback*: Participants in this cluster received printed energy consumption data, slipped into their room

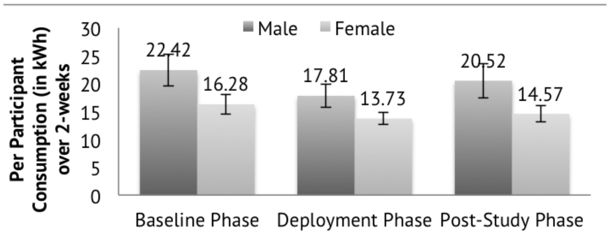

Figure 2. Consumption comparison per participant over the three 2-weeks phases

daily (~7:30 am). The sheet contained yesterday's consumption of that group, and comparison with other groups.

E. *Daily Public Poster Feedback*: Groups belonging to this cluster received daily feedback through a public poster (A3-paper size). Each floor (group) has 3 information boards, wherein posters were put every morning. The poster contained yesterday's consumption of that group (floor), and comparison with the lowest-, highest- and median-consuming groups.

F. *Anytime Individual Online Feedback*: Participants in this cluster received a website URL with login id and password, to view their energy data. The online portal showed live energy consumption by their group, and comparison with other groups.

4. RESULTS

We analyzed data separately for male and female participants. As the number of participating males and females were different, per participant consumption data was used for analysis purposes. Per participant consumption was calculated by normalizing the total consumption in a dormitory by the number of students in that dormitory. While smart meters collected data every 30 seconds; for analysis purposes, aggregated hourly energy data was used.

Independent t-tests between males and females during each phase shows that per hour energy consumed by a participant is significantly lower for females than males (Baseline phase: t_{5038}=27.8, p<0.01, mean difference=18.3Wh, mean standard error=0.65; Deployment phase: t_{5038}=21.5, p<0.01, md=12.1, sde=0.62, Post-study phase: t_{5038}=15.8, p<0.01, md=8.8, sde=0.5. Note: The baseline group was not included for this analysis). This hints that females in general consumed less energy compared to males (Figure 2). However, this could also be due to the fact that on an average, females shared fewer resources, as the room occupancy ratio is higher (1.31 males per room compared to 2 females per room). During the study, the energy consumption gap between males and females reduced (Figure 2), hinting that the males actively participated in the study and were more motivated to conserve energy. This could be because men are more competitive than women in the short term [18].

To compare the five different feedback techniques, we computed the reduction in energy consumption per participant during the deployment phase (Figure 3), by subtracting the deployment phase energy consumption with the baseline phase and the baseline cluster. This subtraction was performed to minimize the effect of external factors such as weather condition. We conducted a 1-way ANOVA on the energy reduction, and found significant effect for the feedback techniques between both the genders (male: $F_{4,2683}$=38.7, p<0.01, female: $F_{4,2347}$=13.1, p<0.001). To analyze this further, we conducted a post-hoc analysis with Bonferroni correction. For males, daily individual paper and daily public poster performed the best (p<0.01), outperforming all other

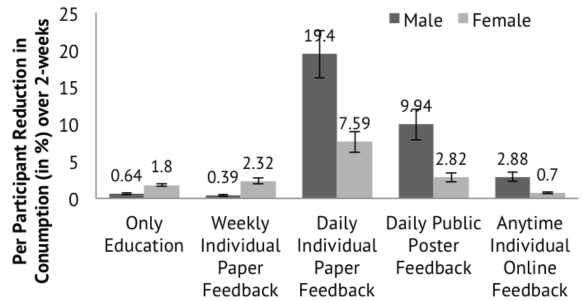

Figure 3. Reduction comparison, from baseline to deployment phase, of the different feedback techniques

feedback techniques, while for females, daily individual paper performed the best (p<0.01). The daily individual paper feedback cluster reported energy reduction of 19.4% among males and 7.6% among females.

To understand the impact of feedback techniques on sustained energy conservation practices, reduction in energy consumption per participant during the post-study phase was calculated, by subtracting the post-study energy consumption with the baseline phase and the baseline cluster. A 1-way ANOVA on the energy reduction showed significant effect for the feedback techniques only among male: $F_{4,2683}$=28.8, p<0.01 (for female: $F_{4,2347}$=6.8, p=0.1). A post-hoc analysis with Bonferroni correction found that for males, daily individual paper performed the best (p<0.01) with reported energy reduction of 11.8%.

During the group discussion with the participants, we found that the level of participation varied, as observed from the quantitative data. Participants mentioned that reduction in energy usage was a combination of conserving both personal and shared resources. In terms of personal resources, participants "*switched off* (their) *table lamps and room lights when not required*", increased the set temperature of room heater, and "*reduced ironing clothes*". As per the participants, majority of conservation was achieved by reducing usage of shared resources, such as "*switching off lights of common area, washrooms and corridors*", "*reducing hot water showers*" in shared washrooms, and reduced usage of washing machine to wash clothes every two weeks (instead of weekly washing and drying).

During the discussions, we found that many students read newspaper in the morning around the same time when the paper-based energy feedback sheet was delivered. This might have resulted in the participants reading the feedback sheet, along with the newspaper. In addition, participants explained the reason for decline in conservation during post-phase. After the deployment phase, efforts to conserve shared resources reduced, as it was "*not impacting anyone directly*", however participants continued to conserve personal resources, such as "*switching off the heating unit when going to take a shower*".

5. DISCUSSION

A. *Regular, Easy Availability of Information*: Daily individual paper feedback technique outperformed all the other techniques for both genders, while daily public poster is the second best performing among male participants. This highlights the importance of easy access to information regularly. This is in accordance with previous findings that eco-feedback with high-resolution regular data performs better [11]. The daily consumption sheet is analogous to the newspaper, as it was slipped under the door in the morning for the participants to look at and ponder about their energy consumption. Similarly daily public poster provides regular access to consumption data. Both these feedback methods are '*completely effortless*' from the participant's perspective, and '*force-feed information*' to them.

B. *Effectiveness of Paper Feedback*: Most recent research has studied online portal-based feedback [2,3,10,12], with limited emphasis on other medium of communication. In our study, paper-based feedback outperformed online feedback. While participants liked the web-based real-time feedback due to its '*dynamic nature*', they also complained about remembering '*to open the website*'. Paper-based feedback might not be a sustainable solution, as it requires extensive manual effort, and is not a green solution. Hence in future, benefits offered by paper should be incorporated into computer or phone-based feedback. For instance, setting the energy portal as user's homepage, sending SMS as reminders, or installing software showing the current energy status on the taskbar.

C. *Public Information*: Complimenting previous findings that public display of information [6] and competition [3,12] motivates people, we found that competitive feedback delivered privately or through public spaces results in reduced energy use. Public poster did not performed well among females, compared to males who are used to read board updates for sports-related news update. In general, students did not noticed the public poster, as it was not shown to them explicitly, and may be a longitudinal study is required to explore the effectiveness of public-display feedback.

D. *Paper Wastage*: Fourteen participants in the daily individual paper feedback condition emailed the study coordinator regarding paper wastage for providing energy feedback. In future, changing the frequency of the individual paper feedback (from daily to alternate days to weekly) based on their energy consumption can reduce paper wastage.

E. *Gender-based Eco-feedback*: As the result shows, there were similarities and differences in the consumption pattern and response to different feedback mechanisms between the male and female participants. Hence, impact of eco-feedback is gender-specific. In future, gender should be taken into consideration while designing energy feedback mechanisms.

6. LIMITATIONS AND FUTURE WORK

Our study is, at best, a first step towards studying eco-feedback techniques in dormitory setting outside of the developed regions context. Even within India, wide socio-economical, climatic, cultural, and demographic diversity makes it difficult to know exactly how broadly these findings generalize. E.g., our study was limited to a single organization in New Delhi, which faces extreme weather throughout the year. Additionally, our participants work in an organization that primarily requires dealing with state of art technologies and sciences, and most of the participants have an engineering background. Thus the results may not be generalizable to students with different backgrounds and/or work environments. Thus, we plan to conduct long-term studies involving many Universities with different characteristics. Cultural differences between developing and developed regions results in differences in energy consumption and conservation patterns, which has been studied previously [9,14,15].

In addition, in future, we would like to study and understand the reasons behind the success of paper-based feedback. This would help us in achieving the objective of replicating and replacing paper-based feedback with a well-designed software-based solution, as paper-based system is not sustainable.

7. CONCLUSIONS

With the increasing number of educational institutions, energy conservation in dormitories can have a significant impact. Our study in an Indian university dormitory shows that eco-feedback techniques result in reduction of energy consumption. Adding to previous findings, easy to use and regular paper-based feedback outperforms other feedback mechanisms. The study also highlights gender-based differences in energy conservation. While our study was limited to university students in India, we believe that the inferences drawn can potentially have a wider applicability to a broad set of consumers.

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