Why Education and User Feedback Won't Close the Performance Gap for University Accommodation

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Abstract
It's often correctly stated that making buildings work requires an educated and engaged end user. This paper presents results from a study of user feedback in student accommodation. Students that volunteered their energy meter readings used 20% less energy than non-participants. However, this did not change before, during, or after the period of enhanced education and feedback. Furthermore, among those that stated higher awareness of energy issues throughout the study, there were no changes in their energy use habits. While it is no doubt true that education and feedback are useful in addressing the performance gap, this research finds two fundamental challenges to implementing such strategies: 1) most feedback is preaching to the converted, and 2) education does not necessarily correspond to action.

Keywords behaviour, education, feedback, social norms, student accommodation

1.0 Introduction

As the efficiency of our building stock improves, occupant behaviour plays an increasing role in our energy consumption (1). Past work has indicated the potential for feedback and 'nudges' to help influence choices through mechanisms such as social norms and default selection (2-4). This paper presents the results of a study designed to explore the potential for low cost energy savings to be made in student accommodation through behaviour change by addressing the following two research questions:

1) How effective are different forms of feedback at curbing energy use among student populations?

2) Does an increased frequency of feedback impact the student's energy use behaviour?

This paper is broken down as follows; first a literature review describes the applications of behavioural economics towards energy issues and explores past studies quantifying the impact of feedback on energy use behaviour. The methodology and data collection are described for a case study at Churchill College in the University of Cambridge, followed by a discussion of the results and description of the limitations of the data set and conclusions about what trends can be drawn and used to direct further enquiry.

2.0 Literature

Studies have examined the balance between design and operation in a building's energy use (e.g. 5), and it is clear that occupant behaviour plays a significant role. Models of energy use that rely on neoclassical economic predictions of occupant behaviour vary significantly from observational results (4). Whereas traditional economics is concerned with how changes in price influence behaviour, an increasing body of research in behavioural economics shows that non-pecuniary interventions can perform comparably to price based mechanisms in changing consumer choices (e.g. 6).

Non-pecuniary methods of influencing energy use are typically centred on feedback and the provision of different types of information to the consumer. There is a considerable body of literature reviewing the impacts of different kinds of feedback on energy consumption. These include providing customers their energy use, live updates through smart-meter displays, providing information on methods of conserving energy, neighbour comparisons, goal setting, and structured commitments. The effect sizes range from 0 to 20%, with usual savings between 5 and 12%, though noting that methodological issues cloud direct comparisons amongst studies (3,7-9).

Thaler and Sunstein (10) promoted the term libertarian paternalism as the influence of behaviour while respecting free will. They argue that the ways in which information is presented (default rules, framing effects, and starting points) will influence their choice selection. Libertarian paternalism suggests that by using knowledge of human behaviour, choice architects can 'nudge' people towards choices with welfare maximising outcomes (2).

A form of nudging called social norms is common in feedback programs because people value social relationships and therefore orient their behaviour in line with what they perceive is socially desired (8). In what has now become one of the most widely cited examples of the effective use of social norms, an American company called OPower has partnered with utilities to deliver targeted feedback to customers on their energy use (11). The motivation for the OPower approach stems largely from the work of Nolan *et. al.* (12) and Schultz *et. al.* (13). Cialdini (14) further noted the distinction between descriptive norms (what others do) from injunctive norms (what people approve). Schultz (13) showed that the use of injunctive norms could limit rebound effects by including positive feedback for efficient behaviour in the form of a 'smiley face'.

The body of research documenting the potential for feedback and social norms to influence behaviour has typically consisted of limited studies with small sample sizes and atypical populations (such as the present study). These studies often document effect sizes around 5-20% (2). The OPower model represents one of the only examples of this type of study being carried out on a large scale, with thousands of participants across a range of population demographics. The effect sizes documented by OPower range from 1.1-2.8% (15), which is significantly lower than what is shown in the more limited studies, which demonstrates the difficulties in expanding such programs to scale. Most significantly, the OPower study is among the only examples of programs that have not used volunteers and thus avoided the selection bias in their sample. As will be shown throughout this study, selection bias can have a significant impact on the effect size.

The Carbon Trust (16) estimates that the further and higher education institutions in the UK pay annual utility costs of £200M, with around 3.2 million tonnes of CO_2 emissions per year. They contend this could be reduced by 20% and emphasise the potential for savings through operational change with no capital investment. Strategies to influence energy use behaviour in university campuses take many forms, from awareness campaigns to energy saving contests. One of the only studies to explore energy use in student accommodation was carried out in the United States by Petersen et al. (17). The study consisted of installing a complex real-time monitoring system that allowed students and staff to view their energy use online. There was also a competition in place amongst dormitories which provided incentives to conserve energy and water. They documented an overall reduction in electricity use of 32% throughout the study.

3.0 Method

This paper presents results from a study conducted throughout the Lent term (17/01/2012-16/03/2012) in Churchill College at the University of Cambridge. The college was built from 1958 to 1968, with 10 residential courts spread across the 170,000 m^2 site. During the 2011-2012 academic years, the residential courts housed 416 undergraduate students. These 416 undergraduate students were asked to participate in an energy feedback study on a voluntary basis. Graduate students and teaching fellows were excluded from the study.

The undergraduate rooms are largely consistent in size and utilities, but vary from standard single rooms to ensuites. The electricity is individually metered at the room level, which includes the installed lighting, plug loads, and fan motors. The heating and domestic hot water are supplied via natural gas and centrally metered. Since room by room data is not available for gas, heating and hot water services were not measured as part of this study; the energy used hereafter will refer to electricity use only.

Since there is no remote monitoring capability, students were sent four emails requesting that they take their own meter readings. The response rates are given in Table 3.1.

	Date	Number of students emailed	Number of responses	Response rate
Meter reading #1	16/01/2012	416	234	56%
Meter reading #2	06/02/2012	416	236	57%
Meter reading #3	27/02/2012	416	212	51%
Meter reading #4	12/03/2012	416	176	42%

Table 3.1: Meter readings

Respondents were split into five groups, each of which would receive different feedback on their energy use when their meter readings were submitted. The groups were divided based on the size and location of their buildings so as to create as even a distribution as possible. Partway through the term, the study received 50 smart meter displays. The smaller Group D and Group E were then created. As the percentage of respondents per staircase varied, the final number of respondents in each group also varies. The goal of the study was to determine the impacts of feedback emails, therefore only data from students that submitted all four meter readings was considered. Once invalid data had been filtered, a total of 138 participant students remained as shown in Table 3.2.

	Total in College	Responded to Email #1	Responded to Email #2	Responded to Email #3	Responded to Email #4	Valid Data from All
Group A	121	57	54	52	40	30
Group B	125	72	69	61	56	45
Group C	118	73	68	62	48	44
Group D	26	-	24	18	16	12
Group E	26	-	21	17	14	7
Total Students	416	202	236	210	174	138

Table 3.2: Participant groups.

Groups A through E were established according to the following feedback types:

Group A – Consumption Feedback:

Group A received feedback stating only the kWh consumed in the time period in question, but no social norms feedback.

Figure 3.1 – Sample of consumption feedback given to Group A

Group B – Social Norms – Monetary Feedback:

Group B was given descriptive social normative feedback in which their own energy use was compared alongside the average energy use of the students in their group. The energy use of the most efficient 10% of students was also shown in green for reference. If the students' energy use was below the average energy use their result was highlighted in orange. If their energy use was above average, then their result was shown in red along with a clipart image depicting money being lost, and a phrase stating how much more they would spend compared to their neighbours should this energy use pattern continue for the course of a calendar year.

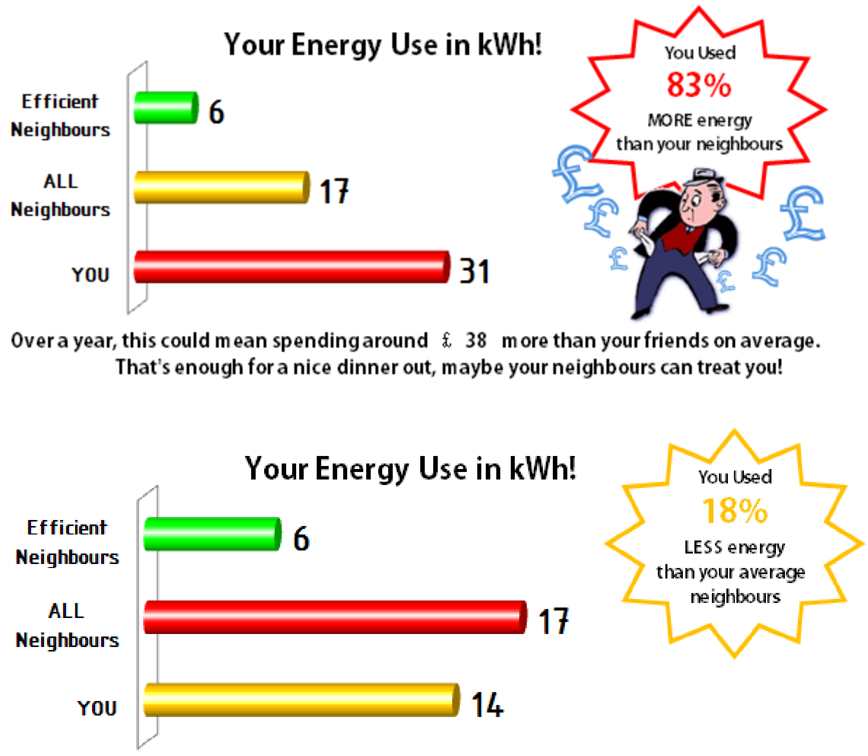


Figure 3.2 – Sample of social norms feedback for Group B

Group C – Social Norms – Environmental Feedback:

Group C was given similar descriptive social normative feedback to Group B in the form of neighbour comparisons. Those that exceeded the average energy use of those in their group the amount by which they exceeded their neighbours was framed in CO_2 emissions. A clipart image depicting excessive CO_2 emissions was shown along with phrases depicting the amount of other activities such as driving a car or leaving a computer on that would have produced equivalent emissions over the course of a calendar year.

Past research with neighbour comparisons has found that those using less energy than their peers have increased their use in response to descriptive social norms. This has been termed rebound, or the 'boomerang effect' (18). In some cases, the use of an injunctive social norm can reduce this rebound effect. Group C received an injunctive social norm in the form of a smiley face as well as an indication of the potential money saved compared to their neighbours over a calendar year, in order to reinforce the positive behaviour.

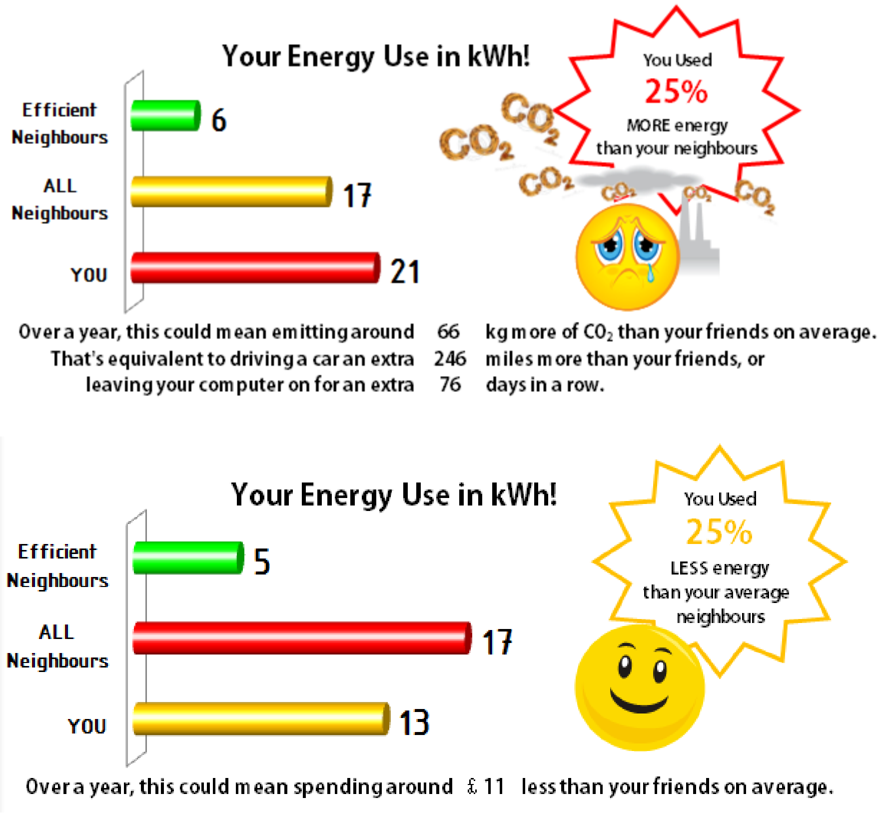


Figure 3.3 – Sample of social norms feedback for Group C

Group D & E – Smart Meters:

The rooms that received smart meters part way through the term were divided into two final groups Group D and Group E. The smart meter displays gave students a real-time feedback on their energy use throughout the day. The display also gave feedback on the total energy use over the previous 24 hour period, broken into daytime, evening, and night time periods.

Group D received only the kWh used in each interval, just as those in the Control Group A, while Group E received social norms feedback as did Group B.

A summary of the feedback mechanisms used for each group are given in Table 3.3.

Group	# Students	Consumption (kWh only)	Social Norms (kWh + Cost)	Social Norms (kWh + CO_2)	Smart Meter Displays
Group A	30	Y			
Group B	45		Y		
Group C	44			Y	
Group D	12	Y			Y
Group E	7		Y		Y

Table 3.3: Group feedback types.

4.0 Results

The four requests for meter readings divided the term into three feedback periods using the dates given in Table 3.1. Since both the interval periods and the dates at which readings were taken varied, all results are given in terms of kWh per day. The meter readings were received by email from the students and recorded by hand in a spreadsheet. This spreadsheet generated the feedback and imagery based on the student's group. Each student then received an individual response email with their energy use feedback. The data was filtered and processed using a set of spreadsheets and statistical tests were performed on the results.

The average energy consumption per day for each group is given in Table 4.1. It shows a drop in energy use for each group as the term progressed, but there is a weak distinction between the different groups.

Research question 1 sought to address whether there was a statistically significant distinction between the impacts of various types of feedback. The significance of the differences between the energy use reductions experienced for each group from interval 1 to 3 was examined using a single factor ANOVA test, which resulted in a p-value of 0.53, which is considerably higher than the p=0.05 threshold for statistical significance. This data set does therefore not demonstrate any meaningful difference between the types of feedback measures tested. The poor statistical performance of the results can be due to several causes which are further explored below.

First, it is important to qualitatively describe sources of variation that could account for the decrease in energy use besides the feedback being tested. The study did not measure heating consumption; therefore the decrease is definitely not due to increasing spring temperatures. It could however be due to increasing daylight hours and a reduced need for artificial lighting.

		Average Energy Use (kWh/day)			**% Drop in Energy Use**	
	Count	**Interval 1 (~Jan)**	**Interval 2 (~Feb)**	**Interval 3 (~Mar)**	**Interval 1 to 2**	**Interval 1 to 3**
Group A	30	1.86	1.74	1.58	6.3%	15.1%
Group B	45	1.49	1.28	1.27	13.8%	14.4%
Group C	44	1.58	1.37	1.24	12.9%	21.5%
Group D	12	1.68	1.41	1.46	15.7%	13.0%
Group E	7	1.15	1.06	1.03	7.6%	10.2%

Table 4.1: Average daily energy use for Lent term (17/01/2012-16/03/2012).

The results in Table 4.1 can be further broken down based on the exact message each student was sent after each interval as shown in Table 4.2.

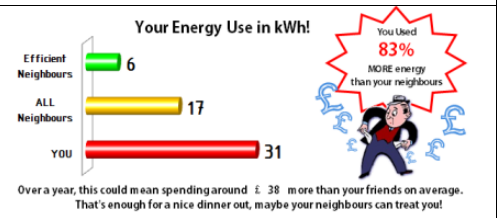
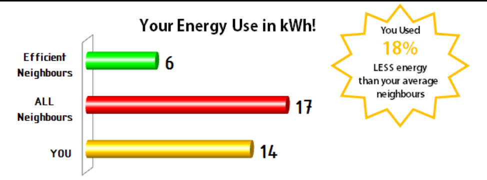
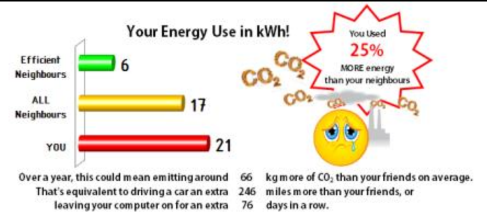
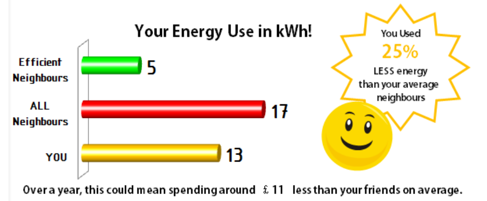
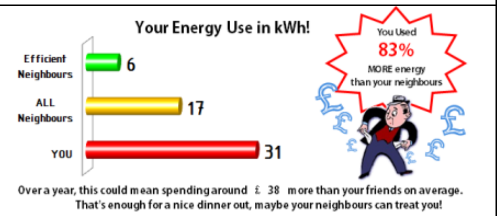
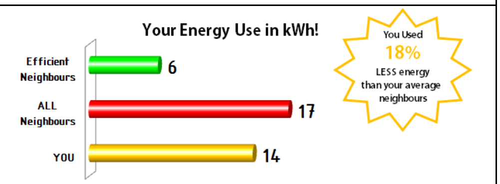
	Energy Use	**Sample Message**
Group A	ALL	**Your Energy Use in March!** **28 kWh**
Group B1	$E > E_{avg}$	
Group B2	$E < E_{avg}$	
Group C1	$E > E_{avg}$	
Group C2	$E < E_{avg}$	
Group D	ALL	**Your Energy Use in March!** **28 kWh**
Group E1	$E > E_{avg}$	
Group E2	$E < E_{avg}$	

Table 4.2: Messaging setup.

This breakdown allows the data to be viewed by energy use reduction in the interval immediately following the receipt of one of the feedback types given. The results are given in Table 3.3.

Group	Feedback count	Average Energy Use Reduction in Interval Following Feedback (kWh/day)
A	60	0.15
B1	34	0.20
B2	56	0.05
C1	39	0.25
C2	49	0.10
D	24	0.11
E1	7	0.07
E2	7	0.05

Table 4.3: Breakdown of energy use by feedback type.

Table 4.3 shows that students receiving feedback type B1 reduced their energy consumption by 0.2 kWh/day, compared to a reduction of only 0.05 kWh/day for those receiving feedback type B2. However, a t-test comparing these two data sets gives a p-value of 0.11. This indicates that while students did respond more strongly to the negative feedback (B1) than to the positive feedback (B2), this did not occur to a degree that was statistically significant for this data set. Additionally, given the small total consumption for each room, there would be less room for further improvement among those who already have lower than average energy consumption.

Feedback types B2 and C2 can be compared to test if the injunctive social norms had any impact on curbing the rebound effects for low energy users that received positive feedback. Here the injunctive social norms feedback corresponded to a reduction of 0.1 kWh/day compared to only 0.05 kWh/day for the descriptive social norms feedback. This may suggest the injunctive norms had some effect, however again a t-test revealed a p-value of 0.16, indicating that the results are not statistically significant for this data set.

The small sample size could potentially limit the significance of the results; however, the more critical factor is the variance of the data. The electricity use in each room varied from 0.14 kWh/day to 5.5 kWh/day. The results of a post-study questionnaire revealed that different students spend anywhere from 3 to 7 waking hours per day in their rooms on weekdays, and 2 to 21 waking hours on weekends. They also possess anywhere from 4 to 12 energy using appliances such as laptops and hair dryers. The high variability and low absolute value of energy consumption in student accommodation limits the extent to which statistically significant quantitative statements can be extracted.

5.0 Discussion

5.1 Comparisons with Billing Data

It should be noted here that the study lacks any obvious control group due to the manner in which the data was collected. With no remote monitoring capability, students were required to volunteer, and simply by contributing their data they removed themselves from any possible control group. A separate control group, however, is not essential to addressing research question 1. Research question 1 considers the change or reduction in electricity use observed throughout the study, and whether the reduction varies among groups receiving different types of feedback. This controls for any slight differences in the total energy use due to varying room sizes and other external factors.

Research question 2 addresses whether the frequency of feedback impacts on energy use. This question does require a separate control, as the participant group that received increased feedback must be compared to one that received the standard feedback. In this case standard feedback means that students only receive information about their energy use on their end of term electricity bill.

The data collected from the students as part of this study can be compared to the data gathered by the college porters and administration for billing purposes. While the two data sets cannot be directly compared, the porters' data can be used to define a participant and a non-participant group based on students room numbers. The college porters collect readings at the beginning and end of each term over the course of several days. The exact date that each meter reading each meter reading is taken is not recorded, however, energy used is converted to kWh/day to normalise for different occupancy periods, and any variations will be randomly distributed throughout the groups.

	Count	**Michaelmas Term (03/10/2011-09/12/2011)**	**Lent Term (17/01/2012-16/03/2012)**	**Easter Term (16/04/2012-15/06/2012)**
Feedback type		Standard feedback (end of term bill only)	Enhanced feedback (emails with social norms)	Standard feedback (end of term bill only)
Non-Participants (kWh/day)	278	1.56	1.98	1.38
Participants (kWh/day)	138	1.22	1.56	1.09
% Difference between Participants and Non-Participants		21.8%	21.1%	20.6%

Table 5.1: Participants vs non-participants.

Table 5.1 compares the average daily energy use for the 138 students that participated in the study and hence received enhanced feedback during Lent term to the energy use of the 278 students that did not participate and thus received standard feedback only at the end of Lent term in their energy bill. Only students that submitted valid readings for each feedback period were considered in the Participants category. The non-participant category therefore includes some students who submitted partial or invalid meter readings, and were thus partial participants. Including partial participants in the Participants category had no significant effect on the results given in Table 5.1.

Table 5.1 shows that for the Lent term, those students that participated in the study used an average of 1.56 kWh/day compared to 1.98 kWh/day for the non-participants, a difference of 21.1%. A t-test yields a p-value of 0.008, meaning that the results are statistically significant.

However, since the same students were in the college throughout the academic year, the Lent term during which the enhanced feedback study took place can be compared to the Michaelmas and Easter terms in which only standard feedback was taking place. The participant group consistently used 20.6-21.8% less energy than the non-participant group whether they were receiving enhanced feedback or not. This suggests that the group participating in the study were self-selected for those with an increased interest in energy issues, and who were already practicing energy conservation regardless of the type of feedback they were receiving. Note that the absolute value of the average energy use increases during Lent term likely because it is winter and there are fewer daylight hours.

5.2 Survey Feedback and Other Trends

In addition to the meter reading data collected, students were asked to complete a short questionnaire at the end of the study. Of the 416 students, 110 students responded. Of the survey respondents, 55% said that they pay the energy bills themselves, while 43% said that their parents paid the bills (2% have their bills paid by another third party). The overall energy consumption was unchanged regardless of who was paying the energy bills. The trends in energy decrease throughout the term were also consistent with the results presented above regardless of who paid the bills, suggesting that the common principal-agent problem is not a significant factor in this data set.

Throughout this study, there has been a very high variability of energy use among rooms. The variation in room size and construction is sufficiently randomised that the differing energy use can be principally attributed to occupant lifestyle and behaviour. It is therefore useful to identify indicators that correlate strongly with differing energy use. Students were asked how many hours a day they spend in their rooms on average for both weekdays and weekends, and their energy use was plotted accordingly. The majority (79%) of students spent between 3 and 11 hours a day in their rooms. Across this range, there was a near zero correlation between the energy consumed and the number of hours that the room was occupied.

Another possible indicator is the number of appliances in use. Students were asked to select from a list of the various appliances that they have in their rooms. The quantity of appliances was again plotted against the average energy use and the correlation was very weak. The average energy use was nearly constant whether the student used 1 appliance or 8. The calculation accounted for both the size of the appliance and its typical operating hours, and this did not impact the results.

Finally, it is commonly said that one of the biggest barriers to energy efficient behaviour is awareness. Much waste can be attributed to the low priority of energy issues. There are numerous types of campus campaigns to engage students in how they use energy. As part of the post-study questionnaire, students were asked whether they discussed their energy use with their friends before the study and whether they discussed it during the study. Only 10% reported discussing their energy use before the study, whereas 40% reported discussing it throughout the enhanced feedback study. The increase was relatively consistent across all Groups, regardless of what type of enhanced feedback they were receiving. This supports the common wisdom that more frequent feedback helps encourage awareness of energy issues. However, awareness did not directly translate to behaviour change. The 40% of respondents that said they did discuss their energy use throughout the study used about the same amount of energy as those that did not discuss it. Furthermore, each group decreased their energy use throughout the term by approximately the same amount, regardless of whether they reported discussing their energy use or not.

5.3 Key Findings

The aim of this study was to test the potential for low cost energy savings to be made in student accommodation through behavioural ‘nudges’. This was among the first off such studies to focus exclusively on student accommodation in the UK. Given the proportionally high regard that the student demographic has towards energy and environmental issues, the potential for energy savings through behaviour change in this group deserves further consideration.

Research question 1 queried whether there was any distinction between the effectiveness of different feedback types in curbing energy use in student accommodation, specifically whether social norms exhibited a stronger influence among a strongly social population such as students. The results suggested that for some groups, the influence of negative descriptive social norms encouraged a stronger response than positive social norm messages or straight consumption feedback, however, the variance in energy use patterns was too high to allow statistically significant conclusions.

It can also be noted that in the social norms feedback, student’s energy use was compared to their average neighbours, not their most efficient neighbours. This was done to better distribute the group sizes, however it would likely deliver higher overall energy savings for the social norm to target the most efficient behaviour as opposed to the average behaviour.

Research question 2 addressed whether or not the increased frequency of feedback affected the students’ energy use behaviour. By using the college’s internal billing meter readings, the study’s Participant group that received enhanced feedback was compared to the Non-Participant group which received standard feedback before, during, and after the study. The Participant group consistently used 20.6-21.8% less energy in each term, whether they were receiving enhanced feedback or not.

This suggests that the Participant group were self-selected as students with a higher interest in energy issues. In responding to the post-study questionnaire, the Participant group largely stated that they had already been practicing energy saving behaviour such as turning off lights and computers prior to the study. Given the small absolute value of the energy used in a student accommodation room, there were few additional energy saving practices that increased feedback could encourage students to take advantage of. It is possible that the Non-Participant group could achieve some savings through behaviour change in order to bring them in line with reduced energy use of the Participant group; however a study to explore such strategies would require equipment beyond the scope of this study.

While the quantitative results of this study are limited to university accommodation, they highlight principles that deserve wider consideration. The often discussed performance gap refers to the difference between actual energy use and that which is technically feasible. As building technology improves, an increasing proportion of the performance gap is attributable to occupant behaviour and thus addressable through behaviour change efforts. The results given in Table 5.1 suggest that much behaviour change messaging is only being received by an audience that is already practicing efficient behaviour. Furthermore, the questionnaire results suggested that even where students embraced messages about energy efficiency and disseminated them amongst their peers, this did not correspond to a change in behaviour. These two points echo the findings of the O-Power study which found far smaller effect sizes in behaviour change programs that included non-volunteers. Simply put, many education campaigns will only be received by those who desire the messages, and even amongst that engaged audience, converting education to action is not always straightforward. While there is great potential to address the performance gap through education and behaviour change, engaging hard to reach audiences remains an insufficiently addressed challenge.

6.0 Conclusions

The conclusion of this study is therefore that increased feedback is unlikely to provide a statistically significant change in students' energy use behaviour because the amount of electricity used in each room is low, and varies considerably with student lifestyle.

A common problem in studying energy use in universities is that it is very difficult to generalise findings as all colleges/universities are set up differently in infrastructure and metering capacity, as well as administratively. Specific contractual arrangements with utility suppliers, as well as distinct usage patterns make it difficult to establish and extrapolate trends in energy saving strategies.

The results do not suggest that student awareness campaigns and energy reduction competitions are not worthwhile, as any energy savings through behaviour change and conservation is likely to be cost effective. The results only suggest that capital expenditures such as remote monitoring and smart meter displays will have weak returns for student accommodation with low electricity use and a high variability in student lifestyle as it is difficult to verify their effectiveness with any statistical significance.

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