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Competition and norms: A self-defeating combination?

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HIGHLIGHTS

- We investigate the effect of information feedback on residential energy consumption.
- A RCT tests whether norms affect the decisions of price-indifferent participants.
- Feedback mechanisms and norms reduce energy consumption by 22% on average.
- Introducing prize competition dissipates the impact of information feedback and norms.

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ABSTRACT

This paper investigates the effects of information feedback mechanisms on electricity and heating usage at a student hall of residence in London. In a randomised control trial, we formulate different treatments such as feedback information and norms, as well as prize competition among subjects. We show that information and norms lead to a sharp – more than 20% - reduction in overall energy consumption. Because participants do not pay for their energy consumption this response cannot be driven by cost saving incentives. Interestingly, when combining feedback and norms with a prize competition for achieving low energy consumption, the reduction effect – while present initially – disappears in the long run. This could suggest that external rewards reduce and even destroy intrinsic motivation to change behaviour.

1. Introduction

Reducing overall energy consumption, as well as managing energy market volatility and demand peaks are increasingly important issues with the growing focus on decreasing greenhouse gas (GHG) emissions and controlling climate change. Internet connectivity and electronic innovations now allow energy providers to develop demand side management systems instead of only concentrating on supply side management. Using combinations of information feedback loops and grid management techniques, operators have the potential to improve the management of energy market volatility and demand peaks. This would lead to lower energy production costs and reduced emissions. As one third of all greenhouse gas emissions come from residential energy consumption (EPA, 2015), understanding how social dynamics can impact household energy demand is an important step in this direction.

In this paper, we investigate the effects feedback information and norms, as well as prize competition, on energy consumption. We conduct a randomised control trial for a cohort of price-indifferent individuals at a student hall of residence in London. Our systematic literature review indicates that we are the first to test such a combination in this particular setting. We provide our subjects with individual as well as group/comparative feedback. A crucial factor of our design is that, because participants do not pay for their energy consumption, the information effect is not confounded by any cost saving incentives. This allows us to solely focus on the effects of behavioural interventions and norms as

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opposed to price effects, which is present in other studies. We find that information mechanisms are strong: providing individuals with weekly feedback about their own consumption and their consumption relative to others leads to a 22% reduction in energy consumption on average. For a subset of our trial participants we combine the information treatment with a prize treatment; this group was promised a prize for the participant with the lowest energy consumption. This reveals an intriguing perverse effect. Whereas, for individuals with pure information treatment, the consumption effect is sustained throughout the trial, for the prize treated group the effect wears off completely after two weeks of treatment. We provide some evidence suggesting that this dropping off is caused by a reversal of efforts by individuals who realise that the prize is out of their reach as a consequence of the information treatment. This hints at a fundamentally different response mechanism when providing a prize: by strengthening external financial incentives, internal incentives such as the desire to reduce consumption because of detrimental social effects – e.g. through pollution – are weakened.

The focus of this paper is on household energy consumption, a key sector when considering energy efficiency and GHG emissions reductions. For example, in the UK, the domestic sector accounted for 27% of overall energy consumption in 2014[1] (DECC, 2015a) and 14% of total UK carbon emissions in 2013 (DECC, 2015b). These figures are expected to increase even further due to population growth and highlight the sector's growing importance. Statistics from the US and Western Europe reveal similar trends (Abrahamse et al., 2005; Gardner and Stern, 2002). In this context, as McMichael and Shipworth (2013) state: "various institutions are trying to encourage the adoption of behavioural energy-efficiency innovations through policy, building regulations and other measures such as direct engagement with communities and constituents".[2]

Our research relates to a vast literature analysing the factors that affect energy use in the residential domain. As described in Costa and Kahn (2013), household electricity consumption depends on individual choices and house characteristics, appliances and the intensity of their utilisation which are linked to the local climate, prices as well as the consumer's personal attributes and behaviour. At the macro level, factors including technological developments, demographic factors, household income and economic growth are also likely to affect consumption outcomes (Abrahamse et al., 2005). Additionally, Hori et al. (2013) show that regulation aimed at reducing energy use is much more effective in the industrial than in the residential sector. These results indicate the need to discover mechanisms that effectively induce lower energy consumption at the household level.

This paper also relates in particular to the literature on the behavioural dimension of energy use. As reviewed by Lopes et al. (2012), this subject pertains not only to economics but also to psychology (Biel and Thøgersen, 2007; Frederiks et al., 2015). From an economics point of view, the base assumption will be that individuals are taking rational decisions when deciding on their energy use (Breukers et al., 2011; Wilson and Dowlatabadi, 2007). However, energy and electricity are not typical consumer products. These are rather an abstract, invisible, intangible and indirect by-product of other economic choices (Fischer, 2008). For example, Kempton and Layne (1994) compared energy consumption to shopping without price tags given that the customer only gets a quarterly bill.

Given these aforementioned characteristics, previous studies have examined dynamic pricing of electricity and shown that it effectively switches consumption from peak hours to non-peak hours during which it's priced lower (for a comprehensive review see Faruqui and Sergici (2014)). Despite these results, it has been demonstrated that decreasing overall energy consumption only through dynamic pricing is challenging (Faruqui and George, 2005; Faruqui et al., 2010). While some studies show a 'short-term effect of financial rewards' (Abrahamse et al., 2005), others conclude that effects of financial rewards for energy conservation are large and persistent over time (Dolan and Metcalfe, 2015). Additionally, policy makers are often wary of using imperfectly designed financial incentives that can distort behaviour and lead to undesired consequences for financially constrained portions of the population or the elderly, for example, by increasing health risks associated with reduced heat consumption (Barnicoat and Danson, 2015). As Buchanan et al. (2015) state, households already suffering from fuel poverty have little capacity to further reduce their energy consumption. Finally, the cost dimension of the energy savings also relates to rebound effect (Khazzoom, 1980; Saunders, 1992), i.e. households saving money from consuming less energy may spend their additional income on activities that can generate more emissions.

As an alternative to financial incentives, existing research has also analysed the importance of information, or feedback mechanisms, and their impact on energy use. Feedback entails providing information to households about their energy consumption or savings, and is a strategy often employed by energy conservation initiatives. The effectiveness of different types, frequencies, duration of feedback on reducing energy use differs at the group, or even individual level (Abrahamse et al., 2005). One possible channel for a potential effect of feedback mechanisms could be that they "rematerialize" energy consumption (e.g. Buchanan et al., 2014).

Norms have been conjectured to be another meaningful channel through which information and feedback will impact energy consumption. They can be descriptive or injunctive; the former simply inform about others' performance while the latter directly suggest what should be done. Feedback that is augmented with a norm, i.e. direct comparison with 'average' or 'normal' behaviour may prove more powerful. Thaler and Sunstein (2008) consider that this feedback bypasses the consumer's decision-making process and acts as a heuristic shortcut or "nudge". Additionally, Fuster and Meier (2010) suggest that financial incentives could be effective if they manage to change the social norm. The literature on the effectiveness of norms is rather inconclusive. Fischer (2008) reviews studies from 1987 to 2006 and finds that norms may not be an important element of feedback, as they do not affect consumption. More recent studies show on the contrary that norms do have a measureable impact on household consumption but some also argue that they can cause a boomerang effect[3] (see for example Ayres et al. (2013), Nolan et al. (2008) or Schulz et al. (2007)). However, Harries et al. (2013) recently address a limitation of these studies: one should differentiate between the impact of pure feedback and that of norms. They find that the effect of norms is not statistically significant. Allcott and Rogers (2014) report how a utility company in the USA called OPOWER mailed home energy use reports, including social comparisons, to a selection of its customers. They find that it leads to energy consumption reduction, but that the frequency of the reports affects the persistence of their effect. Others demonstrate that social interaction and norms play a role in inducing energy saving behaviours at a decreasing rate over time (Dolan and Metcalfe, 2015; Hori et al., 2013). Additionally, post-consumption

[1] Energy consumption by the domestic sector was 38,162 thousand tonnes of oil equivalent (DEC, 2015a).

[2] p.1 McMichael and Shipworth (2013)

[3] Informing low energy consumers about the group norm may inadvertently inspire them to increase their energy consumption.

feedback has been an effective measure when accompanied by financial incentives (Abrahamse et al., 2005).

Given descriptive norms inform the consumer about how she is performing relative to her pairs, its driving force may be competitive behaviour against peers. Psychologists have long debated the role of competition in human behaviour (Deci et al., 1981; Deci and Ryan, 1985; Kohn, 1986). In economics, rational choice theory takes humans' competitive spirit for granted. In this paper, we distinguish competition from descriptive norms. Whilst the literature cited above has in some cases used the word ‘competition’ instead of ‘descriptive norms’, we instead use the former to describe prize competition - the case of people entering a competition to win a prize. The literature on the effect of prize competition on energy saving behaviour in particular is rather limited. However, previous evidence in psychology suggests that tangible extrinsic rewards as well as competition can become demotivating as they undermine intrinsic motivation[4] (Deci, 1971; Deci et al., 1981; Deci et al., 1999; Lepper et al., 1973; Reeve and Deci, 1996; Ryan and Deci, 2000;).

Our research bridges the areas exploring norms, competition over energy levels, financial rewards and reward competition. In our experiment, we rely particularly on descriptive norms to nudge our participants but also use some injunctive norms. We are particularly interested in the effect of norms when they are free from price effects, as well as of competition for a prize. We hypothesise that norms are likely to manifest themselves as intrinsic motivation such as a willingness to preserve the environment out of own enjoyment. Whereas a prize competition, i.e. a type of financial incentive, adds an extrinsic reward dimension to the energy saving decision, thereby diminishing the norms' effect.

The rest of this paper is structured as follows. The next section will give a brief introduction to the theoretical model and experimental hypothesis, while Section 3 will present the methodology used in this study. Section 4 will elaborate on results as well as provide a short discussion of results, and finally Section 5 will conclude and discuss further possible research.

2. Theoretical framework

In this section, we present the framework used in the design and analysis of the RCT when considering how individuals choose their energy consumption. Whilst different methodologies are utilised in the literature (Wilson and Dowlatabadi, 2007), we take the economics approach as a starting point assuming that individuals make rational choices to maximise their satisfaction, also called ‘utility’, given their budget constraints.[5] However, our model conjectures that energy consumption decisions are not purely a rational choice,[6] and therefore include the effect of norms in this context. We build on existing literature showing that individuals care about norms (see for example Akerlof, 1982; Arrow et al., 2004; Ball et al., 2001; Bault et al., 2008; Bénabou and Tirole 2011; Dolan and Metcalfe 2015; Jones 1984; Luttmer 2005; Okuno-Fujiwara and Postlewaite 1995) and assume that the individual's utility could be decreased by deviating from the norm. Moreover, given the participants in our trial do not pay for their energy consumption we diverge from the existing literature by also including in our model the possibility for a price-indifferent individual to prioritise norm deviation over price-related matters.

Our model therefore focuses on energy consumption decisions by representing a typical individual as consumer i who maximises in period $t$an objective function that looks as follows

$$u(E_{it}, r_{it}) = b(E_{it}) - r_{it}w - e_{it}c - \nu \times n(e_{it} - \bar{e}_{t-1}) \tag{1}$$

where her utility is a function u of two components, E_{it} and r_{it}. E_{it} represents the energy services enjoyed by individual i at time t: rather than benefiting from the energy consumption itself, individuals will derive satisfaction from the services it provides such as light, heat or powering of appliances. The second item, r_{it}, represents research on energy saving options, through which the individual can learn how to improve her efficiency. A consumer can improve her efficiency by engaging in research r_{it} on energy saving options, which leads to cost of $r_{it}w$.

The function $b(E_{it})$ measures the benefit, or satisfaction, derived from energy services. We assume it is a concave function,[7] so that it exhibits decreasing returns: for example, the benefit derived from boiling water for my first cup of coffee in the morning will be larger than for the third.

Actual energy used is denoted by e_{it}. We assume that:

$$e_{it} = \frac{E_{it}}{\sigma_{it}} \tag{2}$$

where σ_{it} measures how efficiently a consumer is using energy. The more efficient a consumer is the less actual energy e_{it} is required to achieve a given energy service level E_{it}. In our example, a more efficient kettle will mean a larger σ_{it} and hence a smaller quantity of energy used to produce the same energy service that is a cup of boiling water.

We denote by c a consumer's unit energy cost, so that total energy expenditure is $e_{it}c$. We assume that the individual's utility is decreased by this expenditure.

If a consumer cares about how she performs relative to others - i.e. she is susceptible to norms – then $\nu > 0$ and the convex function $n(e_{it} - \bar{e}_{t-1})$ enters her utility function. We have $\bar{e}_{t-1}$ denoting the energy consumption of the most efficient peer-group consumers in the previous period. If the individual i is lagging behind, i.e. she is consuming more energy than her most efficient peers, then $(e_{it} - \bar{e}_{t-1})$ will be positive. Her utility will be decreased.

This lag relative to the efficient consumers is also likely to affect the productivity of the individual's energy consumption. For simplicity we assume that

$$\sigma_{it} = \sigma_{BAUi}\exp\left(r_{it}\left[e_{it-1} - \bar{e}_{t-1}\right]\right) \tag{3}$$

which suggests that a consumer can improve her efficiency σ_{it} relatively to a Business-as-usual (BAU) level σ_{BAUi}. If she is lagging behind, such that $(e_{it} - \bar{e}_{t-1})$ is positive, it means that there exists ways for her to reduce this lag and consume a quantity of energy that is closer to her most efficient peers. If she is aware that she is lagging behind, her search r_{it} for energy efficiency is more effective if this consumer has a larger amount of catching up to do. If the consumer does no research, or if she is already among the most efficient, the expression in parenthesis in Eq. (3) will be equal to zero, and her efficiency σ_{it} will remain at the level σ_{BAUi} with no improvement.

The key parameter of interest for the purposes of this paper is ν. Consider the hypothesis that $\nu = 0$; i.e. consumers are indifferent to descriptive norms. In that case, the last term of Eq. (1) is dropped. The level of energy service demanded by the consumer would then be determined by maximising utility both with respect to energy services, obtaining the following first order condition

[4] Intrinsic motivation is defined as the doing of an activity for its inherent satisfactions rather than some separable consequence (Deci and Ryan 1985)

[5] A utility framework in this context stems from rational choice theory and allows us to provide a measure of satisfaction and individual preferences over the consumption of a good (Read, 2004), in our context, energy.

[6] Hence, individuals do not only consider selfishly driven consumption decisions.

[7] E.g. consider $b(E_{it}) = B \times E_{it} - E_{it}^2$

$$\frac{\partial b(E_{it})}{\partial E_{it}} = \frac{c}{\sigma_{it}} \quad (4)$$

as well as with respect to research effort, for which the first order condition is

$$c\frac{E_{it}}{\sigma_{it}}\left[e_{it-1} - \bar{e}_{t-1}\right] = w \quad (5)$$

Combining Eqs. (2) and (5) we find that

$$e_{it} = \frac{E_{it}}{\sigma_{it}} = \frac{w}{c\left[e_{it-1} - \bar{e}_{t-1}\right]} \quad (6)$$

This equation indicates that the less costly it is to search for energy efficiency improving opportunities (the smaller w), the higher the energy cost c, and the larger the gap to the most efficient consumer, the lower energy consumption e_{it} will be today. The important takeaway from this is that even if the consumer does not care about norms, her consumption will still be influenced by the consumption level of her peers: a large gap between her and her efficient peers means there are more learning opportunities to improve.

Note that if the marginal cost of energy is zero – $c = 0$ – then the first order condition for energy services derived in Eq. (4) becomes

$$\frac{\partial b(E_{it})}{\partial E_{it}} = 0 \quad (7)$$

As $c = 0$, improving her energy efficiency will not yield any reduction in cost: the marginal benefit from research is always smaller than its marginal cost. As a consequence, consumers would not undertake any research on energy saving options and consequently $\sigma_{it} = \sigma_{BAUi}$ would be unaffected by the performance of the most efficient consumers, $\bar{e}_{t-1}$. This means that if $c = 0$ and we nevertheless observe that consumers are responsive to information about peer energy consumption, it must be the case that $\nu > 0$.

In the RCT conducted in this paper, the trial group is provided with information about $\bar{e}_t$, the control group is not, and marginal energy costs are zero for all. The regressions we report below can then be interpreted as a test of the hypothesis $\nu = 0$. If the hypothesis is true, we would not expect to find any effect of the treatment.

3. Methods

This study was implemented in a student residence in West London (UK) in the summer of 2013. At the time, 466 postgraduate students[8] lived there, and had moved into their studio flats in October 2012. Each studio in this residence is occupied by one to two residents and is approximately the same size (varying between 18 m^2 and 22 m^2). Electricity and hot water for heating consumption are collected for each studio by Schneider Electric meters whose data-readings are stored on a server. This data was collated in weekly increments by Powerlogic ION Enterprise software that produces csv files with this information.

Prior to the field experiment, a survey to collect demographic and socio-economic characteristics of participants (see Appendix A) was distributed to all 466 residents. The main areas of the survey include: demographic information, experience with past energy usage and perceptions regarding energy use and the importance of conserving energy. A total of 89 respondents completed the questionnaire at least in part, implying a response rate of 19.3%.

The survey methodology consisted of sending out (i) an introductory letter, (ii) the questionnaire followed by a (iii) thank you/reminder. Moreover, an additional questionnaire was sent to non-respondents in order to collect more responses. At the beginning of the survey (see Appendix A), each participant was provided with information including the nature and purpose of our research, their role in the study, and a guarantee of confidentiality. The participants were then requested to acknowledge understanding and consent to the use of the subsequent data in order to continue with the survey. This permission was then further used to include consenting participants in the experimental RCT study. Each participant was provided the option to receive further information about the study or to withdraw from the study at any time, without penalty or loss. The online survey was designed and distributed electronically using Qualtrics software. A reminder was also sent before the survey closed. To incentivise completion of the survey, we promised and then offered a £50 Amazon voucher to a randomly selected participant.

In an attempt to monitor social dynamics within groups, respondents were asked to report the number of residents they were familiar with or interacted with on a regular basis. Approximately 50% of the sample reported regular interactions with only five individuals or less within the student residence; therefore, we do not suspect a strong communication bias among participants. The 89 residents that responded to the survey constitute the sample population for our randomised control trial. This was because the survey included a question about consent to using their energy consumption data for research. For these students, we inspected energy consumption data from the beginning of June (Monday the 3rd of June 2013) for 10 weeks. A first intervention report was distributed to participants at the beginning of week 5 (on Monday the 1st of July), and was sent out every Monday for a further 6 weeks. The energy use data collected for each week was used to inform the subjects about their own as well as relative energy consumption via their weekly energy reports.

This weekly energy report, emailed to participants, was developed based on a number of well known pre-established ones such as the OPOWER report (Allcott, 2011) and contains two main sections, namely a social comparison module and an action steps module (see Fig. 1).

The social (peer-group) comparison module consists of descriptive and injunctive norms. Descriptive norms, the first element in the social comparison module, are represented as a comparison of residents' individual energy use for a week to both the overall mean use denoted by 'all neighbours' and the mean of the 'efficient neighbours", the 20% of participating students using the least energy. In addition, this element also reports a weekly rank of the resident in comparison to the 89 participants. Furthermore, the energy use is further broken down into 'electricity' and 'heating' elements, which are then tracked on a weekly graph.

The second component of the social comparison module is a series of injunctive norms. The overall weekly comparison is rated as 'great', 'good', or 'more than average' coupled with appropriate smiley faces. Within the energy progress, a dashboard indicator moves between red, orange, light green and dark green status and a corresponding figure regarding how much energy has been used in comparison to the group.

In the second module, the action steps include a series of energy conservation tips. These tips, differing weekly, are selected based on relative simplicity and ease of implementation, and do not require any additional expenditure from the user. This part of the report is crucial as it helps us define how inputs (i.e. behaviours such as temperature of heating in the home, cooking food, etc.) translate into output (total resource use in kWh): it allows the participants to link the information about the norm behaviour in

[8] This was the whole population of the halls of residence to whom the survey was sent

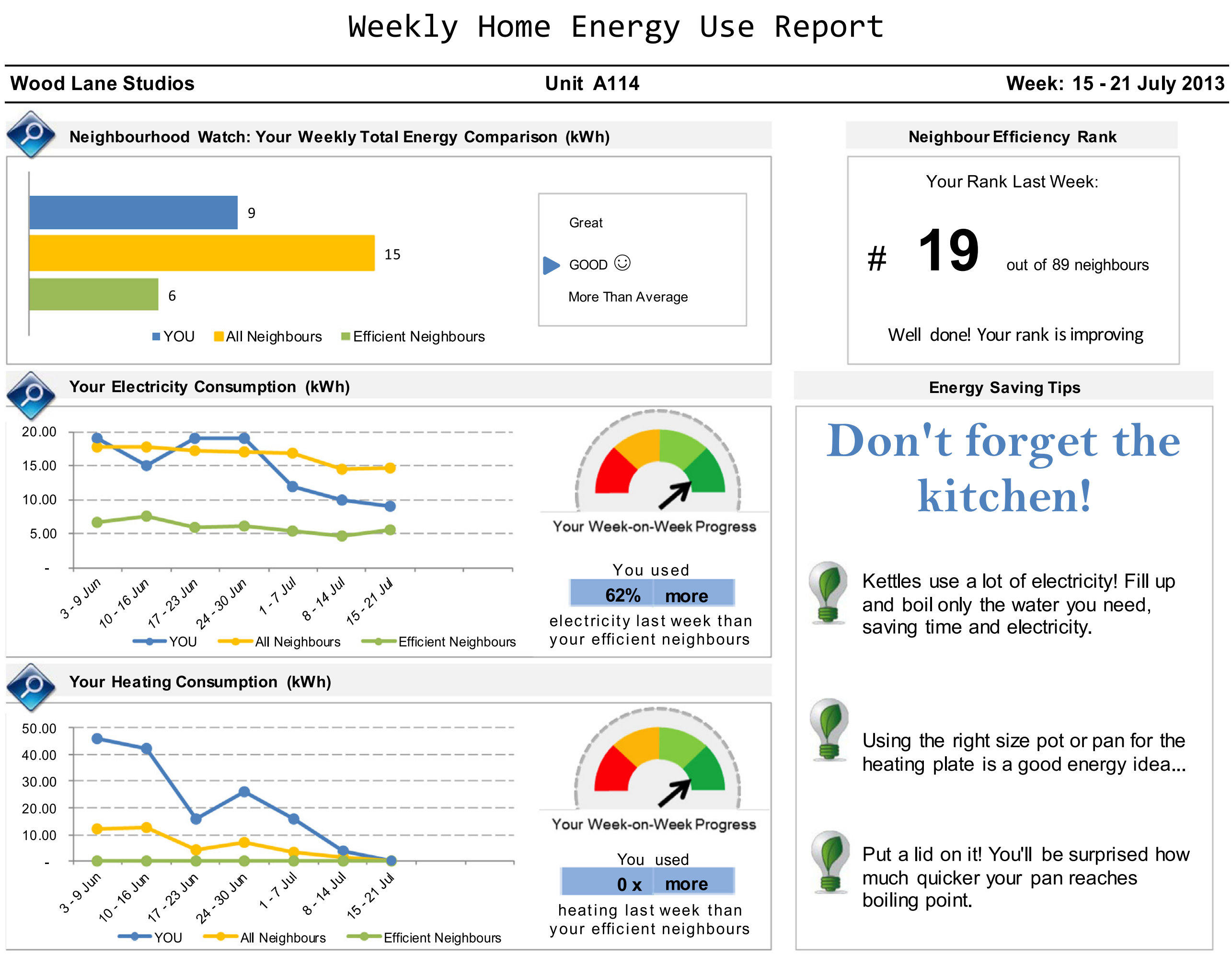

Fig. 1. Example of the study's weekly home energy report.
Notes: the weekly energy report emailed to participants includes social comparison and action steps modules. The social comparison module consists of (i) a comparison of residents' individual energy use for a week to both the overall mean use denoted by 'all neighbours' and the mean of the 'efficient neighbours", the 20% of participating students using the least energy, (ii) a weekly rank of the resident, (iii) electricity as well as heating consumption, (iv) the overall weekly comparison rated as 'great', 'good', or 'more than average' coupled with appropriate smiley faces, and (v) a dashboard indicator. The action steps module includes a series of energy conservation tips, differing weekly.

their residential community to actual behavioural change.[9]

The randomised control trial was based on three experimental groups, namely the control group (1) and two treatment groups (2 and 3):

- Group 1 – Control: Received a single e-mail at the start of the experiment that contained a series of simple energy saving tips.
- Group 2 – 'Information, feedback and norms' treatment: Received the energy weekly report described above.
- Group 3 – 'Information, feedback, norms and prize competition' treatment: Received the same energy weekly report as G2 participants. They were additionally informed that a competition was running to find the resident with the lowest energy consumption over the course of the project, although, no specific prize was communicated.

Finally, in order to gather first-hand information regarding participants' thoughts, feelings and reactions to the study, we conducted a small-scale feedback review from participants. Its main goal was to collect information on what participants thought worked well or was irrelevant, whether they were able to understand the weekly report and their preferred method or frequency of communication. The questions were posed as a combination of structured and open-ended form, in order to encourage honest and detailed feedback and were distributed via a bulk email a week after our experiment concluded. The benefits of this setting for our RCT are emphasised given the existing literature on energy consumption decisions. These decisions are complex for households (Lutzenhiser, 1992) and isolating factors in a field experiment can be difficult. However, we are in a relatively easier position to isolate particular aspects of decision-making: participating students have identical rooms, use identical appliances (fridge, cooker, heating) and similar income status. Of course, the generalisability of results from experiments with student subjects has long been debated; for example, Druckman and Kam (2011) show that in fact student samples are comparable to general population. In our study, their student status makes them easily comparable and allows us to control aspects that we could not have done with a wider population.

To measure and establish the impact of our treatments from the experimental part of the study we implement a simple difference in difference (DID) specification; i.e. we run regressions of the following generic form:

[9] Also noted by Dolan and Metcalfe (2015) about various similar studies, "what is missing here, is the ability of the person to understand how to transform that norm into observable behaviour change. Therefore the norm has to be accompanied by the information to actually change behaviour".

$$\Delta e_{Wi} = \beta_1 Treated_i \times PostTreat_W + \beta_2 Treated_i + \beta_3 PostTreat_W + \beta_X X_{Wt} + \epsilon_{Wi} \quad (8)$$

where Δe_{Wi} is the percentage change in weekly energy consumption for student i relative to a pre-intervention base week, which is week 4 in our results below. We compute percentage changes as

$$\tilde{\Delta} e_W = \frac{e_w - e_4}{0.5 \times (e_w + e_4)} \quad (9)$$

i.e. the change in consumption relative to the average consumption in week w and week 4. This allows us to compute $\tilde{\Delta} e_W$ even if consumption is 0 in either week w or week 4, which is relevant for heat consumption, where most students had weeks without using heating.

$Treated_i$ is an indicator variable that is equal to 1 for students that received one of our interventions. If β_2, the parameter associated with this indicator is not significantly different from zero, then we can conclude that the treatment and control group are comparable before treatment. $PostTreat_W$ indicates weeks during which the treatment is active. The main parameter of interest is β_1 which given the random assignment of treatment gives us an estimate of the average causal impact of the treatment. Because we use percentage changes as the dependent variable the parameter estimate for β_1 can be interpreted as the percentage reduction energy consumption due to the treatment. X_{Wt} is a vector of additional control variables such as nationality or gender of the student. However, note that given the random assignment of treatment it is not necessary to include additional control variables to get unbiased estimates of β_1.[10]

4. Results and discussion

4.1. Survey results

Our main goal in conducting this survey in the first stage of our study was to gain further information into the characteristics of the residents taking part in the study, in particular in relation to their energy use. The descriptive statistics for the results of our questionnaire are shown below. A summary and the summary of descriptive statistics of all the relevant variables can be found in Appendix C.

4.1.1. Demographic variables

The demographic variables include gender, nationality, income/budget, parental education level and previous residential status. Appendix C shows that the three treatment groups are comparable in terms of those observables as could be expected from the random treatment of the students.

Table 1 shows an almost equal split between male and female and the budget level of the respondents is predominantly between £10,000 and £19,000 per annum (41% of respondents). We also observe a very high level of parental education amongst respondents, with 96% having attained some college or higher high school and a further 55% having a graduate degree. This is well above the UK national average – which approximates 79% of adults having completed an upper secondary education (Eurostat, 2013).

4.1.2. Historical energy use

We find that for a large proportion of our student sample, the energy bill at their previous place of residence was either paid for by their parents (38%) or by someone else (2%). Others had experienced a flat rate (26%) or the payment was included in the rent (22%). Hence, we conclude that a maximum of 12% of participants have experience of paying for their energy bills and have some awareness about the cost of energy.

Table 1
Survey results for demographic variables.

Gender	Male 45%	Female 55%			
Nationality	UK 19%	Rest of Europe 31%	Asia 33%	Other 17%	
Previous residence	UK 44%	Rest of Europe 22%	Asia 16%	Other 19%	
Previous living	With family 48%	With others (non-family) 33%	Alone 19%		
Annual Budget (£)	Above 40,000 7%	30,000–39,999 2%	20,000–29,000 17%	10,000–19,000 41%	Below 10,000 33%
Funding source	Self-funded 48%	Scholarship 21%	Students loans 7%	Other 24%	
Parental education	Doctoral degree 24%	Masters degree 31%	College /some college 41%	High school or less 4%	

Notes: 89 participants completed the questionnaire at least in part and hence was included in our RCT. The above results are based on the answers of 42 participants whom have fully completed the survey.

4.1.3. Energy related intent and perceptions

In the residence, flats are supplied with basic appliances, namely, a microwave oven, refrigerator and thermostat. To fully understand the students' means to reduce energy consumption, we collected information on appliances used in the flats, such as laptops.[11] We also asked our subjects whether they felt if they knew how to save energy. A large majority (90%) thought they were aware of necessary measures. We nevertheless included saving tips in the feedback report of our study such as to ensure that 100% of participants understood how to link the change in their behaviour regarding their energy consumption into energy saving output. Literature shows that technology or intervention acceptance increases with perceived usefulness (Davis et al., 1989; Szajna, 1996). The students were also well aware of their daily energy use pattern, with 83% suggesting they used the most energy in the evening.

In order to gauge the perception of our subjects about their own behaviour, we posed some questions about their energy saving habits. We find that lifestyle and comfort take precedence over energy saving with respect to laptop use, as 26% of respondents will always leave it on and 33% only 'when working on something important'. However, we still observe a large positive response (95% of participants) towards the importance of energy saving, with some 83% of participants declaring they always switch the lights off when leaving a room.

Despite not paying for their energy bills, respondents were asked to rank the reasons for which they would consider energy saving as important. The resulting order was (1) saving money – 50% (2) energy security – 43% (3) climate change – 36%. This result is interesting given that the RCT's setting means monetary

[10] Our main results below do not include further controls but we examined the robustness of our results to including such controls and can make them available on request.

[11] Typical energy usage for these appliances is given in Table C2, Appendix C.

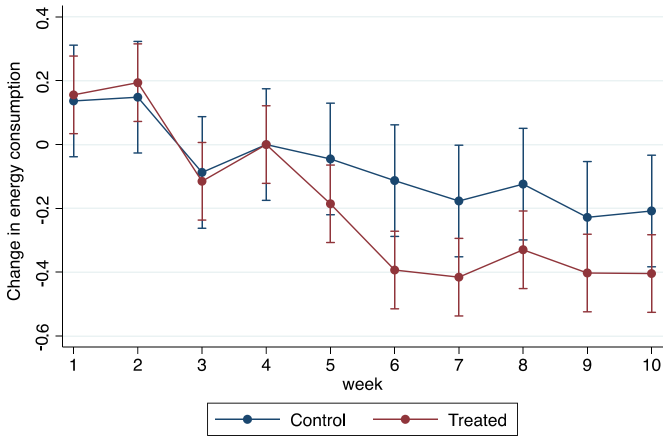

Fig. 2. The effect of information treatment on changes in energy consumption. Notes: the figure shows the average change (separately for all analysed weeks) relative to the last pre-treatment week (week 4) in energy consumption for both the treatment group (i.e. those students that received energy consumption feedback) and the control group that received no feedback for every analysed week.

Table 3
Basic DD estimation.

Dependent variables	Percentage change in (1) Total energy	(2) Electricity	(3) Heat
Treated	0.009	−0.067	0.178
	(0.081)	(0.079)	(0.114)
Treatment Period	−0.198**	−0.062	−0.488***
	(0.091)	(0.073)	(0.131)
Treated X Treatment Period	−0.215**	−0.077	−0.469***
	(0.106)	(0.084)	(0.173)
Observations	890	890	890
Number of rooms	89	89	89
R-squared	0.127	0.034	0.192

Notes: Dependent variables are computed as percentage changes relative to the last pre treatment week; i.e. $\frac{e_w - e_4}{0.5 \times (e_w + e_4)}$ where e_w denotes energy consumption in week w. Robust standard errors. Clusters at the level of individual rooms. **=significant at 5%, ***=significant at 1%

incentives are not part of the main intervention. It also shows that the population in our survey is not primarily environmentally driven, as could have been the case in a student hall.

4.2. Randomised control trial

This section reports the RCT results using a difference-in-difference approach as described in Eq. (8) of Section 3.

4.2.1. Basic Results

A first analysis of the RCT results shows in Fig. 2 that there is an aggregate effect of the intervention on energy consumption, with groups 2 and 3 combined as the "treated". We find that as a result of the intervention, the treated groups showed a drop in consumption after treatment begins in week 5, whereas before the treatment in weeks 1–4 they follow similar trends on average. In Table 2, we confirm that before the treatment both average energy consumption and the average growth in energy consumption are statistically indistinguishable before treatment begins between treatment and control groups (rows 1 and 2 of Table 2), which is to be expected given the random assignment of treatment. Average energy consumption is 25–28 kW h per week for both treated and control groups. Energy consumption declines on average per week by 5%. In Table 3, we confirm the impact of treatment by fitting the regression suggested in Eq. (8). Column 1 reports results for total energy, column 2 for electricity and column 3 for heat energy consumption. Across all specifications the treatment and control groups follow the same trends, which is reflected by the "Treated" dummy not being statistically significant. The coefficients of the treatment period dummy interacted with the treated group indicator – "Treated X Treatment Period" – we can interpret as the percentage causal impact of treatment; i.e. the treatment reduces the (total) energy consumption of the treated by approximately 22% on average. The treatment effect seems to arise primarily from reductions in heating energy consumption. This might be due to the fact that the RCT being conducted in summer means that heating is less of a necessity and its demand is more elastic. Note that the majority of students participating in the trial (68%) have been using their heating during the trial period.

Table 2
Descriptive statistics.

		Total energy consumption pre treatment in kW h: Average	Average growth
Treatment groups	Control	24.509	−0.046
	All Treated	27.679	−0.053
	Information	29.367	−0.031
	Competition	25.992	−0.076
Position relative to peers	Marginal	40.281	−0.038
	Non Marginal	21.612***	−0.056

Notes: The table reports descriptive statistics on energy consumption for different subsamples participating in our RCT. Stars indicate if means are significantly different between different groups. ***=significant at 1%. In Panel 1 difference test are relative to control group. In panel 2 (comparing position relative to peers) difference test is between the marginal and non-marginal group. A marginal group is defined as a student who is not in the bottom 20 in week 5 and neither in the top 5 in week 6. This definition is further explained in Section 4.2.3 Incentives and Learning.

4.2.2. Information versus Competition

Within our treatment group of 60 residents we administered two different kinds of treatment: pure norm only, which we refer to as 'information' in the tables and figures, or the same norm but combined with prize competition, which we refer to as 'competition'. Fig. 3 looks at these two groups separately. This reveals an interesting pattern. Initially, in weeks 5 and 6, both treatment groups behave very similarly, by reducing their energy consumption once exposed to treatment. However, starting in week 7, the competition group starts to fall back so that the average growth in energy consumption resembles more that of the control group. Indeed, the regression results in the first column of Table 4 confirm that in weeks 5 and 6 (Period 1) the energy consumption for both treatment groups reduces significantly by around 20% relative to the control group. However, in treatment period 2 (weeks 7-10), the gap between the competition and the control group is no longer significant and only around 9%. For the information (norm only) group on the other hand, the reduction gap deepens to around 30%. Rows 3 and 4 of Table 2 confirm that neither in terms of levels of energy consumption nor in terms of growth rates are there significant differences between the two different treatment groups and the control group. Non-significant differences in pre-treatment trends are equally confirmed by the non-significant

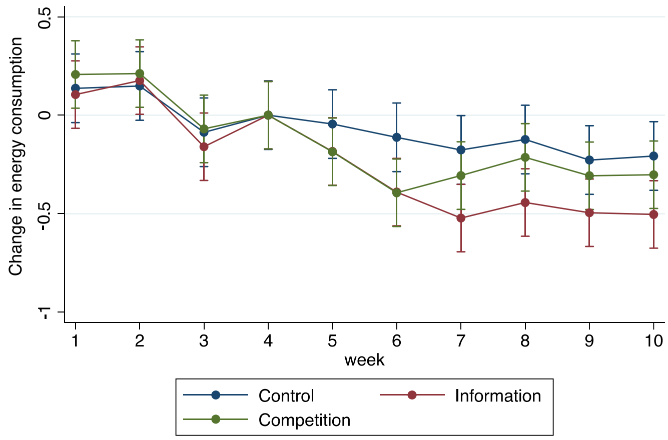

Fig. 3. The effect of information treatment on changes in energy consumption for different treatment groups.
Notes: the figure shows the average change (separately for all analysed weeks) relative to the last pre-treatment week (week 4) in energy consumption separately for the two treatment groups (i.e. pure information feedback and feedback in combination with a competition to reduce consumption) and the control group that received no feedback for every analysed week.

Table 4
DD of the intervention for treatment and control groups – distinguishing between different treatments.

Dependent Variable	Percentage change in Total energy consumption	
Information	−0.019 (0.086)	
Competition	0.038 (0.091)	
Treatment period 1	−0.128 (0.087)	−0.135 (0.083)
Treatment period 2	−0.234** (0.102)	−0.240** (0.093)
Period 1 X Info	−0.190 (0.115)	−0.209** (0.102)
Period 1 X Comp	−0.250** (0.108)	−0.212* (0.107)
Period 2 X Info	−0.289** (0.137)	−0.308** (0.126)
Period 2 X Comp	−0.137 (0.131)	−0.099 (0.133)
Observations	890	890
Rooms	89	89
R-squared	0.144	0.143

Notes: Dependent variables are computed as percentage changes relative to the last pre treatment week; i.e. $\frac{e_W - e_4}{0.5 \times (e_W + e_4)}$ where e_W denotes energy consumption in week w. Robust standard errors. Clusters at the level of individual rooms. *=significant at 10%, **=significant at 5%.

dummies for “information” and “competition” groups in column 1 (row 1 and 2) of Table 4. Given this absence of significant pre-trend differences between the two treatment and the control groups, we report in column 2 of Table 4 the same regression as in column 1, but restricting the two treatment group dummies to zero. This improves the efficiency of the regression, and confirms statistically the differential evolutions of the information and competition groups in periods 1 and 2 of the treatment weeks.

4.2.3. *Incentives and learning*

The results above raise the question of why the two treatment groups behave differently after week 6. We explore an explanation that combines two elements. Firstly, we suggest that treatment period 1 serves as a learning period. Individuals discover how they perform relative to others. Secondly, we propose that the behavioural drivers are fundamentally different between the two treatment groups. The information group is driven by the individuals' desire to reduce energy consumption in order to achieve societal objectives (i.e. preventing emissions and climate change). However, given the possibility of a financial gain is introduced for the competition group, their behaviour is driven by the individuals' efforts to maximise this gain.

Only the student with the lowest energy consumption would win a prize. Hence, if this becomes the main behavioural driver, there is little incentive to change behaviour if it seems completely out of reach to be the best student at reducing energy consumption and winning the prize. From the information and norms provided during the trial, students were able to assess their chances of coming first. Hence, we might be able to explain the pattern seen in Fig. 3 by some students initially trying to win the final prize but after week 6 realising that it is out of reach to them, thereby abandoning their previous efforts. We may call such students the marginal group.

To explore this potential explanation, we define this marginal group as follows: a student who is **not** in the bottom 20 in week 5 and neither in the top 5 in week 6. This will therefore include students who, in the light of week 5 comparison, would have a chance to win the prize competition – they are not those with the highest energy consumption, ranked the worst – but who, by week 6, realise they are unlikely to be the winner of the prize –they are not in the top 5 consuming the least energy.

The precise thresholds are of course arbitrary and we have explored various alternatives – some reported in the Appendix D – which show that our main results are robust to variety of different thresholds. Table 2 (in rows 5 and 6) reports average energy consumption and growth trends pre treatment for the two groups. In terms of consumption levels, non-marginals have on average significantly lower energy consumption: 21kWh as opposed to 40. However, in terms of growth trends – which is what we rely on for identification of effects – they are statistically not distinguishable. In Fig. 4, we report average trends over our 10-week sample for these two groups. Consider first the top row of the diagrams. They compare the two treatment groups; i.e. information treatment only vs. information and competition/prize treatment. We see that in weeks 5 and 6 the two groups trend similarly. However, in week 7, we observe the opening of a gap for the marginal group: energy consumption for the information treated students continues to decline whereas the competition treated students increase their energy consumption on average. In the non-marginal group no such gap opens up.

In the figures in the second row, we compare the competition treated students with the control group that received no treatment at all. For the marginal group we see that a gap opens up in weeks 5 and 6 but that the gap becomes smaller after week 6. For the non-marginal group we do not find any such pattern.

In Table 5, we report regressions corresponding to the four diagrams of Fig. 4. We regress $\tilde{\Delta} e_W$ on a treatment period 2 dummy and on interactions between the period 2 dummy and each group. In column 1, we only include in the sample the marginal group and excluding control group students. Hence, the coefficients on the interaction dummies, ‘Competition X Period’ correspond to the average difference in energy growth between the two treatment groups in each period. As seen visually in Fig. 4, the average gap is small and indeed negative in period 1 but not significant: the average reduction for competition treated students

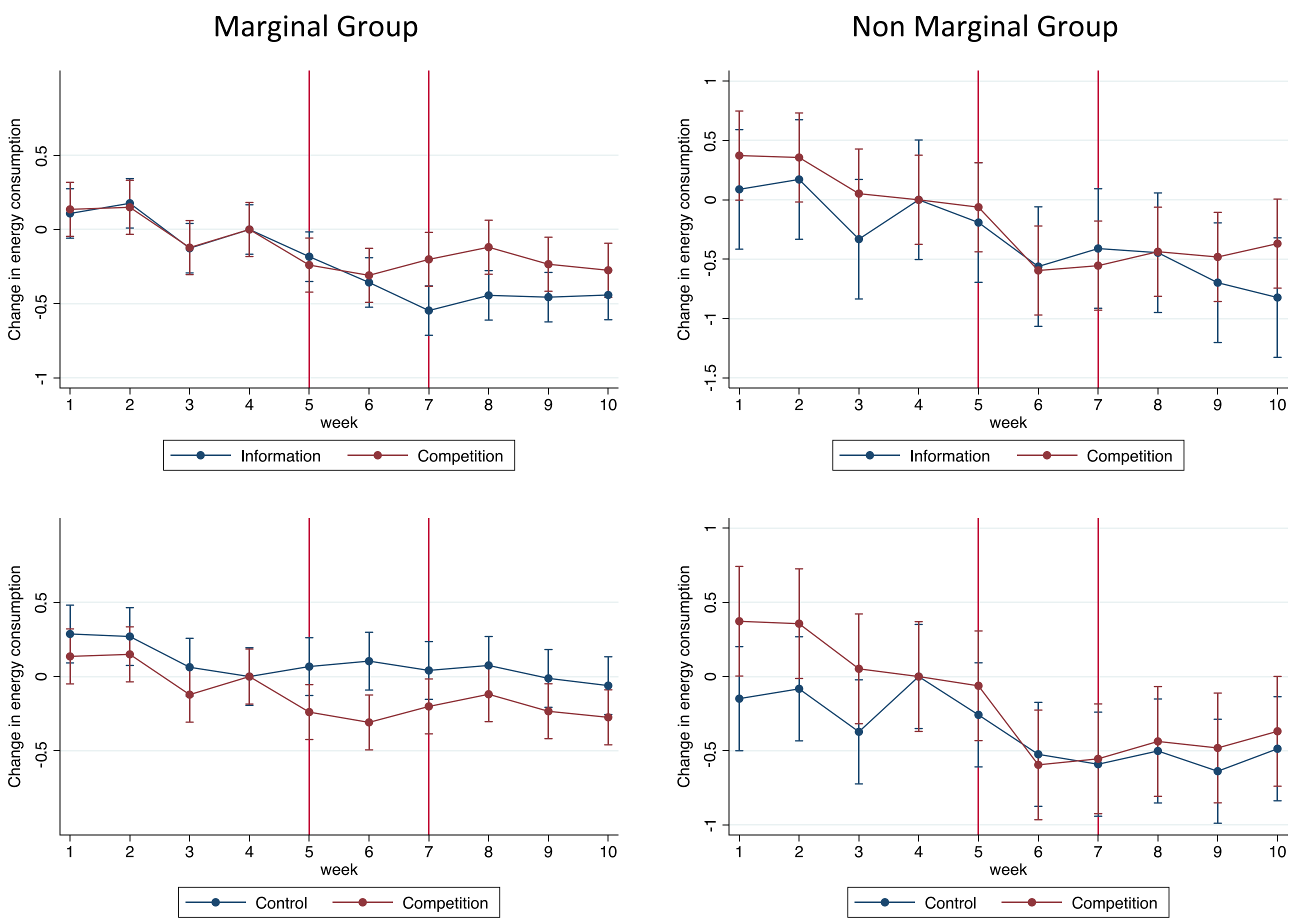

Fig. 4. Distinguishing between different treatments for the Marginal and Non Marginal group of treated students.
Notes: these figures report average trends for change in energy consumption over our 10-week sample for marginal and non-marginal groups. Marginal group is defined as students who are not in the bottom 20 in week 5 and neither in the top 5 in week 6. In the top row, two treatment groups are compared (Information treatment only vs. information and competition/prize treatment). In second row, the competition treated students are compared to the control group that received no treatment at all.

Table 5
Marginal vs non marginal consumers.

	(1)	(2)	(3)	(4)
	Competition vs Info		Competition vs Control	
Dependent Variables	Marginal	Non marginal	Marginal	Non marginal
Treatment Period 2	−0.202* (0.110)	−0.218 (0.261)	−0.075 (0.141)	−0.163 (0.166)
Competition X Period 1 (Mean difference in Period 1)	−0.004 (0.098)	0.048 (0.149)	−0.360*** (0.121)	0.062 (0.180)
Competition X Period 2 (Mean difference in Period 2)	0.265** (0.125)	0.134 (0.346)	−0.218 (0.137)	0.094 (0.261)
Observations	276	84	240	114
Rooms	46	14	40	19
Rooms in Control Group	0	0	19	10
Rooms in Info Group	25	5	0	0
Rooms in Competition Group	21	9	21	9
R-squared	0.062	0.022	0.081	0.021

Notes: Dependent variables are computed as percentage changes relative to the last pre treatment week; i.e. $\frac{e_W - e_4}{0.5 \times (e_W + e_4)}$ where e_W denotes energy consumption in week w. Robust standard errors. Clusters at the level of individual rooms. *=significant at 10%, **=significant at 5%, ***=significant at 1%.

was 0.4% points higher than for information treated students. However, in treatment period 2 the average gap becomes a positive and significant 26% points.

In column 2, we restrict the sample to non-marginal students. In neither period is there a significant gap. In column 3, we include marginal students from treatment group 3 and marginal control group students. We see that, on average, competition treated students reduce their energy consumption by a significant 36% points more than students in the control group. However, this gap reduces to non-significant 21.8% points in period 2. Again, we cannot detect a significant gap in the non-marginal group (column 4).

Hence, both the graphical analysis and the regression analysis suggest that the dropping-off effect identified in Fig. 2 for the competition treated group is driven by students in the marginal group.

5. Conclusions and policy implications

Our societies are facing important challenges, such as climate change, that require a new low carbon energy system. Delivering such a solution, whilst addressing fuel poverty and ensuring energy security, raises many issues on different fronts. A smart grid, integrating network and demand control technologies, will need to ensure the balancing of supply and demand. Another key element will be the improvement of energy efficiency. Policies such as the rollout of smart meters rely on the hypothesis that considerable efficiency improvements can be achieved through providing consumers with more information about both their own energy consumption as well as that of others. In this paper, we explore these questions in the unique setting of a student hall with a large number of identical and smart metered studio flats.

As we described above, various previous studies have established that feedback provision can have sustained impact on energy consumption. The main contribution of this paper is that we can examine the effects of feedback in a setting where the treated consumers do not have to pay for the energy they consume. We find a strong and significant impact of providing residents with feedback on both their own consumption and how it stands relative to other consumers: on average total energy consumption reduces by more than 20% relative to a control group that receives no information. This suggests that such effects are – at least in part – driven by intrinsic motivations – e.g. the willingness to reduce pollution – and the desire to comply with norms rather than by external rewards from reduced costs. Awareness seems to be key for energy management even with no specific price motives, corroborating similar findings in the literature regarding the use of social norms.

For a subset of our sample population we combine the feedback treatment with a prize for the resident with the lowest energy consumption. Hence, we re-introduce an external reward. Interestingly, for this group we find that the treatment effect dissipates after two weeks. This could imply that external incentives, far from re-enforcing intrinsic motivation could cancel it out and be less effective overall. This shows how important the design of such interventions can be. These results can be useful to energy market operators who need to carefully plan their approach towards energy demand management through various instruments such as the inclusion of norms with prize competition. By understanding individual characteristics and behavioural responses, they will be in a better position to estimate the energy elasticity of demand. This means they can meet their environmental objectives and target customers in a more efficient way.

The results of this paper are also an interesting contribution to the existing evidence. Even though the opportunity to track their energy consumption proved to be valuable to our participants in reducing their consumption and hence improving energy efficiency, we highlight the delicate relationship between the use of norms and behavioural change in energy demand. Other studies have similarly observed that once households realise their energy saving potential they might become frustrated and demotivated (Hargreaves et al., 2013). Besides, our RCT design benefited from and its results reinforce those of existing studies, including highlights of the importance of feedback (Allcott and Rogers, 2014) or the persistence of energy consumption reductions (Dolan and Metcalfe, 2015).

Our study also has a number of limitations. While the context of a student residence provides for highly comparable treatment and control units and a well-developed metering infrastructure, it raises questions regarding external validity. Our prior would be that 'real' households, with a higher and more diverse usage of energy, also provide more opportunities for saving energy. Indeed, students in our study are equipped with basic appliances and a self-adjustable thermostat, such that the variation in their energy consumption is much more limited than a typical household. We could expect to find stronger effects in a 'real' household context. On the other hand, students provide a sample that is more highly educated and driven by intrinsic incentives than the rest of the population, which might imply that effects in such a context would be more muted. Ultimately, the temporal dimension of the experiment is ten weeks thus limiting the identification of potential seasonality in energy demand elasticity. We are currently working with several energy retailers and service companies to conduct similar experiments in other settings, which should provide clarity on these questions in the near future.

Finally, the finding of a weaker effect when providing what appears to be more high-powered incentives, i.e. prize competition, is a surprising and unexpected result that deserves further attention. Can this effect be replicated in other settings? Is it contingent on providing external rewards via a competition where the winner takes it all, or would it also occur with more balanced rewards? These lines of inquiry are left for further research.

Importantly, our findings inform policy through the insights they bring on energy management and efficiency. The smart meter rollout that is being required by EU and UK policy will be used in the future to give all consumers a real-time feedback on their energy consumption. Understanding the optimal amount, content and frequency of information feedback, as well as its combination with other financial incentives and prizes, is a necessary input in the design of smart meter interfaces that are a key element of the smart grid needed to face society's challenges. The results of this paper points towards the fact that incentives, norms and feedback, if used in a well-thought combination, reduce overall consumption. It is clear that in the area of residential energy use, implementing system monitoring and intelligent control require a strong knowledge of consumer behaviour.

Acknowledgements

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Appendix A. Survey communications

A1: Survey questionnaire

Energy Consumption and Perceptions

Thinking about your energy use, please answer the following questions by checking the box that corresponds to your opinion.

Questionnaire Number

SECTION 1: DEMOGRAPHIC INFORMATION

1 **Institution:** ……………………………………………………………………………………

2 **Room no:** ……………………………………………………………………………………

3 **Name:** ……………………………………………………………………………………

4 **Gender:** Male ☐ Female ☐

5 **Nationality:** ……………………………………………………………………………………

6 **What is your annual budget:**

1	Below £10,000	
2	£10,000 - £19,999	
3	£20,000 - £29,999	
4	£30,000 - £39,999	
5	Above £40,000	

7 **What is your main source of funding:**

1	Self-funded (e.g. savings or part-time job)	
2	Student loans	
3	Scholarship	
4	Other	

8 **In which city and country were you living before moving to Wood Lane Studios:**

……………………………………………………………………………………

9 **For how long did you live in your previous address (before moving to Wood Lane Studios):**

1	1 year or less	
2	More than 1 year and less than 5 years	
3	More than 5 years	

10 **In your previous address (before moving to Wood Lane Studios) did you live:**

1	By yourself	
2	With non-family members	
3	With parents or other family members	

11 **What is the highest education level of your parents (if you have parents with differing education levels please state the highest among them):**

1	Less than high school	
2	High school / GED	
3	Some college	
4	College degree	
5	Masters degree	
6	Doctoral degree	

SECTION 2: HISTORICAL ENERGY USE

12 **In your previous address (before moving to Wood Lane Studios) how did you pay for electricity:**

1	Utility bills included in the rent	
2	Individual meter with flat electricity tariff	
3	Individual meter with top-up	
4	Other payment schemes	
5	I did not pay for electricity	
6	My parents paid for electricity	

13 **Would you say the cost of electricity at your previous address (before moving to Wood Lane Studios) was:**

1	Cheap	
2	Fair	
3	Expensive	
4	I don't know	

14 **How much did you pay on average per month for electricity at your previous address:**

1	£0 - £20	
2	£20 - £50	
3	£50 - £100	
4	£100 or more	

SECTION 3: ENERGY BEHAVIOUR AND PERCEPTIONS

15 **Do you feel you know how you can save energy:**

1	Yes	
2	No	

16 **Do you switch off the light every time you leave a room**

1	Yes	
2	No	

17 **Which of the following appliances do you have in your studio at Wood Lane [select all that apply]:**

1	Electric heater	
2	TV or computer monitor	
3	Laptop	
4	Desktop computer	
5	Sound system	
6	Hair dryer	
7	Iron	
8	Kettle	
9	Toaster	
10	None of the above	
11	Other (please specify)	

18 **Do you have a habit of turning off appliances when you do not use them [rate on a scale of 1 (never) to 5 (always)]:**

1	2	3	4	5

19 **Do you often leave your computer / laptop on standby while not using it:**

1	Always	
2	When I'm working on something important	
3	Every now and then	
4	Never	

20 **Do you think it is important to save energy:**

1	Yes	
2	No	
3	I don't know	

21 **If yes, why: [Rank the following reasons from 1 (most important) to 4 (least important)]:**

1	Saving money	
2	Energy security	
3	Climate change	
4	Other (please specify)	

22 **When do you use the most energy:**

1	Morning	
2	Afternoon	
3	Evening	
4	Night	
5	I don't know	

SECTION 4: EXPERIMENT CONTAMINATION CHECK

23 **How many of the other residents at Wood Lane Studios do you know:**

1	None	
2	Less than 5	
3	Between 5 and 10	
4	Between 11 and 20	
5	More than 20	

24 **How many of the other residents at Wood Lane Studios do you interact with on a regular basis:**

1	None	
2	Less than 5	
3	Between 5 and 10	
4	Between 11 and 20	
5	More than 20	

A2: Survey launch letter

Dear Student,

We would greatly appreciate your input in an academic research study being conducted at the Grantham Institute for Climate Change and Business School at Imperial College. The main aim of the study is to understand people's awareness of energy consumption in our community. **It's a short questionnaire and for useful results your response is very important.**

By filling in the survey you will be entered in a draw to win a £50 Amazon voucher*! The deadline for entering the draw has been extended to the 9th of June at midnight.

Follow this link to the Survey:

${l://SurveyLink? d=Take the Survey}.

Or copy and paste the URL below into your Internet browser: ${l://SurveyURL}.

We very much appreciate your help.

Best regards,

Dr. Mirabelle Muuls.

*Note: The draw for the £50 Amazon voucher will take place on the 3rd of June and the winner will be notified by email. The voucher will be valid for 11 months and redeemable on www.amazon.co.uk.

Follow the link to opt out of future emails:

${l://OptOutLink? d=Click here to unsubscribe}.

Appendix B. Energy consumption communications

B1: Singular energy saving report (control)

Standby to shutdown!

- When you're away or asleep, switch your laptop or computer off. It's better for the device and your energy bill too.
- Unplug appliances when they're not in use. Even chargers continue to use electricity when they aren't charging.

Switch off and save!

- The lights in your home contribute 20% to your electricity use. If you're out or in another room - kill the lights.
- Remember to turn off plugs when they're not in use!
- Shrink your bill not your clothes! Washing your clothes at a lower temperature will make them both clean and more energy friendly.

Go easy on the heating!

- Now that summer is here you can turn down the heating! Just one degree uses much less electricity and you won't notice the difference. And make sure to turn down the thermostat when you open the windows!
- Turning off the heating at night and when you're away can save £££...

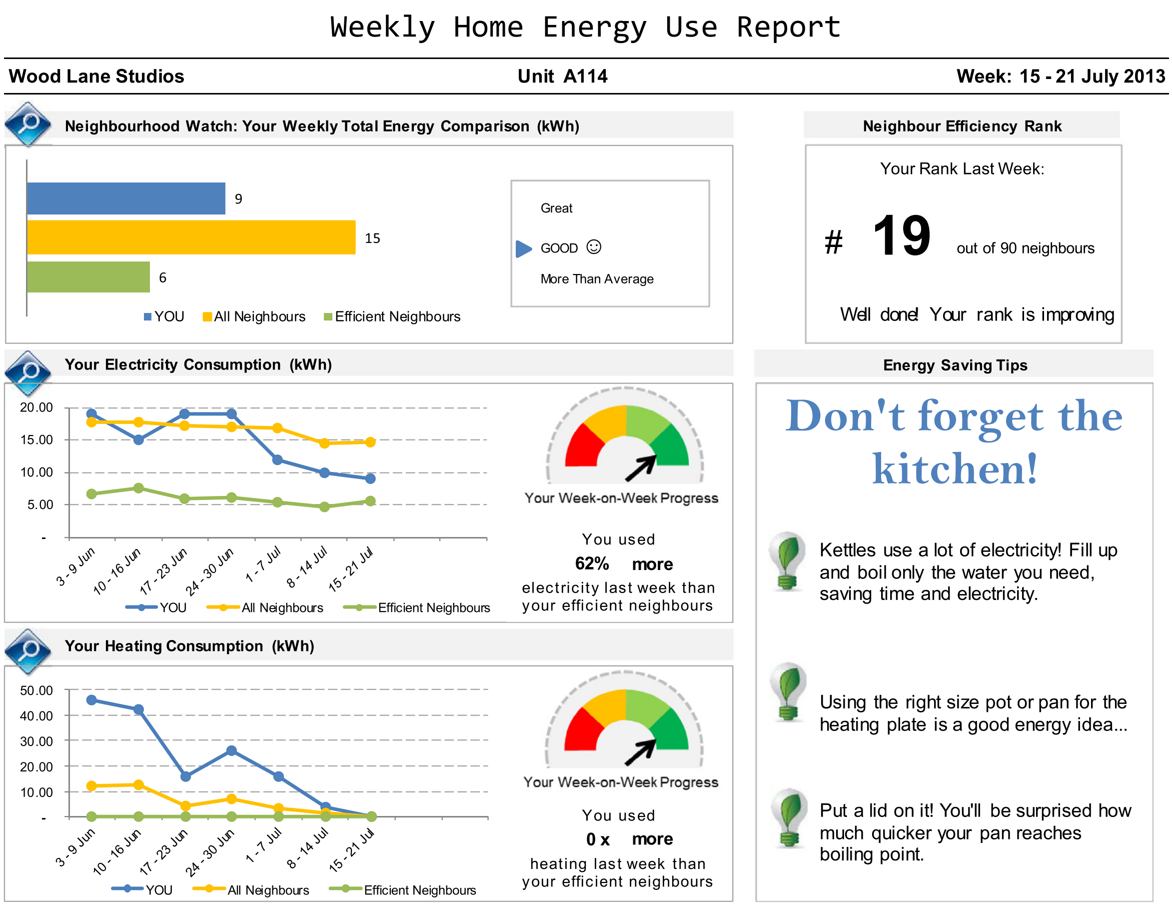
Every drop counts!

- Showering at a lower temperature during summertime will save energy and leave you feeling as cool as a cucumber.
- Report water leaks or dripping taps. Leaving them could pour 5,500 litres of water down the drain a year.
- Turning off the tap while you're shaving or brushing your teeth saves more than six litres of water a minute!

Don't forget the kitchen!

- Kettles use a lot of electricity! Fill up and boil only the water you need, saving time and electricity.
- Using the right size pot or pan for the heating plate is a good energy idea.
- Put a lid on it! You'll be surprised how much quicker your pan reaches boiling point.

B2: Weekly energy report (experiment)



B3: Qualitative feedback communication

Dear Resident,

As you are no doubt aware, you have been receiving a personalised Home Energy Reports weekly for the past few weeks. This pilot project has now come to an end and we would like to thank you for your participation.

We would also like to ask you a few short questions about the study. Replying should only take a few minutes of your time, and will be extremely valuable in improving the study going forward:)

1) Did you understand the report? Please explain any aspects that were confusing or conversely that you felt were effective.
2) Did you find the feedback report valuable?
3) Would you like to receive a report like this in future? If so, how often?
4) Were you motivated to decrease your energy consumption when receiving the report? Why?
5) Did the study result in a change in your energy consumption behaviour? In what way? Please explain any steps or actions you took that were different after receiving the weekly email.
6) Please rank how useful you found the following parts of the report: *(1= completely useless; 2= useless; 3= I'm not sure; 4= useful; 5= very useful)*

i) Electricity and heating consumption graphs	ii) Energy saving tips
iii) Neighbour's energy consumption	iv) Weekly rank

Please rank your change in the following: (1= significantly worse; 2= worse; 3= no change; 4= better; 5= significantly better).

i) Knowledge about saving energy	ii) Attitude towards saving energy
iii) Intention to save energy	iv) Ability to save energy

If there is anything else you would like to tell us about, or feedback on please feel free to do so!.

Thank you again.

Kind regards, ICL Energy Team.

Appendix C. Summary of survey descriptive statistics

see: Tables C1 and C2.

A summary of the various descriptive elements of the survey, including the percentage where relevant, mean score, and standard deviation for the group in total as well as per experimental group are found below in Table 1. Despite some variation in demographic variables (such as gender and nationality) between groups, the summary shows that an even spread of question response was achieved. We conclude that the randomisation of groups based on demographic and other independent variables have been effective since the results of each group are closely aligned with one another as well as the group as a whole.

Table C1
Summary of survey descriptive statistics by total and experimental group.

Variable	Coding	All	Group 1	Group 2	Group 3
Demographic information					
V1: Institution	1 Science, technology and medicine 2 Business, economics and finance 3 Other (humanities, art, law)	1: 81% 2: 14% 3: 5%	1: 87% 2: 13%	1: 71% 2: 14% 3: 14%	1: 85% 2: 15%
V2: Gender	1 Male 2 Female	45% male	67% male	29% male	38% male
V3: Nationality	1 Europe 2 United Kingdom 3 North America 4 Caribbean 5 Asia 6 India 7 Middle East 8 Africa	1: 31% 2: 19% 3:2% 4: 5% 5: 24% 6: 10% 7: 5% 8: 5%	1: 53% 2: 20% 5: 20% 8: 7%	1: 14% 2: 14% 4: 7% 5: 36% 6: 7% 7: 14% 8: 7%	1: 23% 2: 23% 3: 8% 4: 8% 5: 15% 6: 23%
V4: Annual budget	1 Below £10k 2£10k–£19,999 3£20 k–£29,999 4£30 k–£39,999 5 Above £40k	2.10 (1.11)	2.12 (1.11)	2.08 (1.13)	2.10 (1.14)
V7: Funding source	1 Self-funded 2 Student loans 3 Scholarship 4 Other	2.21 (1.26)	2.22 (1.28)	2.32 (1.28)	2.28 (1.26)
V9: Residence period	1 1 year or less 2 More than 1 year and less than 5 3 More than 5 years	2.02 (.86)	2.00 (.86)	2.00 (.86)	2.08 (.85)
V10: Living situation	1 By yourself 2 With non-family members 3 With parents or family members	2.29 (.76)	2.27 (.77)	2.32 (.76)	2.30 (.78)
V11: Parental education level	1 Less than high school 2 High school / GED 3 Some college 4 College degree 5 Master's degree 6 Doctoral degree	4.55 (1.18)	4.56 (1.19)	4.55 (1.23)	4.58 (1.18)
V12: Energy payment method	1 Utility bills included in the rent 2 Individual meter - flat tariff 3 Individual meter with top-up 4 Other payment schemes 5 I did not pay for electricity 6 My parents paid for electricity	3.57 (2.09)	3.51 (2.09)	3.61 (2.13)	3.68 (2.09)
Historical energy use					
V13: Previous energy cost	1 Cheap 2Fair 3 Expensive 4 I do not know	2.48 (.98)	2.44 (.96)	2.47 (.99)	2.53 (.97)
V14: Avg. energy bill	1£0–£20 2£20–£50 3£50–£100 4£100+	2.05 (.96)	2.05 (.97)	2.09 (1.00)	2.08 (.97)
Energy behaviour and perceptions					
V15: Know how to save	1 Yes 2 No	1.10 (.30)	1.10 (.30)	1.08 (.27)	1.10 (.30)
V16: Switch off light	1 Yes 2 No	1.17 (.37)	1.15 (.35)	1.16 (.36)	1.18 (.38)
V18: Turn off appliances	1 Always - 5 Never	3.98 (1.06)	4.02 (1.02)	4.08 (1.04)	3.95 (1.07)
V19: Leave PC on standby	1 Always 2 Working on something important 3 Every now and then 4 Never	2.31 (1.03)	2.32 (1.05)	2.32 (1.05)	2.30 (1.05)

Table C1 (*continued*)

Variable	Coding	All	Group 1	Group 2	Group 3
Demographic information					
V20: Important to save energy	1 Yes 2 No	1.10 (.43)	1.10 (.43)	1.11 (.45)	1.10 (.44)
V22: Usage pattern	1 Morning 2 Afternoon 3 Evening 4 Night 5 I do not know	3.50 (.82)	3.51 (.83)	3.50 (.82)	3.50 (.84)
Experimental check					
V23: Resident familiarity	1 None 2 Less than 5 3 5 – 10 4 11–20 5 20+	3.60 (1.16)	3.56 (1.15)	3.53 (1.19)	3.60 (1.18)
V24: Resident interaction	1 None 2 Less than 5 3 5 – 10 4 11–20 5 20+	2.57 (1.00)	2.56 (1.01)	2.61 (1.04)	2.60 (1.02)

Notes: % indicates the split between categories. Standard deviations appear in parentheses below means. Sample size (N): All =42; Group 1=15; Group 2=14; Group 3=13

Table C2
Typical energy usage for household appliances. (Source: Adapted from US DoE, 2012; Warwickshire Switch It Off Campaign, n.d.)

Appliance	Maximum power (W)	Typical standby (W)
Microwave oven	750–1100	2
Refrigerator	90–120	n/a
Laptop	50	–
Kettle	900–1200	–
Hair dryer / straightener	1200–1875	–
Toaster	800–1400	–
Electric heater	750–1500	400
Monitor	150	30
Iron	1000–1800	n/a

Appendix D. Appendix D. Marginal vs non marginal groups

see: Table D1.
see: Figs. D1 and D2.

Table D1
Electricity and heat energy consumption.

		Electricity consumption pre treatment in kWh		Heat energy consumption pre treatment in kWh	
		Average	Average growth	Average	Average growth
Treatment groups	Control	18.198	−0.037	6.310	−0.123
	All Treated	17.329	0.009	10.350	−0.300
	Information	17.167	0.022	12.200*	−0.230
	Competition	17.492	−0.004	8.500**	−0.387
Position relative to peers	Marginal	23.958	0.009	16.323	−0.139
	Non Marginal	15.269***	−0.011	6.342***	−0.330

Notes: *=significant at 10%, **=significant at 5%, ***=significant at 1%.

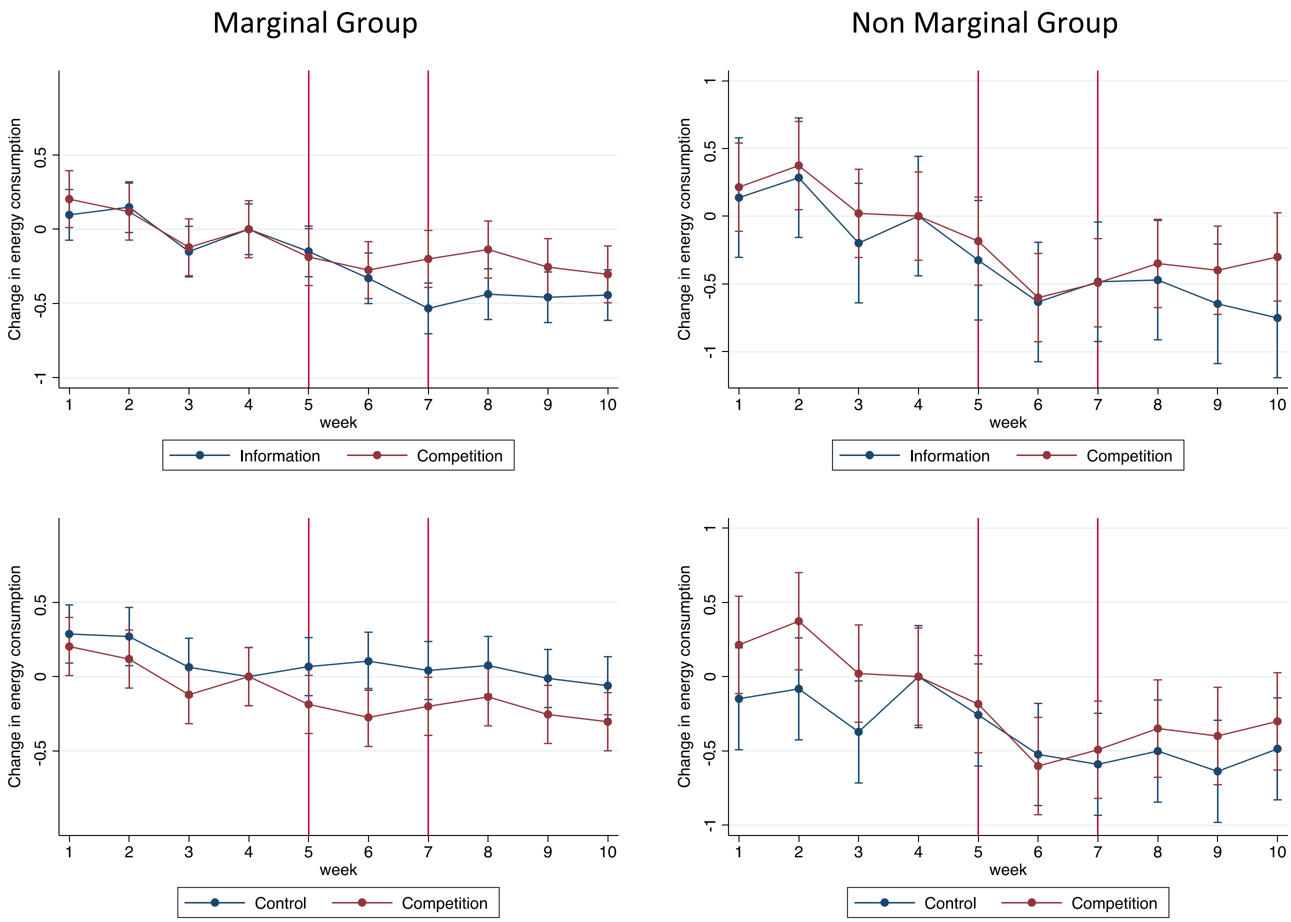


Fig. D1. Marginal vs Non Marginal group – Top 10 threshold.
Notes: As Fig. 4 but marginal group only includes students that are ranked 10 or lower in week 6 (rather than ranked 5 or lower).

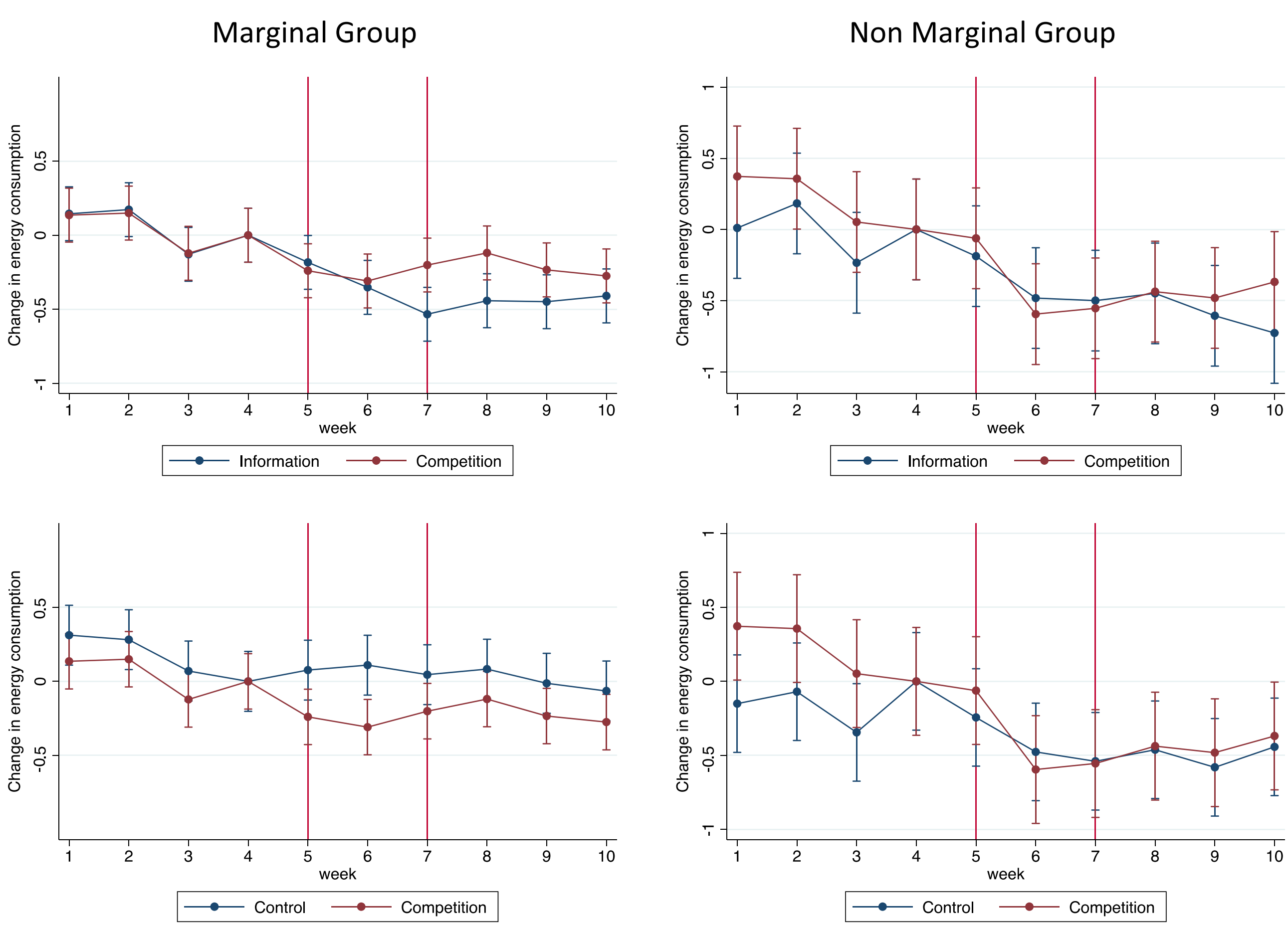


Fig. D2. Marginal vs Non Marginal group – Bottom 25 threshold.
Notes: As Fig. 4 but marginal group excludes bottom 25 (rather than bottom 20).

References

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T., 2005. A review of intervention studies aimed at household energy conservation. J. Environ. Psychol. 25 (1), 273–291.
Akerlof, G.A., 1982. Labor contracts as partial gift exchange. Q. J. Econ., 543–569.
Allcott, H., 2011. Social norms and energy conservation. J. Public Econ. 95 (9), 1082–1095.
Allcott, H., Rogers, T., 2014. The short-run and long-run effects of behavioral interventions: experimental evidence from energy conservation. Am. Econ. Rev. 104 (10), 3003–3037.
Arrow, K., Dasgupta, P., Goulder, L., 2004. Are we consuming too much? J. Econ. Perspect. 18, 147–172.
Ayres, I., Raseman, S., Shih, A., 2013. Evidence from two large field experiments that peer comparison feedback can reduce residential energy usage. J. Law Econ. Organ. 29 (5), 992–1022.
Ball, S.B., Eckel, C.C., Grossman, P.J., Zame, W., 2001. Status in markets. Q. J. Econ. 116, 161–188.
Barnicoat, G., Danson, M., 2015. The ageing population and smart metering: a field study of householders' attitudes and behaviours towards energy use in Scotland. Energy Res. Social. Sci. 9, 107–115.
Bault, N., Coricelli, G., Rustichini, A., 2008. Interdependent utilities: how social ranking affects choice behavior. PLoS One 3 (10), e3477.
Bénabou, R., Tirole, J., 2011. Identity, morals, and taboos: Beliefs as assets. Q. J. Econ. 126 (2), 805–855.
Biel, A., Thøgersen, J., 2007. Activation of social norms in social dilemmas: a review of the evidence and reflections on the implications for environmental behaviour. J. Econ. Psychol. 28 (1), 93–112.
Breukers, S.C., Heiskanen, E., Brohmann, B., Mourik, R.M., Feenstra, C.F.J., 2011. Connecting research to practice to improve energy demand-side management (DSM). Energy 36 (4), 2176–2185.
Buchanan, K., Russo, R., Anderson, B., 2014. Feeding back about eco-feedback: how do consumers use and respond to energy monitors? Energy Policy 73, 138–146.
Buchanan, K., Russo, R., Anderson, B., 2015. The question of energy reduction: the problem (s) with feedback. Energy Policy 77, 89–96.
Costa, D.L., Kahn, M.E., 2013. Energy conservation “nudges” and environmentalist ideology: evidence from a randomized residential electricity field experiment. J. Eur. Econ. Assoc. 11 (3), 680–702.
Davis, F.D., Bagozzi, R.P., Warshaw, P.R., 1989. User acceptance of computer technology: a comparison of two theoretical models. Manag. Sci. 35 (8), 982–1003.
Deci, E.L., 1971. Effects of externally mediated rewards on intrinsic motivation. J. Pers. Social. Psychol. 18 (1), 105.
Deci, E.L., Betley, G., Kahle, J., Abrams, L., Porac, J., 1981. When trying to win competition and intrinsic motivation. Pers. Social. Psychol. Bull. 7 (1), 79–83.
Deci, E.L., Koestner, R., Ryan, R.M., 1999. A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. Psychol. Bull. 125 (6), 627.
Deci, E.L., Ryan, R.M., 1985. Intrinsic Motivation and Self-determination in Human Behavior. Plenum, New York.
Department for Energy & Climate (DECC), Cabinet Office, 2015a. Energy Consumption in the UK. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/337452/ecuk_chapter_1_overall_factsheet.pdf.
Department for Energy & Climate (DECC), Cabinet Office, 2015b. 2013 UK Greenhouse Gas Emissions, Final Figures. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407432/20150203_2013_Final_Emissions_statistics.pdf.
Dolan, P., Metcalfe, R.D., 2015. Neighbors, knowledge, and nuggets: two natural field experiments on the role of incentives on energy conservation. CEP Discussion Papers, CEPDP1222. Centre for Economic Performance, London School of Economics and Political Science, London. (Available at) SSRN 2589269.
Druckman, J.N., Kam, C.D., 2011. Students as experimental participants: a defense of the ‘narrow data base’. In: Druckman, James H., Green, Donald P., Kuklinski, James H., Lupia, Arthur (Eds.), Cambridge Handbook of Experimental Political Science. Cambridge University Press, New York.
EPA, 2015. Inventory of US greenhouse gas emissions and sinks: 1990–2013. http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf.
Eurostat, 2013. Total population having completed at least upper secondary education.
Faruqui, A., George, S., 2005. Quantifying customer response to dynamic pricing. Electr. J. 18 (4), 53–63.
Faruqui, A., Sergici, S., Sharif, A., 2010. The impact of informational feedback on energy consumption—a survey of the experimental evidence. Energy 35 (4), 1598–1608.
Faruqui, A., Sergici, S., 2014. Arcturus: An International Repository of Evidence on Dynamic Pricing. In Smart Grid Applications and Developments 59–74. Springer, London.
Fischer, C., 2008. Feedback on household electricity consumption: a tool for saving energy? Energy Effic. 1 (1), 79–104.
Frederiks, E.R., Stenner, K., Hobman, E.V., 2015. Household energy use: applying behavioural economics to understand consumer decision-making and behaviour. Renew. Sustain. Energy Rev. 41, 1385–1394.
Fuster, A., Meier, S., 2010. Another hidden cost of incentives: the detrimental effect on norm enforcement. Manag. Sci. 56 (1), 57–70.
Gardner, G.T., Stern, P.C., 2002. Environmental Problems and Human Behavior. Pearson, Boston 2002.
Hargreaves, T., Nye, M., Burgess, J., 2013. Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy Policy 52, 126–134.
Harries, T., Rettie, R., Studley, M., Burchell, K., Chambers, S., 2013. Is social norms marketing effective? A case study in domestic electricity consumption. Eur. J. Mark. 47 (9), 1458–1475.
Hori, S., Kondo, K., Nogata, D., Ben, H., 2013. The determinants of household energy-saving behavior: survey and comparison in five major Asian cities. Energy Policy 52, 354–362.
Jones, S.F., 1984. The Economics of Conformism. Blackwell, Oxford.
Kempton, W., Layne, L.L., 1994. The consumer's energy analysis environment. Energy Policy 22 (10), 857–866.
Khazzoom, J.D., 1980. Economic implications of mandated efficiency in standards for household appliances. Energy J. 1 (4), 21–40.
Kohn, A., 1986. No Contest: The Case Against Competition. Houghton Mifflin, Boston.
Lepper, M.R., Greene, D., Nisbett, R.E., 1973. Undermining children's intrinsic interest with extrinsic reward: a test of the “overjustification” hypothesis. J. Pers. Social. Psychol. 28 (1), 129.
Lopes, M.A.R., Antunes, C.H., Martins, N., 2012. Energy behaviours as promoters of energy efficiency: a 21st century review. Renew. Sustain. Energy Rev. 16 (6), 4095–4104.
Luttmer, E.F.P., 2005. Neighbors as negatives: relative earnings and well-being. Q. J. Econ. 120 (3), 963–1002.
Lutzenhiser, L., 1992. A cultural model of household energy consumption. Energy 17 (1), 47–60.
McMichael, M., Shipworth, D., 2013. The value of social networks in the diffusion of energy-efficiency innovations in UK households. Energy Policy 53 (1), 159–168.
Nolan, J.M., Schultz, P.W., Cialdini, R.B., Goldstein, N.J., Griskevicius, V., 2008. Normative social influence is underdetected. Pers. Social. Psychol. Bull. 34 (7), 913–923.
Okuno-Fujiwara, A., Postlewaite, A., 1995. Social norms in random matching games. Games Econ. Behav. 9, 79–109.
Read, D., 2004. Utility theory from Jeremy Bentham to Daniel Kahneman. London School of Economics working paper No. LSE OR 04-64. London: London School of Economics.
Reeve, J., Deci, E.L., 1996. Elements of the competitive situation that affect intrinsic motivation. Pers. Social. Psychol. Bull. 22, 24–33.
Ryan, R.M., Deci, E.L., 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. Am. Psychol. 55 (1), 68.
Saunders, H.D., 1992. The Khazzoom-Brookes postulate and neoclassical growth. Energy J., 131–148.
Schultz, P.W., Nolan, J.M., Cialdini, R.B., Goldstein, N.J., Griskevicius, V., 2007. The constructive, destructive, and reconstructive power of social norms. Psychol. Sci. 18 (5), 429–434.
Szajna, B., 1996. Empirical evaluation of the revised technology acceptance model. Manag. Sci. 42 (1), 85–92.
Thaler, R., Sunstein, C., 2008. Nudge: The Gentle Power of Choice Architecture. Yale, New Haven, Conn.
Wilson, C., Dowlatabadi, H., 2007. Models of decision making and residential energy use. Annu. Rev. Environ. Resour. 32, 169–203.