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Behavioral opportunities for energy savings in office buildings: a London field experiment

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Experimental work sponsored by Carbon Smart

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If we examine a man alone, without his relation to everything around him, his every action appears free to us. But if we see at least some relation to what is around him, if we see his connection with anything whatever – with the man who is talking to him, with the book he is reading, with the work he is doing, even with the air that surrounds him, even with the light that falls on things around him – we see that each of these conditions has an influence on him and guides at least one side of his activity.

- Leo Tolstoy, War and Peace (1869)

Abstract

Barring a transformational breakthrough in the near future in investment for and the use of non-fossil fuel energy sources, energy efficiency serves as a crucial strategy for major progress to be made in slowing the emission of greenhouse gases and lessening the scale of the impacts of climate change. Office buildings are a major and growing source of energy consumption and carbon dioxide (CO_2) emissions. While there are vast opportunities to reduce energy consumption in office buildings through energy efficient technologies and materials, these opportunities possess financial costs, physical disruptions and other impacts that at present people may not be willing to bear. Behavior change, on the other hand, also has the potential to reduce energy consumption in office buildings yet possesses just a fraction of these costs and can be adopted without delay.

In order to contribute to needs in the emerging field of research on the role of behavior change in office buildings to reduce energy use and related greenhouse gas emissions, a controlled field experiment including about 1,100 participants was conducted from July to August 2013 in five organizations across four office buildings in London, UK. The aim of the field experiment was to evaluate the effectiveness and 'stickiness' of behavior change interventions in private, public, and university office building settings that facilitate new expectations among employees – i.e. workplace norms – and therein modify the individual decision making context. The specific objective involved in the experiment was to increase the number of computer monitors turned off by employees during non-working hours. The change in behavior was therefore – in the literal sense – within an arm's reach of employees: pressing the power button on monitors. The behavioral intervention sought to modify the choice context by creating new expectations and norms through invoking either *public commitment* or *social comparison*. Data was collected in the form of observational (proportion) data from on-site visits of the number of monitors left on/turned off during non-working hours and in the form of electricity meter readings.

The results of the experiment suggest that the facilitation of new expectations and workplace norms among employees significantly increases the adoption of energy saving behavior in office buildings. To evaluate the observational data results, a quasi-binomial generalized linear model was used and demonstrated that the behavior change intervention led to a statistically significant increase in the monitors turned off during non-working hours. Public commitment and social comparison were equally effective in facilitating behavior change. Differences in the impacts of the intervention across private, public, and university buildings as well as within organizations were insignificant. To evaluate the electricity meter readings, a general linear model was used and as expected – due to the relatively small amount of electricity consumed by computer monitors – the behavioral intervention did not significantly affect overall building electricity use. Even so, the meter readings highlighted the significant role of energy efficient technologies and materials in reducing office building energy use during non-working hours.

The experiment provides insights that potentially can be applied to other and larger sources of energy use in office buildings. With a minimal set of conditions being met, small interventions can compel dramatic increases in energy saving behaviors. Yet despite the expanding knowledge readily available for reducing energy use in office buildings such as was provided by this experiment, it appears that organizations are largely failing to adopt energy saving measures, suggesting that the adoption of available voluntary measures has reached a plateau. Recommendations are offered for policymakers to spur the adoption of energy saving strategies in office buildings and thereby better capture the low-hanging fruit of mitigation opportunities to reduce the scale and scope of impacts expected from climate change.

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Introduction

Energy use in office buildings

According to the International Energy Agency's (IEA) *World Energy Outlook 2012*, it appears certain that fossil fuels will maintain their majority share of the world's energy production for at least the near future. From a global perspective it also is expected that the overall consumption of fossil fuels – and related greenhouse gas emissions – will continue to increase. Thus, barring a transformational breakthrough in investment for and the use of renewable energy sources, energy efficiency serves as a crucial strategy for major progress to be made in slowing the emission of greenhouse gases into the atmosphere. Sweeping and concerted efforts are required across all sectors to find opportunities – both great and small – to reduce greenhouse gas emissions in order to alleviate the scale of the impacts of climate change.

Office buildings are a major and growing source of energy consumption as well as carbon dioxide (CO_2) emissions. The US Department of Energy's (US DOE) *Buildings Energy Data Book* (2012) offers an illustration of the general trends and breakdown of commercial energy use and CO_2 emissions[1]: US commercial buildings increased their share of total US energy consumption from 13.5% in 1980 to 18.6% in 2010. Similarly, US DOE (2012) shows that the rise in energy consumption by US commercial buildings has been accompanied with an increase in CO_2 emissions from 653 million metric tons in 1980 to 1,036 million metric tons in 2010. The report also indicates the major end-uses for energy consumption in US commercial buildings, such as lighting (20%), space heating (16%), space cooling (15%), ventilation (9%), refrigeration (7%), water heating (4%), electronics (4%), computers (4%), and several others. The US DOE report *Energy Efficiency Trends in Residential and Commercial Buildings* (2008) further elaborates upon the trends in office buildings associated with energy use.

[1] See Appendix I for various figures that were compiled using data from the US DOE's *Buildings Energy Data Book*.

The office buildings sector "is the largest in the commercial sector in floor space and energy use in most countries" and energy use within the office buildings sector is dominated by heating, cooling, and lighting (Nguyen & Aiello, 2013: p. 247)[2]. Office buildings "range from small, single story multi-occupied buildings to the skyscrapers that form the skylines of all major cities" and "tend to be newer than other buildings" (World Business Council for Sustainable Development, 2009: p. 40). Because the commercial buildings sector and, more specifically, the office buildings sector hold a significant share of overall energy consumption both in the US and around the globe, a large source of opportunities is available to reduce global energy consumption and CO_2 emissions.

Numerous studies have been conducted assessing the potential for energy savings through investments in energy efficient technologies. For example, Farrell and Remes (2008) identify financially attractive and cost-effective energy efficiency investments – in appliances, lighting, heating/cooling, and water heating – that capture a 13.8 quadrillion British Thermal Unit (BTU) commercial building end-use opportunity across the developed and developing world. However, while technological opportunities are vast, they are not directly investigated further in this paper. Instead, the paper will focus on the potential for energy savings in office buildings through changes in individual behavior. The reason for this is that measures involving behavior change, unlike technological improvements, can reduce energy use and greenhouse gas emissions immediately *and* without significant financial costs. Even though the investments in new technologies and materials will be recouped over time – often within a couple years – through cost savings, these investments are made much less frequently than would be expected due to the discounting of future benefits so prevalent in a setting where short-term thinking leads to the tendency "to emphasize the initial cost rather than life cycle costs" (World Business Council for Sustainable Development, 2009: p. 42). Many companies now require "a one-and-a-half- to two-and-a-half-year payback" (Creyts et al, 2010: p. 6). Similarly, the payback periods associated with the upfront costs can take

[2] Two figures from Nguyen & Aiello (2013) are provided in Appendix I to show the impact of behavior on the energy consumption of buildings and the energy saving potential associated with heating/cooling, lighting, and plug loads.

longer than an organization may plan to or be certain it will stay in a given office. Moreover, organizations often choose to make investments for purposes other than cost reductions. If an organization does invest in cost reduction measures it may choose to lower costs other than those related to energy, since energy can be perceived as an 'invisible' cost and is often not a substantial cost for an organization to bear in relation to other costs, like salaries. Organizations may also hesitate to invest in new technologies due to the physical disruption, hassle, and general inconveniences associated with these projects. Time "is a resource that needs to be available in order to allow employees to take action" (Pellegrini-Masini & Leishman, 2011: p. 5412). Finally, it can also be the case that a company may not be in a position to make decisions about these types of investments, as is often the case in commercial buildings with multiple tenants.

Azar & Menassa (2012) point to the long-term impact of targeting the operations phase of commercial buildings: generally more than 80 percent of a commercial building's total energy consumption over its lifespan occurs during its operation phase, versus its materials and construction. Colmenar-Santos et al. (2013) also indicate that most of the energy consumed and CO_2 emitted by commercial buildings takes place during their lifetime operations. And energy use in the operations phase of a building will be affected by user behavior: for example, Pfafferott & Herkel (2007) find that variations in room temperature – and thus related energy use – "result mostly from *variations* in *use* of the offices" (p. 678). Hence because occupants play a central role in the way energy is consumed and the amount of energy consumed over the lifetime operations of a building, behavior change should be seen as a core strategy for reducing energy use and related CO_2 emissions.

Potential for energy savings through behavior change

While there are vast opportunities to reduce energy consumption in office buildings through energy efficient technologies and materials, these opportunities possess financial costs, physical disruptions and other impacts that at present people may not be willing to bear. Behavior change, on the other hand, also has the potential to reduce energy consumption yet possesses just a fraction of the costs of technological change. Moreover, there is an emerging interest in this topic, as suggested by the creation of the UK Government's Behavioural Insights Team and new behavior change services by environmentally focused consultancies. Dietz et al. (2009) offer evidence that behavior change measures can on their own lead to substantial reductions in energy use and related CO_2 emissions. Nguyen & Aiello (2013) suggest that careless energy consumption in office buildings "can add one-third to a building's designed energy performance, while conservation behavior can save [an additional] third" (p. 245). Hence, energy unaware behavior "uses twice as much energy as the minimum that can be achieved" (Nguyen & Aiello, 2013: p. 246).

Behavior change must be at the center of the overall strategy to reduce energy use and greenhouse gas emissions associated with office buildings. Behavioral interventions may also have a positive spillover effect related to energy efficient technologies: the behavior of individuals "can strengthen or undermine the effectiveness of technical measures which have been implemented with energy conservation and efficiency considerations in mind" (Lo et al, 2012-a: p. 227-228). The World Business Council for Sustainable Development (2009) endorses the need for behavior change – through workforce engagement, energy saving skills training, and an energy aware culture – within a set of mutually reinforcing strategies to reduce building energy consumption.

Behavior change experiment and expected results

Research on the role of behavior change in office buildings to reduce energy use and related greenhouse gas emissions is in its infancy. In order to address research needs and contribute to the wider literature on this subject, a controlled field experiment involving about 1,100 participants was conducted from July to August 2013 in five organizations across four office buildings in London, United Kingdom. The aim of the field experiment was to evaluate the effectiveness and 'stickiness' of behavior change interventions in private, public, and university office building settings that facilitate new expectations among employees – i.e. workplace norms – and therein modify the individual decision making context.

The specific objective of the behavior change intervention was to increase the number of computer monitors turned off overnight, during non-working hours. The experiment therein targeted a change in behavior that is – in the literal sense – within an arm's reach of employees: pressing the power button on monitors. In addition to showing employees how to achieve the desired behavior, the behavioral interventions sought to modify the choice context by creating new expectations through invoking either public commitment or social comparison. Data was collected in the form of observational (proportion) data from on-site visits of the number of monitors left on/turned off during non-working hours and in the form of electricity meter readings.

Based on the review of existing literature that is presented in the following section, there were several expected results from the experiment: It was expected that the behavioral intervention would compel a significant increase in the number of computer monitors being turned off during non-working hours and thus a significant change in behavior. Moreover, it was expected that behavioral change would endure over time ('stick') because they engaged staff by modifying the choice context through social mechanisms. However, because the targeted behavior change involved computer monitors – a relatively low source of energy use in office buildings – it was expected that there would *not* be significant reductions in overall energy use, related greenhouse gas emissions, or to the operating costs of participating office buildings.

Rather, the insights from this experiment were therein expected to demonstrate the critical role of modifying the office building choice context through new workplace norms in facilitating energy-saving behavior that endures over time. Such insights could then be more broadly incorporated into behavior change strategies addressing other, more energy-intensive practices and devices in office buildings.

Literature review

This section offers an extensive yet concise review of current behavior change literature in order to provide a framework for the behavior change experiment presented in this paper[3]. There are several reasons why conducting a review of relevant literature is useful for the purpose of the present research: It informs the expectations of the potential office energy savings that can be achieved through behavior change, the strategies that are developed to facilitate energy saving behaviors, and the interpretation of the findings from the experiment. At the conclusion of this section, the current gaps in behavior change literature relating to office settings are presented.

Individual behavior and behavior change

Behavior change measures will only succeed if they revolve around the realities of individual human cognition and why people behave as they do. Kahneman (2011) suggests that human decision-making is characterized by two processes: System 1 and System 2. He argues that most human cognition and resulting behavior is primarily guided by System 1 processes, or those that “are fast, automatic, effortless, associative, and often emotionally charged; they are also governed by habit, and are therefore difficult to control or modify” (p. 232). Moreover, System 1 processes largely operate in an unconscious manner, occur in response to cues in the surrounding environment, are context-dependent, and follow a set of heuristics (or rules of thumb). System 2 processes, however, are effortful, slower, deliberative, and flexible. System 2 processes are avoided if possible because they invoke greater cognitive effort and individuals “are not accustomed to thinking hard, and are often content to trust a plausible judgment that quickly comes to mind” (Kahneman, 2011: p. 231). Simply consider the difficulty in changing one’s own morning routine – even slightly – versus just doing the same old thing again today.

[3] A summary of the key themes and takeaways from the literature review is provided in Appendix I.

Kahneman (2011) demonstrates through extensive empirical analyses the central role of System 1 processes in individual decision-making and resulting behavior. In sum, people prefer to operate in auto-pilot mode. Hence the difficulty of behavior change and the resistance people show towards it: any behavior change measure requires effort, deliberation, and time. Nevertheless, the distinction between System 1 and 2 offers a roadmap for behavior change. Because most decisions are shaped by System 1 processes, behavior change measures should go along with these processes rather than clash with them. Dolan et al. (2009) provide an arsenal of tools – as summarized in their mnemonic *MINDSPACE* (Messenger, Incentives, Norms, Defaults, Salience, Priming, Affect, Commitment, Ego) – that is based on System 1 cognition and can be used to better facilitate behavior change. When applying these tools, Johnson et al. (2012) argue that it is important to distinguish between "those used in structuring the choice task and those used in describing the choice options" (p. 487). By designing behavioral measures that appropriately integrate the characteristics of System 1 processes, change becomes easier and more likely to become part of an individual's auto-pilot mode.

Darnton (2008) evaluates over sixty models of behavior and theories of behavior change in a comprehensive review of potential strategies for behavior change relating to environmental matters. Although no single model is perfect, each contributes to a broader understanding of what it takes to bring about new (desirable) behavior. Intervention mapping (IM) offers a process through which current needs toward achieving a desired change are found, target behaviors for change are identified, a plan of action is developed, and continuous evaluation is conducted to continue progress towards achieving the objective(s) of the intervention. Kok et al. (2011) argue that applying existing systematic approaches like Intervention Mapping to energy related behavior change will more effectively address the "personal, social, and economic barriers to performing desirable behaviors" and yield behavior change (p. 5281). In line with this argument, according to Steg & Vlek (2009) it is important to account for the factors that promote or inhibit pro-environmental behavior because the "effectiveness of behavioral interventions generally increases when they are aimed at important antecedents of the relevant behavior and at removing barriers for change" (p. 311). Chatterton & Wilson (2012) argue that interventions "need to be targeted in different ways for different groups" of people (p. 6). Intervention Mapping begins with a needs assessment, then moves on to identifying program objectives, methods and applications, program development, planning for program implementation, and planning for evaluation. Through this process, Kok et al. (2011) suggest that lasting behavior change will occur when there are (1) strong positive intentions, following from advantages outweighing disadvantages of the change, perceived social norms and support, consistency of behavior with self-image/self-evaluation, positive emotional reaction, and perceived capability/self-efficacy, (2) no environmental constraints, and (3) employees possess the necessary skills to enact the change (p. 5282). Kok et al. (2011) also cite the importance of there being "general organizational determinants (e.g. general trust in management), proenvironmental policies, proenvironmental management, and physical facilitation of proenvironmental behavior (e.g. placing easily accessible recycling bins)" (p. 5283).

Darnton (2008) presents a similar but less complex approach in the form of the UK's Department for Environment, Food and Rural Affairs' (Defra) 4Es (Enable, Encourage, Engage and Exemplify) model. The 4Es model is one of the more useful frameworks because it encapsulates many of the insights that can be useful in facilitating changes in individual behavior and goes with the grain of how individuals behave and make decisions. Moreover, the 4Es model shows how intervention mapping can be better applied in cultivating behavior change by combining a mix of behavioral tools:

1. *Enable*: remove barriers, give information, provide facilities, provide variable alternatives, educate/train/provide skills, provide capacity
2. *Encourage*: tax system, expenditure-grants, reward scheme, recognition/social pressure (league tables), penalties/fines/enforcement action
3. *Engage*: community action, co-production, deliberation, personal contacts/enthusiasts, media campaigns/opinion formers, use networks
4. *Exemplify*: leading by example, achieving consistency in policies

Darnton (2008) also suggests that expanding the boundaries of the 4Es model to include the wider context of culture change enhances the impact of behavioral strategies. The Cultural Capital Framework is presented to highlight the links between individual behavior, behavioral norms, cultural capital (which includes the attitudes, values and aspirations shaped by the society, community, organization(s), and people with whom individuals affiliate), behavioral intentions, behavioral drivers (the 4Es model), and behavioral paths. Darnton (2008) therein puts considerable weight behind non-prescriptive, adaptive strategies in bringing about behavior change. He suggests the importance of developing solutions based on local contexts, adopting participative methods, establishing directions of change (and providing related resources) rather than externally determined targets, ensuring that strategies adapt over time through learning and innovation, and viewing failure as "an opportunity to build understanding" (p. 63). Therefore, it appears that proactive, inclusive, flexible, and contextual methods may be more effective in bringing about long-term changes in behavior in comparison to top-down, external, prescriptive, and predictive methods.

Applying energy saving behaviors in an office setting

The core questions raised in this study revolve around the opportunities for energy savings through changes in repeated behaviors among office building occupants. The focus is hence on energy use related habits, or the routine behaviors driven by System 1 (automatic, sub-conscious, quick) cognition that contribute to wasted energy consumption. The aim of the present study is therein to gain a better understanding of the potential for energy savings in office buildings through behavioral improvements, or the *software* of buildings. This stands in contrast to other research on energy savings in office buildings through technological improvements, or the *hardware* of buildings.

Energy saving behavior change measures will be more likely to succeed if they work with System 1 cognition rather than against it: successful interventions "must change the environmental cues that sustain habits" (Kok et al, 2011: p: 5283). Behavioral interventions utilizing research from fields like behavioral economics that place the realities of human behavior at their core will be better equipped to bring about change. For example, Shogren (2012) offers a summary of lessons – spanning topics such as 'rationality', risk perception, framing, cooperation, fairness, trust, goal setting, discounting, and stakeholder engagement – that can be applied in to better align pro-environmental behaviors with the primary drivers of human decision making and resulting behaviors.

The formation of new, energy saving habits will indicate whether interventions have been effectively applied and will endure after an intervention is implemented. Yet therein rests the challenge: how can a new set of energy saving habits become ingrained in employees throughout an organization? Generally speaking, habits refer to the manner by which behavioral choices are made and "are reconsidered only when the context changes significantly" (Steg & Vlek, 2009: p. 312). In addition to creating a remarkably modified decision making context, there must be both a goal and satisfactory outcome associated with the new behavior. The habitual behavior must become learned, stored in memory, and retrieved in instances when individuals confront the new decision making context. The new context will therein trigger the energy saving and, by this point, automated behavior. As long as that particular context remains intact, the energy saving habits will be cultivated while wasteful behaviors are inhibited. Bicchieri (2006) and Goldstein et al. (2008) demonstrate the particular importance of norms in the context of individual behaviors and the extent to which many behaviors are entirely contingent upon the beliefs individuals have of what other people do and what they think others expect of them. Similarly, Miller (2012) points to the presence of norms that inhibit the adoption of pro-environmental behaviors.

In developing strategies to reduce office energy use through changes in employee behavior, it is valuable to delve into prior research investigating how to bring about lasting change in employee behavior. Unfortunately, Lo et al. (2012-a) suggest that "the research on household energy conservation and other proenvironmental behaviors cannot be easily generalized to organizational contexts" like offices (p. 2934). Focus must be placed on energy saving behaviors in an office setting *directly* because the personal motivations for energy consumption and energy savings vary in comparison to a household setting. The existence of split incentives – whereby organizations reap the financial benefits of changes in behavior enacted by employees – therein presents a potential barrier to behavior change. Those engaged in behavior change likely perceive the process as providing only costs and no tangible benefits. Nesse et al. (2011) further this point by stating that individual motivation to reduce energy use in office buildings "is perhaps the most complex, requiring engagement in not only information, but translation of abstract data into meaningful information for people to use, and tools to help them make a positive impact" (p. 1). Despite the fact that "occupant behavior is a major determinant of energy use in buildings, energy savings potential due to behavior are usually neglected, albeit being referred to as significant as those from technological solutions" (Lopes et al, 2012: p. 4096). Moreover, focusing on energy efficient technologies alone without behavior change will likely fail in reducing overall energy use: Loveday et al. (2008) argue in their analysis of households that even though homes and products have become more energy efficient since 1970, the "increasing numbers of products and the advanced technological innovation they contain have brought a sharp rise in domestic energy consumption" (p. 4641). It seems fair to presume a similar trend in office buildings, thus suggesting the crucial role of behavior change in reducing overall energy consumption in office buildings. Yet the central challenge remains over what it takes to spur behavior change measures, especially given the research of Kunreuther & Weber (2012) which discusses the difficulty for people to perceive the risk of climate change and therein delay available mitigation strategies into the indefinite future. Semenza et al. (2011) found that people will engage in mitigation strategies – in this case, reduce energy use – if they believed their way of life or actual life to be at risk and if they believed themselves to be incapable to adapt to the impacts of climate change.

There is emerging literature that directly addresses the ability of organizations to instill lasting energy saving behavior. Carrico & Riemer (2011) cite behavior change "as one of the more immediate and cost-effective options available for meeting near-term targets while more systematic changes can be implemented" (p. 1). The 2012 Accenture report *Sustainable Energy for All* argues that energy efficiency offers a major cost reduction measure and form of employee engagement. In comparing this cost savings measure to others, behavior change is an attractive strategy since it "does not require high technological knowledge and can be used in both new and existing buildings" (Nisiforou et al, 2012: p. 300). And organizations are interested: Pellegrini-Masini & Leishman (2011) found that organizations "appeared keen to improve their energy management through the optimization of use of installed technology, new low cost and low disruption technology (efficient lighting, motion sensors, energy efficient office equipment) and behavior change" (p. 5415). Moreover, the fact that employees "are a 'captive' audience that can be more easily targeted [than households] through low-cost means such as motivational appeals delivered through e-mail or newsletters" and that energy use "is more easily observed by one's peers in the workplace" suggests there are at least some factors which favor energy saving behavior in offices in relation to homes, where some behavioral strategies have already been shown to work.

Nevertheless, there are numerous reasons why organizations are adopting behavioral measures to a far lesser extent than might be expected. Allcott & Mullainathan (2010-a) argue that there must in fact be an assortment of (non-financial) barriers preventing the adoption of the non-price-based behavioral interventions that potentially could save billions of dollars in costs if scaled across economies. Attari et al. (2011) show that failure to implement behavior change measures that reduce energy consumption is not unique to office buildings but rather can also be observed in households, a setting where people have an even greater (financial) incentive to adopt such measures. Shove (2010) points to the blind spots created by as well as the need to move beyond the ABC – attitude, behavior, and choice – model in the definition(s) of the problem at hand. Keenan et al. (2012) emphasize two major issues in any change initiative: change fatigue and resistance to change.

Organizations that successfully implement change offer clearly defined and achievable goals, methods for measuring progress, commitment from those in positions of leadership, employee engagement, as well as two-way, consistent and constant communication. Keenan et al. (2012) stress the importance of working with both early adopters of change among employees as well as skeptics. Furthermore, they suggest that less tangible factors must be communicated – such as self-worth and job satisfaction – that help gain emotional buy-in from employees.

Bonini & Görner (2011) argue that despite the potential value offered by sustainable organizational practices such as energy reduction measures, most organizations do not actively pursue these strategies and therefore miss an opportunity to reduce costs while also addressing climate change. Bonini (2011) supports this argument in a set of survey findings that only one-quarter of executives believe sustainable operations are embedded across their organization. Similarly, the 2013 Deloitte report *Culture of purpose* presents a further word of caution for organizational change efforts: in its core beliefs and culture survey it was found that while employee development programs serve as a major way to build a culture of purpose – to address issues such as energy use – the gap between employer and employee beliefs on the integration of these programs in the workplace is larger than for any other issue. Peloza et al. (2012) point out another perceptual gap worth considering: organizations are often believed to perform better in sustainability metrics like energy consumption than their real performance, presenting both a risk to organizations in terms of their performance, reputation, as well as to the environment should the failures continue. Pellegrini-Masini & Leishman (2011) recommend that policymakers "magnify the reputational significance of energy efficiency" (p. 5418).

Bonini (2011) points out that while reducing energy use serves as one of the largest value creators of any sustainability-related measure, these efforts may be hampered due to an assortment of barriers such as there being a lack of incentives tied to reducing energy consumption. Metz et al. (2007) suggest that other barriers to behavior change include the tendency to ignore small energy savings opportunities, organizational failures (such as split/dual incentives), lack of awareness, culture, and tradition. Furthermore energy use is not a salient issue for employees since they generally neither observe energy use measurements nor receive feedback on their own changes in energy consumption over time. There is hence a resulting gap between intentions to reduce energy use and the actual adoption of energy saving actions.

There are various aspects of the office environment that further complicate the development of successful behavior change strategies. Nisiforou et al. (2012) found through a questionnaire that while employees are willing to engage in energy saving measures, they "are not willing to sacrifice their own personal satisfaction for these measures" (p. 299). They also suggest that individual behavior in office buildings is multifaceted due to the differing roles, schedules, social interactions, personal context, and other variables found in this setting. Moreover, Loveday et al. (2008) stress the impact on continual rises in energy consumption due to the non-stop, always 'on' societal contexts within which people now live and work.

To foster strategies that successfully bring about enduring energy saving behavior, it seems that new and creative approaches are required because organizations continue to miss opportunities to reduce energy consumption and related greenhouse gas emissions. Prior attempts to compel energy savings have, to be blunt, largely failed: mission statements by organizations to reduce energy use are not put into action, intentions float up in the clouds, and energy saving measures continue to remain near the bottom of the to-do list. There is therefore a dire need for new narratives, forms of engagement, leadership and excitement over energy conservation in order to take the steps available right now to help mitigate the effects of climate change.

Instead of continuing to develop new theories or implement strategies from an external perspective, a more effective route to bringing about behavior change may be to identify those pieces of the office energy savings puzzle which best fit together in terms of the organization and people involved by directly working with them. The pieces can then be moved around depending on what seems to work best. Nesse et al. (2011) recommends the use of the broad framework offered by the Fogg Behavior Model (FGM) as a starting point in putting together this puzzle due to its identification of (1) motivation (high or low), (2) ability (easy or difficult), and (3) trigger (a reminder or prompt) in approaching behavior change. Building on this, Robinson (2012) argues that if "there's a positive buzz AND we offer hope AND an enabling environment AND a sticky solution AND expanded comfort zones AND the right invite THEN people will do things they have never done before and sustain those changes" (p. 239).

There is growing support for new kinds of approaches to addressing environmental issues like those relating to energy consumption. But as is argued by Johnson (2013), these new approaches need not start from scratch: the environmental field should learn from the failures and successes of public health campaigns. Johnson (2013) stresses the need to provide people with practical tools rather than more information, inspire people, understand that changes take place over time, and keep in mind that behavior is driven by context rather than attitude (unlike what is commonly believed). If the aim is to change behavior, it must therefore be pursued "primarily through modifying the environment in which people make their choices" (Robinson, 2013). This is because many "contextual factors may facilitate or constrain environmental behavior and influence individual motivations" (Steg & Vlek, 2009: p. 312). Hence there is "a need to take account of the physical, social, cultural and institutional contexts that shape and constrain people's choices" (Owens & Driffill, 2008: p. 4412) since "behaviors are influenced by their context" (Carrico & Riemer, 2011: p. 2). The findings from Lo et al. (2012-a) align with these arguments and compel recommendations for interventions within organizations that focus on physical facilitation of pro-environmental behavior, environmental leadership by superiors within an organization, tailored persuasive communication, and active engagement of employees. The "core elements required in a successful intervention include information about how to change behavior, feedback, and a supportive social environment" (Carrico & Riemer, 2011: p. 2).

Moreover, Johnson (2013) emphasizes the importance of engaging the people who in fact will be the ones to 'change', since direct involvement in the change process will ensure that people feel empowered during the change process and that the changes will lead to a brighter future for them. Energy saving behaviors must become aligned with the values and priorities of those who are being targeted to change. More generally, it is necessary to move away from one-size-fits-all approaches – as the can make a situation worse – and instead focus on developing solutions that fit for the people and organizations involved. And fit involves taking into account the multiple factors that shape the context in which people make decisions. An enabling context is therefore of utmost importance because information on its own does not mean individuals will change their behavior, as Barlow & Fiala (2007) show that 91 percent of employees are already aware of ways to save energy. Furthermore, if engagement instills in employees a sense of psychological ownership and feelings of possession, then according to van Dyne and Pierce (2004) employees will be more likely to demonstrate "feelings of responsibility that lead to investing time and energy to benefit the organization" (p. 445). This is especially true of informal, non-prescribed behavior such as how people consume energy at the workplace. But psychological ownership can also work against behavior change, as people may not want to be told how to manage what is 'theirs'.

Guarraia et al. (2012) provide four key measures shown to ensure cost reduction transformations that are sustained over time and ensure a new culture is formed "in which keeping costs low is the primary objective:" (1) set targets based on external, market-based data rather than internal benchmarks; (2) establish tailor-made cost saving measures that 'fit' for the organization; (3) use appropriate and relevant metrics; and (4) address waste at the 'seams' of the organizations that operate in the space between different departments (p. 2). Owens & Driffill (2008) also point to the key interaction between technical infrastructures and social norms in the stickiness of behavior over time. Moreover, Guarraia et al. (2012) stress the importance of winning over frontline managers and employees as well as addressing employees' anxieties over change. Davis-Peccoud et al. (2013) echo this last point by saying that those successfully instilling pro-environmental measures organization-wide “hold employees accountable for sustainable practices in their jobs” and “equip employees with tools and training in order to raise the bar for further improvements” (p. 5). Providing employees with proper tools and training thus provides a backbone upon which organizational energy saving goals can be realized. It is also important for energy use to be salient: Zografakis et al. (2012) show that exposure to factors increasing the salience of energy-related issues influences a greater willingness on the part of managers to reduce energy use (in this case, through more efficient lighting technologies and related practices).

Bouton et al. (2010) suggest that failing to engage employees in reducing office energy use is one of the primary forms of energy waste in offices and that behavioral barriers are one of the three barriers inhibiting energy savings in this setting. Hatherall et al. (2012) argue that “a strong sense of purpose, ample autonomy, opportunity for growth and a sense of affiliation” are critical aspects of achieving engagement in the workplace. It is recommended by Bouton et al. (2010) that organizations should take a visible leadership role in addressing energy consumption and demonstrate to employees how to reduce energy use (through measures such as providing ‘coaches’). The coaching, or feedback, process “is as much about reinforcing what employees should do and are doing right as it is about correcting what they did wrong” (Hatherall et al, 2012). Through an empirical study of 252 line managers at a large and diverse company, Conger et al. (2000) provides insights for what it takes to establish the charismatic and effective leadership which helps facilitate change: individuals will follow the guidance of a leader when they attribute reverence, trustworthiness, satisfaction towards the leader; when the leader is able to build a collective identity and establish a broader mission for which everyone in the group works together towards; and when a leader makes individuals feel empowered. The combination of a shared purpose, coaching, and revered, trusted leadership therein appears critical for the adoption of the desired changes.

Previous studies applying energy saving behaviors in an office setting

A handful of studies have assessed the role of occupant behaviors in the energy consumed and CO_2 emissions released by office buildings. Pro-environmental behavior change in office settings is an area of limited research but increasing interest. These studies tend to show that behavior change strategies can achieve noteworthy energy savings. The findings from Roetzel & Tsangrassoulis (2012) indicate that significant variations in CO_2 emissions result from the behavior of occupants in office buildings. Their research shows that a "major mitigation potential regarding energy consumption and greenhouse gas emissions is related to occupant behavior" (Roetzel & Tsangrassoulis, 2012: p. 349). In related terms, Schweiker & Shukuya (2010) found in their analysis of four scenarios with varying building envelopes and occupant behaviors that the "influence of occupant behavior was highly significant," especially in situations when indoor and outdoor temperatures are similar (p. 2976). In fact, the UK government successfully reduced its energy use by more than ten percent through behavioral measures such as changing defaults and social norms, and is now calling on others to follow its lead (Cabinet Office, 2011). Furthermore, Wang et al. (2012) investigate the uncertainties associated with annual energy consumption due to weather and building operational practices in medium-size office buildings across four regions in the US. They found that energy consumption at each site can be drastically affected by building operations and thus that building operations inflict a high level of uncertainty on expected annual energy use. In fact, the level of uncertainty associated with the use of a building's HVAC system (-15.8 to 70.3 percent), plug load (-11.3 to 7.0 percent), and lighting (-5.8 to 9.0 percent) – each of which are affected by employee behavior – was greater than that which was due to weather (-4.0 to 6.1 percent) (Wang et al, 2012: p. 157)[4].

Behavior change measures are potentially a cost-effective approach for reducing energy consumption. Carrico & Riemer (2011) show that "significant and substantial reductions

[4] See Appendix I for two figures from Wang et al. (2012) on the uncertainties in energy consumption in buildings due to building operations as well as a summary of the range from worst to best practices in building operations.

in energy use can be achieved almost immediately with currently available technology and little upfront cost" in their experiment assessing the impact of two behavioral interventions on energy use: monthly group-level feedback via email and peer educators that essentially served as energy 'coaches' (p. 11). The group-level feedback led to 7 percent energy savings, peer education led to 4 percent energy savings, and this took place while there was 4 percent *increase* in energy use for the control group. Carrico & Riemer (2011) also found that the peer education intervention saved $15 per every dollar spent and that the feedback intervention saved about $32 per dollar spent (or $12 and just over $5 per ton of CO_2 saved, respectively).

According to their review of behavior change literature, although limited research has been conducted on potential energy savings in offices through behavior change, Lopes et al. (2012) cite studies on behavior change[5] in commercial buildings from the US in which energy use was lowered by 18 to 35 percent and from South Africa/Botswana in which there were 56 percent reductions in electricity consumption. They also found energy reductions through behavior change in residential settings to typically be between 5 and 20 percent. The potential energy savings in developing nations are likely to be much greater.

While the energy savings from behavior change strategies are noteworthy, the scale of energy savings will likely be less than what is possible through technological improvements. Furthermore, strategies based on information or awareness have no impact on energy use and lead to wasted time, money, and effort. Metzger et al. (2011) compared technological and behavioral strategies in reducing the energy use from plug loads (any device plugged into wall outlets) in a four-week experiment conducted at the US EPA's LEED Gold certified building in Denver. Colorado. It was found that the automatic, technological control system that turned off plug load devices after 15 minutes of no occupancy in a pod (a cluster of cubicles of six to eight people) reduced energy use by 21 percent from the baseline, competition between pods led to a six

[5] See Appendix I for the summary of research on potential behavioral energy savings shown in Lopes et al. (2012).

percent reduction from the baseline, and that letters providing information about energy use and how to reduce energy use resulted in no change. The annual cost savings in the building would be $3,476 for the control system, $991 for pod competition, and -$41 for the informational letters. Moreover, in an exit survey Metzger et al. (2011) found that none of the respondents found the experiment disruptive.

Opportunities for energy savings through behavior change will vary based on climate and the building size. Azar & Menassa (2012) conducted a sensitivity analysis in which thirty energy models were created to encapsulate three building size categories and ten different US weather conditions in relation to changes in nine different occupancy behavioral parameters. Some of the main conclusions were that occupancy behaviors significantly influence overall building energy use and that the influence of different occupancy behaviors depends upon building size and weather conditions. Moreover, Azar & Menassa (2012) found that “a significant portion of energy use in small buildings is typically attributed for the HVAC systems, as opposed to large buildings that spend higher portions of energy use on equipment and lighting” (p. 849). Thus it appears that behavior change measures should primarily target heating/cooling for small buildings and lighting/electronic device use in larger buildings for the greatest energy savings.

Moderate changes will be more likely to stick and receive less resistance in comparison to drastic changes. With the aim of reducing the energy consumed by heating/cooling, Brown et al. (2012) show the role of small changes in temperature default settings in a randomized controlled experiment: while they found a 1°C decrease in the default office building temperature setting over a six-week experiment during the winter heating season resulted in a average reduction in the chosen setting by 0.38°C, it was also discovered that “small decreases in the default (1°) led to a greater reduction in chosen settings than large decreases (2°)” (p. 2). People would manually modify the office temperature if the change in temperature was large, but left the new default temperature intact if the change was small. Additionally, Brown et al. (2012) indicate in their analysis of the experimental findings that 65 percent of the effect could be explained to variations in occupant behavior and that “office occupants who are more apt to adjust their thermostats prior to the intervention were less susceptible to the default” (p. 2). Thus implementing a more moderate level of change may lead to a larger impact on energy use in the long-term than more dramatic changes. Steg & Vlek (2009) also imply that people will prefer strategies framed as promoting the adoption of energy saving behaviors over those targeting a reduction in wasteful energy behaviors.

It appears that a major opportunity to reduce energy use in office buildings is during non-work hours. Webber et al. (2006) found in a series of after-hours audits of office equipment (computers, monitors, printers, fax machines, copiers, scanners, multi-function devices) for sixteen businesses across three regions in the US that user behavior (which “determines the number of hours per day during which a device is in use, the number of hours the device is turned on but idle, and the number of hours the device is off”) like turning off devices at night or enabling power management significantly influences energy use (p. 3). Masoso & Grobler (2010) present an astounding finding on the scale of energy wasted during the hours when offices are empty yet lighting, temperature control, and equipment are still in use: “more electricity is used during non-working hours (56%) than during working hours (44%)” (p. 176). Yet there are also opportunities to reduce energy consumption during work hours since, according to a study of 48 offices in three buildings, nearly everything remains turned on throughout the day even though occupants on average “spend more than 50% of the time away from their work station” (Masoso & Grobler, 2010: p. 173). Zero-cost measures like ensuring that items not in use are turned off could thus lead to dramatic reductions in energy use and greenhouse gas emissions.

Webber et al. (2006) discovered that turn-off rates during non-working hours “vary widely over the types of office equipment, from 0 percent (for fax machines) to 75 percent (for wide-format printers). For most equipment types, turn-off rates are under 50 percent” (p. 20). Moreover, it was found that “around one half of the electrical load occurs when the building is unoccupied, due to lights and equipment being left on” (de

Wilde & Tian, 2010: p. 1679). In terms of temperature settings during non-work hours, Korolija et al. (2013) "suggest the change in set point temperature during unoccupied hours to 12°C in all zones in winter and to 28°C for office zones and 30°C in common areas for summer" (p. 156).

Behavior change measures should build upon the values and aims held by employees and their respective organizations. In a qualitative study by Lo et al. (2012-b) conducted through semi-structured interviews and focus groups among office building facility managers and employees in four Dutch organizations, several insights were discovered that may prove useful in bringing about energy saving behavior. First and foremost, behavior change interventions are more likely to be successful should they be compatible with or supportive of the work-related interests (work quality, efficiency, etc.) of an organization. Energy saving measures must not be perceived – as they often are – as "harming the organizational interest indirectly through their employees" (Lo et al, 2012-a: p. 238). Second, there must be clear communication of the desired behavior changes, related skills training for new lower energy work routines, adjustments to work procedures, and direct feedback on behavior. Each of these acts would reduce the actual and perceived amount of effort required by employees. Finally, interventions that change workplace norms may be more successful since norms often serve as a (most often underreported) barrier to behavior change. Lo et al. (2012-b) also suggest that behavior change measures are likely to be viewed by employees through three general orientations: normative orientation (moral stances and individual responsibility), gain orientation (cost-benefit analysis and efficiency), and hedonic orientation (personal convenience and comfort). Varying forms of engagement that tailor to these employee orientations towards change may hence be necessary to ensure behavioral measures become ingrained across an organization.

Physical comfort in the workplace must be considered when designing and implementing behavior change strategies. Survey research by Barlow & Fiala (2007) suggest it is important to value occupant notions of physical comfort in the workplace, as comfort levels will affect the favorability of occupant views towards energy saving behaviors. Lakeridou et al. (2012) show in an experiment involving two floors of a modern London office building in which the room temperature was increased during the summer by 2.6˚C on average on one floor and the temperature for a second, 'control' floor was unchanged that while employees on the intervention floor noticed that it was warmer, overall there was not a significant difference in comfort levels or satisfaction between employees on both floors. However, the temperature set-point increase "only lasted two days due to some occupants complaining, and hence if a policy is implemented, facilities managers will need clear instructions on the complaint threshold at which action should be taken" (Lakeridou et al, 2012: p. 347). This latter point is not surprising given the finding from de Wilde & Tian (2010) that "indoor temperature is a predominant stressor in office buildings" (p. 1676) and from Lo et al. (2012-b) that "climate control is one of the most frequent sources of complaints among employees" (p. 239). And if people become uncomfortable and feel that temperature settings are outside their control, Herkel et al. (2008) show they will for instance be more likely to open windows, which can lead to varying levels of energy losses over the course of a year. Besides temperature, Yun et al. (2012) show that internal lighting affects the level of comfort experienced by employees and reveal that the use of lighting cannot be explained by external daylight.

Energy savings could be used as a method to increase physical comfort in office buildings. de Wilde & Tian (2010) present an alternative way to frame energy saving behavior. The costs associated with energy use are meager in relation to overall labor costs: Pellegrini-Masini & Leishman (2011) suggest mechanical/electrical running and maintenance costs represent 4 percent of the typical business' total costs, while staff salaries amount to about 85 percent of the total costs. De Wilde & Tian (2010) therein focus their work on the sensitivity of employee work performance based on changes in the physical office environment, placing particular emphasis on comfort associated with temperature. Their research hints that behavioral measures taken to reduce energy use may in fact improve employee work performance by increasing comfort levels through various means. Hence, by framing energy savings around comfort levels it seems possible for energy saving behaviors to not only reduce energy related costs but also boost employee performance. As an example, Pino et al. (2012) argue that better utilization of natural light, through measures such as ensuring blinds are used properly, "can positively act on a user's comfort, besides the reduction of artificial lighting use which generates an internal gain of heat and increase in electricity consumption" (p. 448).

Research needs

After conducting a review of relevant literature, it appears that there are several important gaps in the literature that the experiment conducted as part of the present study paper addresses:

- Metz et al. (2007) summarizes its contribution to the IPCC Fourth Assessment Report: Climate Change 2007 by saying "there is a critical lack of understanding, characterization and taxonomization of non-technological options to reduce GHG [greenhouse gas] emissions" and that this lacking may lead to an underestimation of potential ways to cut emissions (p. 437). The present study places its central focus on the role of non-technological options in relation to energy saving behavior in office buildings.
- Nisiforou et al. (2012) point to the general need for research on energy use and energy savings in office buildings at the individual, behavioral level. While most studies on energy saving behaviors focuses mainly on the residential sector, studies "that quantify potential behavior savings at service buildings are scarce" (Lopes et al, 2012: p. 4098). The present experiment directly investigates these gaps in research by measuring the impact the impact of behavior change strategies on energy use in an office setting.
- Lo et al. (2012-a) state that there are "no studies on organizational environmental behavior which have integrated individual and organizational variables in their analysis *and* used more than one organization in their sample"

(p. 2957). The present experiment addresses this by evaluating the impact of behavior change interventions implemented in several office buildings operated by different types of organizations (private sector, public sector, and university).

- In addition, Lo et al. (2012-a) stress the need for greater understanding on the role of commitment, norms, social comparison as well as other variables such as office culture on pro-environmental behavior. To contribute to the broader literature, the present experiment invokes several of these variables within the behavioral interventions that were implemented at office buildings participating in the study.
- Azar & Menassa (2012) believe it would be useful to figure out the frequency of various occupancy behaviors – such as leaving equipment 'on' during non-work hours – in commercial buildings. The present experiment collected on-site observational data of buildings participating in the study to get a grasp on the major sources of energy waste within each building.

Moving forward, there are in sum various key themes in existing research that should be incorporated into office based behavior change measures. More generally, it is essential that interventions create an enabling choice environment that engages employees and makes change easy. Active feedback and support, trust, bold leadership, consistent communication, compatibility with work-related interests of employees, and an emphasis on building new expectations and norms are also vital. These and other findings from related research were considered in the methods developed to conduct the behavior change experiment examined in the present paper as well as in the interpretation of its results.

Methods

In this section, the general framework of the experimental methodology is described to highlight the manner in which the experiment was conducted. The behavioral interventions used in the experiment were informed by the research presented in the Literature Review and were developed in collaboration with the London-based sustainability consultancy Carbon Smart.

The experiment

A controlled field experiment was conducted in collaboration with Carbon Smart in order to evaluate the potential scope for energy savings in office buildings through behavior change. The experiment took place from July through August 2013 and involved about 1,100 participants in five organizations across four office buildings in London, UK.

The various components of the experimental process are listed below and then explained in greater detail in the ensuing paragraphs:

- Recruitment of participants
- Initial meetings
- Observed potential energy savings and barriers assessment
- Behavioral strategy design and implementation
- Data collection
- Data analysis

Recruitment of participants

Beginning in mid-May 2013, the recruitment of organizations and their respective building(s) was the first and crucial step in the experimental process. Due to the limited timeframe available to conduct the study, it was not possible to use a randomized recruitment process. Many of those that were initially recruited were either a client of

Carbon Smart or an organization for which an employee at Carbon Smart suggested a contact. Electronic messages were sent and/or phone calls were made to individuals in charge of his or her respective organization's estates management, environmental, or energy management division. After this, organizations appearing to be likely to have interest in an experiment aiming to reduce energy use – for example, an organization that had CO_2 targets or other climate change initiatives – were identified. Thus, those that eventually became participants in the experiment were quite receptive to the importance of reducing energy use and addressing climate change. While it would have been ideal to include those both receptive and less receptive to reducing energy use, the time constraints of the study period meant that it would be necessary to make the recruitment process as quick and as successful as possible.

The like-mindedness of participants therein contributes a two sided twist to the experiment and the broader interpretation of its findings. While on the one hand their like-mindedness may mean that there could be more barriers at other organizations less receptive to the need to reduce energy use, those participating in the study were probably already ahead of the curve in terms of making efforts to save energy. Participants in the experiment therefore likely had less potential to reduce energy use than those who would have been more difficult to recruit.

The recruitment process began by cold-calling and/or sending emails to prospective participants from the Carbon Smart office. The experiment was presented to prospective participants as a *free* piece of staff engagement that would be used for the present author's master's dissertation at Imperial College. It is worth noting that the messages did *not* include any mention of climate change, carbon dioxide, or any related terminology; only the themes of energy and cost savings, behavior change, and staff engagement were presented. A description of the experiment was then given to prospective participants, placing particular emphasis on the limited amount of time or effort they would have to contribute. The description would resemble the following:

> From June to August this year, Carbon Smart and Imperial College's Centre for Environmental Policy are conducting an experiment to measure the effects of staff behavior interventions on energy use in an office environment.
>
> The experiment is relatively straightforward: I am working together with Carbon Smart to carry out a number of communication and engagement activities to support new staff working practices and behavior. The study will take place in a defined space (a discrete office or site, for example) and will compare the impact on energy use in comparison to a similar space that is not subject to the interventions.
>
> The results will be published at the conclusion of the experiment. This is an area in which little research has been undertaken, so we hope the work will greatly increase our collective understanding of what works to change staff behavior and reduce office energy use.
>
> The study will involve just a small amount of your time and will likely lower your energy related costs. Furthermore, this is an opportunity for [Prospective Participant] to participate in the development of innovative strategies for addressing climate change. Carbon Smart will also write a briefing paper for [Prospective Participant] presenting key learning points for your staff engagement going forward.
>
> Nearly all of the work will be carried out by us. On your end, we will need just two similar spaces as well as the cooperation of staff.

Follow-up calls and emails were then made in order to set up initial in-person meetings. However, before meeting in person, further energy data would also be requested for the prospective site. Buildings needed to be able to collect sub-metered electricity readings in order to be considered for the study. Several prospective sites were dismissed at this stage due to a lack of sub-metering capabilities, insufficient data coverage, and due to overly variable data from previous summer months.

Initial meetings

An initial meeting was held at the office of each organization interested in participating in the study. The meetings typically lasted thirty to forty-five minutes. More details of the experiment were explained to the person(s) representing the prospective participant and then any questions were answered.

After the initial in-person meeting, the representative of the prospective participant would speak with various people and engage in the actions necessary to determine whether it would be possible to run the experiment in their building(s). Once any required approvals and/or other measures were in order, the experiment then would begin at the organization's building(s). This bureaucratic hoop brought an end to prospective participants, as the building's main decision-maker(s) decided not to proceed further.

Various challenges were encountered in the recruitment process. On several occasions, it turned out that what seemed to be a promising site for the experiment ended up falling through. These setbacks would render the experiment impractical at the site and in sum occurred due to bureaucratic issues within the organization, internal time/work pressures, or an insufficient/inadequate capability to collect electricity sub-metered electricity readings.

Observed potential energy savings and barriers assessment

The first step of process in developing behavioral opportunities for energy savings involved the identification of potential sources of energy waste and related barriers to behavior change. This knowledge contributed to the targeted behavioral strategies that would eventually be implemented in the office to reduce energy use. At each office building, an extensive set of observations were made to identify computers, lights, and other electronic devices that appeared to be left on unnecessarily. These observations took place at the end of the workday – a time expected to be full of opportunities to reduce energy use – in order to discover what would be left on during non-work hours. The 'checklist' used for the on-site evaluations was inspired by the office energy use evaluations conducted by Webber et al (2006). Even though there are numerous categories of office devices, the on-site assessments focused on a limited number of devices, including personal computers (PCs), computer monitors, printers, copiers, scanners, and fans.

The observations made while walking around the office were crucial in the initial stages of developing the behavioral strategies to reduce energy use because they illuminated various opportunities for energy savings. In addition, these observations enabled the identification of physical barriers inhibiting energy saving behaviors, such as light switches being hidden behind objects. After various sources of waste and possible barriers were identified, the behavior change interventions were designed and then approved with the points of contact at each participating site.

It is worth noting that the original plan for the study included holding focus groups at each site. The reason for holding focus groups would be to directly engage and learn from employees so that energy savings could be better captured. Focus groups also had the potential to offer deeper insights on the barriers to and opportunities for energy saving behavior in each office, as well as create a notion of ownership over the implementation of the energy saving strategies. However, it would have been possible to hold a focus group at only one participating site. Moreover, given the nature of the specific behavior change that in the end was targeted for intervention in this experiment, it was deemed that a focus group may do more harm than good. Making participants step away from their work for a period of time to discuss and collaborate over how to facilitate a single (and simple) behavior change might cause frustration.

Behavioral strategy design and implementation

A set of behavioral strategies was designed for the experiment based on the insights garnered through the observational assessment, discussions with contacts at each building, and through a review of related literature. The strategies sought to capture the opportunities to reduce wasted energy by both removing barriers and facilitating new behaviors in order to create a new choice context. These strategies also incorporated various components of behavioral insights described in the Literature Review. In so doing, the aim was to create an enabling environment in which the new energy-saving behavior became ingrained in the office culture and employee practices.

One of the two behavior change interventions developed for the experiment was applied in each building. The interventions were applied on the experimental floor(s), while no intervention was implemented on the control floor(s). Each participating site had in place an open-plan office setup in which employees work in a shared space (there were neither cubicles nor individual employee offices). Being that two strategies were implemented across participating buildings and that there were participants from several sectors, the overall approach of the experiment is in line with the view presented by Steg & Vlek (2009) that studies aimed at evaluating an intervention's effectiveness "should follow solid experimental research designs that reveal the effectiveness of single as well as combinations of interventions for one or more 'treatment' groups and a comparable control group" (p. 314).

It became increasingly clear during the observed potential energy savings and barriers assessments that there was a shared, albeit relatively small, source of energy waste: computer monitors (LCDs) left on or left in standby mode overnight. This became the central focus of the intervention mapping process and behavioral intervention design because capturing the opportunity for energy savings from the large share of computers remaining on or in standby mode overnight required a simple change in repeated, habitual behavior. The desired change was for more employees to simply press the power button on their computer monitor(s). As such, this experiment evaluated the potential for reductions in energy use and CO_2 emissions that are – in the literal sense – within an arm's reach.

Even though computer monitors use much less energy than heating, cooling, lighting, and various office equipment/devices, interventions focusing on monitors offer a 'free' source of potential reductions in energy use and CO_2 emissions that are visible to and can be easily addressed by everyone in the office. The simplicity of the change in behavior – pressing a button within arm's reach of each employee – suggests that the reason for monitors not being turned off rests in the choice context rather than the difficulty of executing the desired behavior. Thus by creating a new choice context, it was expected that there would be a resulting increase in monitors being turned off by employees.

An additional motive for selecting monitors as the focus of the behavioral interventions was that monitors served as a common source of potential energy savings for each of the participating organizations that could be addressed via behavior change interventions. In some offices, for example, heating/cooling and lighting were automated and outside the realm of employee behavior. In such situations, behavioral strategies could not be applied. Moreover, the commonality of potential energy savings from monitors left on or in standby mode allowed for greater comparability of differences in the impact of behavior change interventions across organizations and sectors.

In developing behavioral strategies to increase the number of monitors turned off rather than left in standby mode (or left entirely 'on'), Lockton et al. (2013) offer a useful intervention mapping approach that incorporates System 1 cognition: their approach accounts for the heuristics (or 'rules of thumb') that may keep people from turning off their computer monitors and therein can be used to help identify possible strategies to increase the rate of monitors turned off. Using Table 3 from Lockton et al. (2013)[6] as a way to organize the intervention mapping process and develop strategies that engage employees by changing the decision making context around computer monitors, the following table offers a set of possible heuristics that sustain current practice and potential matching intervention design(s):

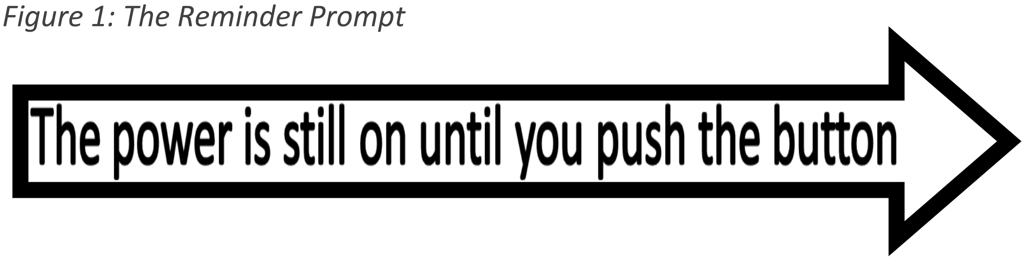
Table 1: Possible heuristics and intervention design implications

Possible heuristics	Intervention design implications
If I find out monitors left in standby mode continue to use energy, then I will turn mine off	Ensure employees know that monitors continue to use energy unless they are turned off by pressing the power button
If I learn how to turn off my monitor, then I will do it	Show employees how to turn off their computer monitor
If it is easy to turn off my monitor, then I will do it	Illustrate to employees the simple step required to turn off their monitors
If I remember to press the power button, then I will do it	Remind employees with prompts and make monitor energy use salient
If my colleagues turn off their monitors, then I should do it	Highlight to employees what their colleagues are doing
If everyone else in the office turns off their monitor, then I will do it	Show employees that lots of other people in the office turn off their monitors
If I want to be 'normal', then I will turn off my monitor	Emphasize that turning off computer monitors is 'normal' among colleagues in the office
If I say I will turn off my monitor, then I will do it	Have employees commit to turn off their monitors

[6] See Appendix I for Table 3 from Lockton et al. (2013).

In order to address the aforementioned heuristics that may affect whether people turn off their computer monitor, a set of prompts matching these heuristics were designed. First of all, as shown in Figure 1, a *Reminder Prompt* was placed on each monitor directly next to the power button to indicate that the power button must be physically pressed to turn off the monitor, remind people to turn off their monitor, and show how to accomplish the task. It was also expected that some employees might not have known before the prompts were put in place that the power button must be pressed to turn off the monitor.

Figure 1: The Reminder Prompt



Behavioral interventions were then developed with the aim of modifying the choice context by creating a new set of expectations among employees. Two types of behavioral approaches were implemented and sought to modify the choice context by either (1) establishing public commitment to turn off monitors, highlighting the general norm of the office that most people turn off their computer monitor or (2) providing social feedback (feedback of individual behavior in comparison to others in the office). This aim aligns with the argument made by Lockton et al. (2013) that the application of visual comparisons of an individual's energy use in relation to others can be used in many contexts as well as their argument that commitment and consistency can facilitate behavior change. Only one of the two prompts was applied in each building on the desk/monitor of each employee. The *Social Feedback Prompt* shown in Figures 2a-i and 2a-ii was developed to provide feedback on whether an individual turned off his or her computer monitor before leaving work the previous day. This feedback was shown in relation to whether neighboring monitors were turned off or left on overnight. The total number of monitors turned off in the experimental site was also shown at the bottom of the prompt. The information about neighboring computers was handwritten in either green (for 'off' monitors) or red (for 'on' monitors) individually for the monitor each desk after data was collected for the entire floor of the building. This prompt created a context in which the fact that a slight majority of employees – but not all – in the office turned off their monitors, creating a situation where likely some would want to join the side of the majority. While the prompt shown in Figure 2a-i was used on the first day of feedback, the prompt shown in Figure 2a-ii was used during ensuing visits to the site to show progress on monitor on/off rates compared to the previous week. Feedback was provided for three consecutive weeks in July at the Royal Borough of Kensington and Chelsea's (RBKC) Town Hall, and indicated to employees whether progress was being made towards increasing the number of monitors turned off.

The alternative prompt – the *Public Commitment Prompt* (illustrated in Figure 2b) – was designed in order to engage individuals in publicly committing to turning off their monitor and implemented at all other sites besides RBKC. For this prompt, the imagery of a monitor's power button being turned off (coloring the button in orange, as occurs when the monitor goes into standby mode) and text ("I push buttons") that was used clearly demonstrated what was necessary to turn off the monitors and that a power button illuminated in orange (indicating standby mode) meant that a monitor was still on. The message "I push buttons" also invokes a sense of humor, embracing the fact that behavior change around energy use can be seen by some as pushing people's buttons (i.e. be seen as annoying or petty). Moreover, because the Public Commitment Prompt was placed above each monitor it could be observed by everyone, creating a context in which everyone knew that everyone else in the office 'committed' to turn off monitors and everyone knew that everyone else knew this. The Public Commitment Prompt was complemented on the first day it was put in place with a brief *Explanation Prompt* (shown in Figure 2c) to state why the prompts were installed and also to create a situation where people could choose to 'opt out' of saving energy by removing the prompts from their own monitor. An explanation prompt was not used to complement the Social Feedback Prompt because it was believed that doubling the amount of information placed at employees' desks would yield a cognitive burden. It was also believed that the Social Feedback Prompt was relatively self-explanatory compared to the Public Commitment Prompt, and thus did not warrant further explanation.

Figure 2a-i: The initial Social Feedback Prompt

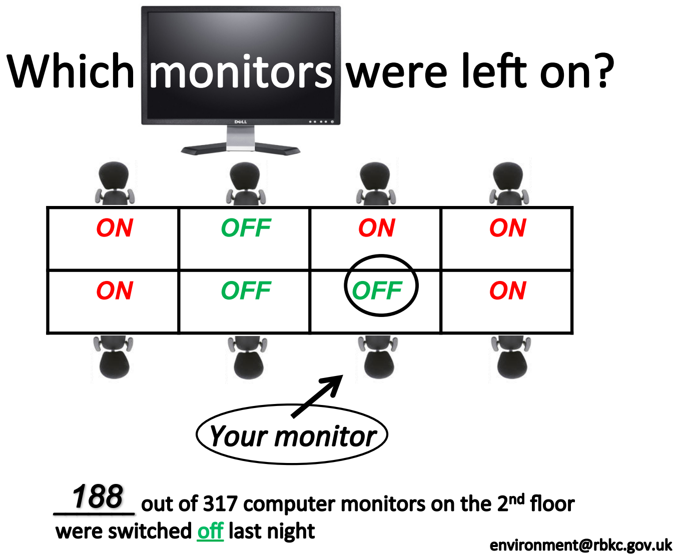


Figure 2a-ii: The ensuing Social Feedback Prompt

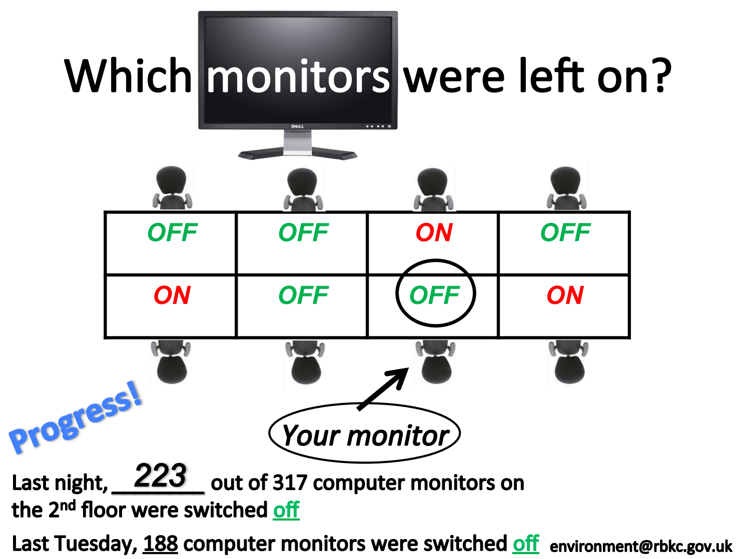


Figure 2b: The Public Commitment Prompt

Figure 2c: The Explanation Prompt

Good morning.

You may have noticed the two new messages placed on your computer monitor.

Please help us save energy in the office by pressing the power button on your monitor when you leave your desk and when you leave to go home.

Energy continues to be used until you press the power button, even when the light is orange.

If you do not wish to join the rest of the office in our commitment to saving energy, you can remove the messages from your monitor.

Figures 3a and 3b are also provided below to demonstrate the appearance of the prompts as was observed by employees.

Figure 3a: Appearance of workstation with Social Feedback Prompt and Reminder Prompt

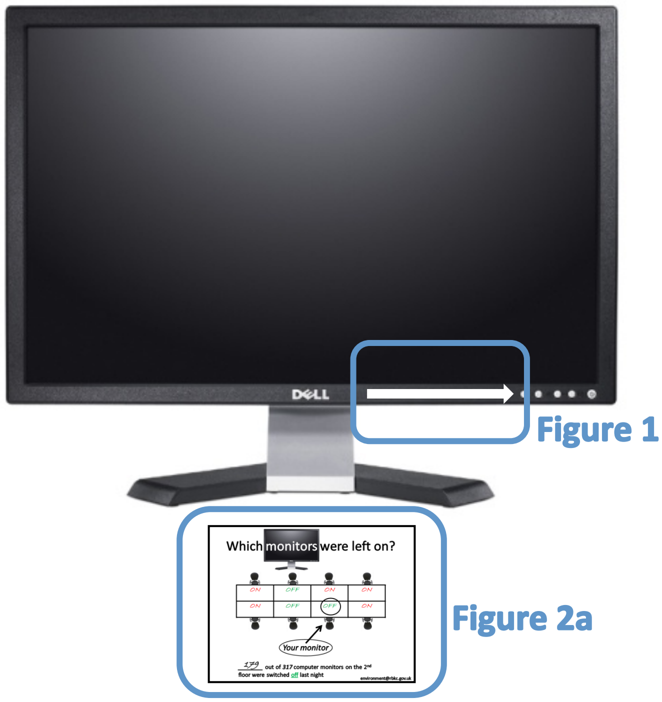
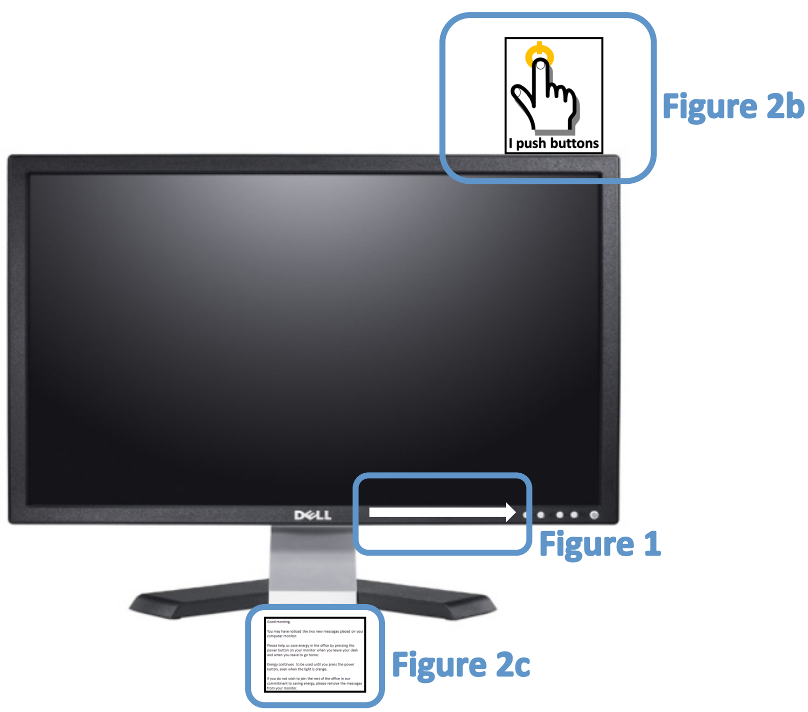


Figure 3b: Appearance of workstation with Public Commitment Prompt, Reminder Prompt, and Explanation Prompt



Both behavior change strategies were designed to invoke new expectations among employees, and in so doing modify the choice context. Offering socially oriented feedback created a new situation in which employees both could compare their own behavior to those in their immediate vicinity and realized that their use of monitors was a source of evaluation. On the other hand, creating an environment where people commit to turning off their monitors posed a new situation in which each employee would be more likely to expect that others would turn off their monitors as well as that others would expect the employee to turn his or her monitor off. It was expected that the implementation of interventions in which the focus was to facilitate new expectations among employees would likely lead to enduring changes in behavior in which a higher proportion of employees would turn off their monitor(s) and therein achieve reductions in energy use and CO_2 emissions.

As will be highlighted in greater detail in the following sections, the use of two behavioral designs allowed for a comparison of strategies based on social feedback versus public commitment in their ability to change the decision context and therein facilitate energy saving behaviors. More specifically, because each prompt was implemented in local council town hall (public) buildings, this permitted comparisons to be made about the relative effectiveness of (1) providing social feedback versus (2) using public commitment to establish the expectations and related norms conducive to instilling a culture around turning off monitors and to create dissonance for those not turning off their monitors which can only be relieved by engaging in the new behavior. Additionally, as will also be explained further, comparisons were made about the relative effectiveness of the public commitment prompt across public, private, and university buildings as well as across organizational departments within a single building.

Visits were made to each participating office on a weekly basis during non-working hours – starting sometime between 5pm-7pm depending on when employees left the particular office – throughout the implementation phase of the interventions to observe the impact of the interventions and collect observational data. The timing of the visits was not announced to employees besides the primary contact person that provided access to enter the building.

Data collection

Observational (proportion) data were collected from July through August 2013 on computer monitors' power status on experimental and control floors in participating buildings. These data show counts of monitors being left on and those being turned off during non-working hours, and thereby served the purpose of capturing the scale of behavior change that took place due to the behavior change strategies. The observational data was collected before the experiment began (the day the experiment was launched at each site) and then – depending on the timeframe when the study was launched at each site – between one to three weeks after the interventions were introduced. These data help provide detail at the granular, individual level about changes that may have occurred as a result of the interventions.

The collection of observational data also addressed the potential risk that changes in monitor on/off rates may not – due to the lower amount of energy savings possible from turning off computer monitors – be captured by electricity meter readings. Hence, even if meter readings failed to show a statistically significant reduction in energy use, the observational data ensured that it would possible to show whether changes in employee behavior took place. Collecting this information in addition to meter readings thereby would contribute to a better understanding of the potential impact of the behavioral interventions in future applications.

Electricity meter readings were collected by sub-meters in each building. These sub-meters were installed in some sites for the purpose of this experiment. This experiment helped some of the building managers justify to their superiors their long-awaited wish to install sub-meters. Kilowatt-hours (kWh) served as the unit of measurement provided by the meter readings. The impact of behavior change on energy use was evaluated in terms of kWh. Sub-metering made it possible to evaluate whether there was a significant change in energy use on the experimental floor(s) relative to the control floor(s). In order to create a common metric for comparison and applying the findings from the study in the future, Nguyen & Aiello (2013) suggest the use of “better evaluation metrics such as kWh/m^2” (p. 253). However, because this study focused on monitors rather than temperature controls or lighting, physical area was of little relevance. Hence it seemed appropriate to use kWh as the evaluation metric. Due to the focus of the behavior change interventions on monitors – a small source of potential energy savings – it was not expected for there to be significant reductions in energy use in participating sites.

At Imperial College London’s Sherfield Building, only the 5^{th} floor could be used for the experiment. It was, however, possible to separate the meter readings for this floor in half. The intervention was applied on half of the 5^{th} floor while the other half of the floor operated normally (served as the control). Each half of the floor hosted a different set of departments and was physically separated by a long hallway, thereby mitigating the risk of contamination from the experimental half-floor to the control half-floor. It was assured by the building’s contact person that little to no communication across the two halves of the floors takes place, so it was likely that little to nothing was known about the behavioral interventions on control half-floor.

There were differences in the frequency of meter readings taken in each building. Meter readings were taken as often as every half-hour in some buildings, while in others it was collected twice daily (once in the morning and a second time in the evening, in order to capture non-working hours). For ease of analysis, meter readings were organized into a standard format of two 12-hour windows to show energy use during work hours (6am-6pm) and non-work hours (6pm-6am).

In the end, it turned out that only the Royal Borough of Kensington & Chelsea’s (RBKC) Town Hall and Merton Council’s Civic Centre could provide sufficiently detailed meter readings. The energy use data analysis thereby includes the meter readings from just these two buildings.

Data analysis

In order to assess whether the behavior change interventions brought about changes in employee behavior and whether they led to significant reductions in electricity consumption, statistical analyses were made using the statistics program *R*.

A quasi-binomial generalized linear model was made to evaluate the relative role of various variables in observed changes in computer monitors' non-working hours power status. This model was selected because the data are – in line with Crawley (2007) – an example of proportion data because it was known how many monitors were in both the 'on' category and in the 'off' category. According to Crawley (2007), model processes involving proportional response variables should be assessed in *R* within the *binomial* family. Moreover, the presence of a two-vector response variable (on and off) in the collected data required these two vectors to be bound together into a binomial denominator. A quasi-binomial function was used rather than a binomial function to account for the potential of overdispersion in the data.

The purpose of producing this model was not for the purpose of the model itself but rather to show whether the interventions brought about significant and lasting changes in behavior, whether there was a significant difference in the impact of social feedback or public commitment in changing behavior, and whether the interventions were significantly more effective in public, private, or university buildings. More specifically, four explanatory variables (each with several levels) were assessed:

(1) *Visit* (pre-experiment and within three weeks after introducing the interventions)
(2) *Treatment* (control; public commitment; social feedback)
(3) *Sector* (public; private; university)
(4) *Organization* (Imperial College London; Merton Council – Environmental Division; Merton Council – Children, Schools and Families Division; Royal Borough of Kensington & Chelsea; Workspace – Arlington Estates; Workspace – Clothes Aid)

It should be noted that the fourth variable, *Organization*, was included to evaluate whether the interventions varied in effectiveness across different divisions within an organization, namely in terms of Merton Council's Environmental (13^{th} and 14^{th} floors) and Children, Schools and Families (9^{th} and 10^{th} floors) divisions. The 9^{th}/13^{th} floors and the 10^{th}/14^{th} floors served as the control and experimental floors, respectively, for each division.

A general linear regression model was also used to analyze the electricity meter reading data collected from the RBKC Town Hall and Merton Council Civic Centre for the first 19 days after the experiment began at each site to determine whether the behavior change interventions led to a significant reduction in electricity consumption over the experimental time period compared to the controls of the experiment. The response variable was the electricity meter readings collected from participating buildings (in terms of kWh). Five explanatory variables assessed:

(1) *Treatment* (experimental; control)
(2) *Days* (number of days after beginning the experiment)
(3) *Hours* (work hours; non-work hours)
(4) *Organization* (RBKC; Merton Council's Children, Schools and Families division; Merton Council's Environmental division)
(5) *Monitors* (number of monitors in each group)

In a similar vein as the observational data, the aim of the linear regression was to determine whether behavioral interventions compel reductions in electricity consumption, whether any observed changes fluctuated significantly over time, and whether RBKC or Merton Council had significantly different reductions in electricity consumption as a result of the interventions. As such, both main and interaction effects were incorporated into the analysis of the meter readings.

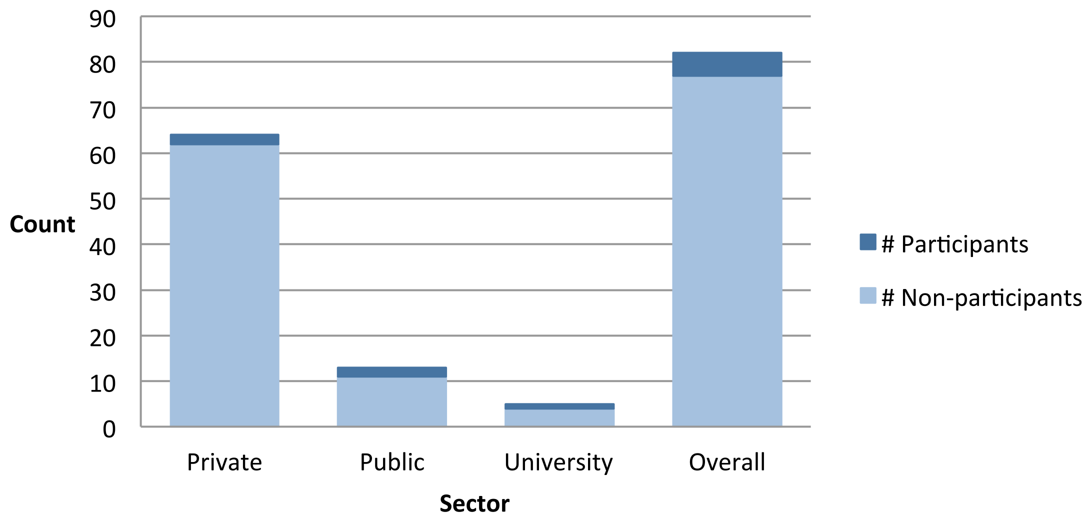
Experimental results and discussion

The experimental results, related statistical analyses, and an interpretation of the results from the behavior change experiment conducted across four London office buildings from July to August 2013 are presented in this section. The results are shown both in terms of observed counts of monitors that were left on/turned off during non-working hours and electricity meter readings. Before offering the analysis and interpretation of the results, a summary is first provided of the recruitment process and the participants involved in the experiment.

Recruitment process

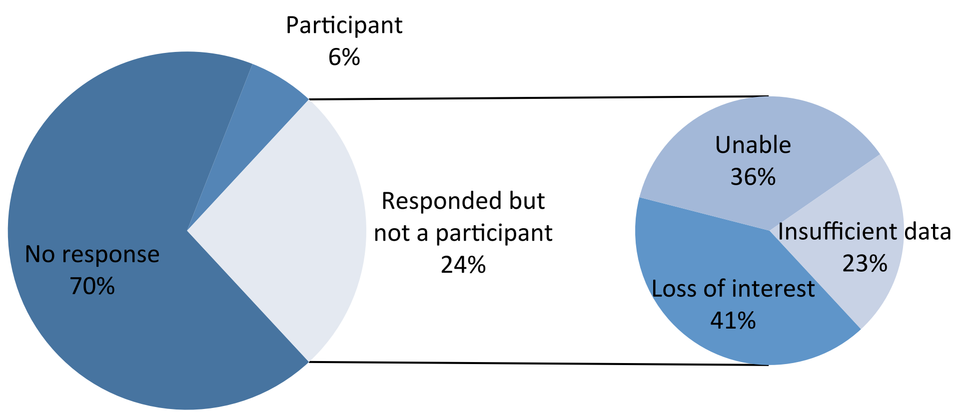
A total of 82 organizations were contacted during the participant recruitment process. These organizations included private companies, government authorities, and universities: 78 percent were private sector organizations while 16 percent were public sector organizations, and 6 percent were universities. There was a large variation across sectors in the recruitment success rate, as illustrated below. While only 3 percent of recruited private sector organizations participated in the experiment, 15 percent of recruited public sector organizations and 20 percent of recruited university buildings participated in the experiment.

Figure 4: Participation among recruited organizations



Of the 82 organizations that were contacted by phone and/or email about participating in the experiment, 57 organizations did not respond, 20 organizations responded but in the end did not participate, and 5 organizations (2 of which are located within the same building) participated. The three primary hindrances for the 20 organizations that responded but did not participate in the experiment included a loss of interest (41 percent), an inability to participate for logistical or bureaucratic reasons (36 percent), and insufficient historic building data and/or lack of sub-metered electricity readings (23 percent).

Figure 5: Recruitment summary



The process of recruiting participants for the experiment highlighted the great difficulty associated with implementing the seemingly easy and 'free' behavior change interventions. First of all, organizations possess a range of bureaucratic hoops that any behavior change intervention must go through in order to be implemented. The strategy might be thwarted outright at one of the levels of the bureaucratic structure, watered down in such a way that renders the behavior change measure ineffective and/or relatively meaningless, or may simply be placed at the bottom of the to-do pile. Second, even if the behavior change intervention is agreed upon by all of the necessary players it may fail to be implemented, be implemented poorly, or be implemented half-heartedly. This includes the failure to engage staff on the need to adopt the given changes in behavior and demonstrate how the new behaviors align with the values of the organization and the daily work of employees. Finally, measuring the impact of behavioral interventions may be difficult. The availability and type of energy use data at the disposal of an organization will affect its ability to evaluate the success of any behavior change measure. In hindsight, however, since the targeted behavior change ended up involving computer monitors – a low source of energy use – organizations that were dismissed due to a lack of electricity sub-meters could have been included for just the observational (proportion) data component of the experiment.

Participants

Five organizations across four buildings in London participated in the experiment. The buildings included Imperial College London's Sherfield Building, Merton Council's Civic Centre, the Royal Borough of Kensington & Chelsea's (RBKC) Town Hall, and Workspace's LeRoy House. Buildings from the public, private, and university sector were thus involved in this study. While the implementation of the experiment in the public and university sector buildings included a large number of employees and monitors, the private building (Workspace) included a relatively small sample. There was only so much that could be done given the timeframe and recruitment process to have large samples from each buildings sector. Each of the buildings made use of an open office plan, meaning that all of employees worked in a shared space (where everyone is visible).

RBKC's Town Hall had several distinguishing characteristics compared to the others. In addition to being the only site where the social feedback prompts were used, the Town Hall was recently renovated and had in place particularly energy efficient office equipment, an automated lighting control system, and automated temperature control system. Moreover, the building made use of 'hot-desking', meaning that no employees had an assigned desk. Employees also did not have access to person computers (PCs); each employee had a laptop that would be plugged into a monitor at the desk where they happened to sit during a particular day. Employees at RBKC's Town Hall for the most part therefore sit in a different place (on the same floor) from one day to the next.

Table 2: A detailed summary of the participants in the experiment

Organization	*Sector*	*Building*	*Floor/Office in Building*	*Intervention type*	*# of monitors*
Imperial College London (IC)	University	Sherfield Building	5th floor, non-Queen's Tower side	Public commitment	110
			5th floor, Queen's Tower side	Control	50
Merton Council (MC)	Public	Merton Civic Centre	10th (CSF) & 14th (Env) floors	Public commitment	221
			9th (CSF) & 13th (Env) floors	Control	194
Royal Borough of Kensington & Chelsea (RBKC)	Public	Kensington Town Hall	2nd floor	Social feedback	317
			3rd floor	Control	288
Workspace (Work)	Private	LeRoy House	Office 4B, Arlington Estates	Public commitment	14
			Office 4N/R, Clothes Aid	Public commitment	5
			Total computer monitors, Experimental Group		**667**
			Total computer monitors, Control Group		**532**
			Total computer monitors, overall		**1,199**

It should be clarified that the observational data collection from these sites was based on the number of *monitors* rather than the number of *employees* for three reasons. First, the number of monitors and number of employees was approximately the same (except for about several dozen instances at Imperial College London and Merton Council where employees had two or three monitors at their desk). Second, because the focus of this study revolved around capturing energy savings from monitors it makes sense for numbers to be collected on monitors. Lastly, not all organizations had easy access to determining the number of employees working on each floor at a given time.

As indicated in the table above, the public commitment prompt was implemented in three buildings (public, private, university) while the social feedback prompt was implemented in one building. There were a total of 1,199 computer monitors across all experimental groups included in the experiment, in which 667 were in experimental groups and 532 were in control groups.

Behavior change: results and discussion

Table 3 below displays the results of the observational data that was collected before the behavioral interventions were implemented and then one to two weeks after the interventions were implemented. The table indicates the proportion (in percentage terms) of the monitors that were turned off during non-working hours at each site. Figures 6 and 7 are also presented to provide a visual representation of the observational data results. Figure 6 highlights the overall results across the control group, public commitment, and social feedback groups. Figure 7 provides greater detail by distinguishing between buildings in the impact of the behavioral interventions.

Table 3: Observational data results (Visit 1 versus Visit 2)

Organization – Site (treatment group)	*Visit 1, pre-intervention*			*Visit 2, post-intervention (1-3 weeks)*		
	# ON	# OFF	% OFF	# ON	# OFF	% OFF
Imperial College London – 5th floor (control)	30	20	40.0%	24	26	52.0%
Imperial College London – 5th floor (experimental)	50	60	54.5%	31	79	71.8%
Merton Council – 9th floor (control)	26	30	53.6%	27	29	51.8%
Merton Council – 13th floor (control)	58	80	58.0%	67	71	51.4%
Merton Council – 10th floor (experimental)	55	79	59.0%	29	105	78.4%
Merton Council – 14th floor (experimental)	36	51	58.6%	18	69	79.3%
RBKC – 3rd floor (control)	97	191	66.3%	98	190	66.0%
RBKC – 2nd floor (experimental)	129	188	59.3%	64	253	79.8%
Workspace – Arlington Estates (experimental)	4	1	20.0%	2	3	60.0%
Workspace – Clothes Aid (experimental)	8	6	42.9%	3	11	78.6%

Figure 6: Behavior change by experimental group (Visit 1 versus Visit 2)

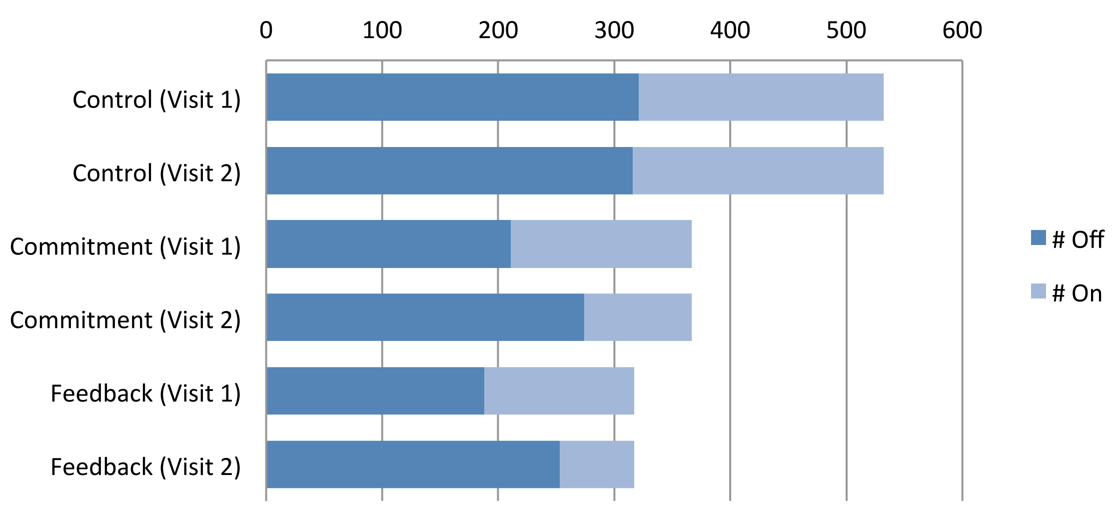
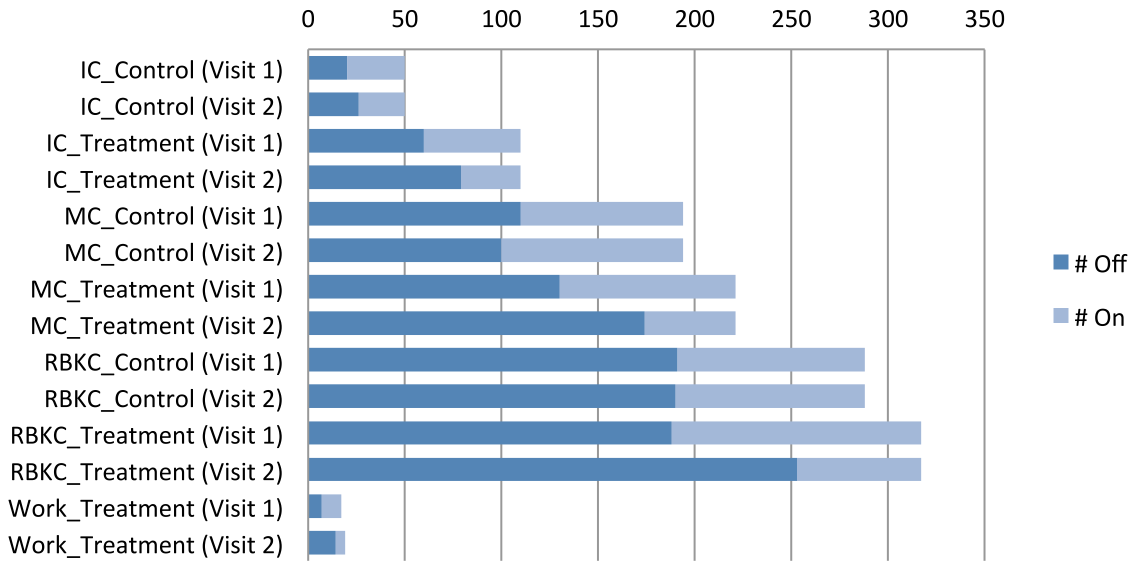


Figure 7: Behavior change by building and experimental group (Visit 1 versus Visit 2)



Both the observed number and proportion of monitors turned off increased sharply in all experimental groups, while for the control groups across participating buildings the number and proportion of monitors turned off either decreased, increased slightly, or remained essentially unchanged. Overall, there were 40.4 percent and 50.4 percent decreases across public commitment and social feedback groups, respectively, in monitors left on during non-working hours. While these reductions in off monitors took place in both experimental groups, there was at the same time a 2.4 percent *increase* in monitors left on across control groups. At first glance it thus appeared that the behavioral interventions were quite successful in facilitating behavior change.

The output from the quasi-binomial generalized linear model[7] revealed that the behavior change interventions led to a statistically significant change in behavior (at the $p < 0.05$ level). There was a significant increase in the monitors turned off during non-working hours in the experimental groups between the pre- and post-intervention stage, while during the same period of time there was no significant change in the power status of monitors across control groups. The explanatory variable *Visit* therefore helps explain the significant differences that were observed between the experimental and control groups in the power status of monitors during non-working hours monitor.

[7] See Appendix II for quasi-binomial generalized linear model output.

The explanatory variable *Treatment* was significant only for the control group because this group possessed a significantly higher proportion of monitors left on compared to either of the two experimental groups (public commitment and social feedback). Thus, although it was found that where public commitment or social feedback was implemented that there was a significantly different proportion of monitors left on/turned off – as indicated by the explanatory variable *Treatment* – neither was on its own significantly better than the other in facilitating behavior change. Public commitment and social feedback were therefore similar in their effectiveness in achieving significant change in behavior.

These results strongly suggest that interventions modifying the choice context through the creation of new expectations among employees will compel a significant change in behavior. Since both the social feedback and public commitment approaches brought about significant behavior change relative to control groups, it seems that it is not the specific way in which new employee expectations is brought about that matters but rather (and simply) the very creation of new expectations and workplace norms. A new set of expectations hence appears to have provided an enabling environment wherein the energy-saving behavior – in this instance, turning off computer monitors – would become adopted by a large majority (70-80 percent) of employees.

These results are similar to those found in a controlled experiment conducted in the residential sector by the company Opower: the inclusion of socially oriented feedback (in this case, in comparison to neighboring homes) on home energy reports led to significant behavior change, as indicated by an average 2 percent reduction in energy use per home versus those in the control group (Allcott & Mullainathan, 2010-b).[8]

In a study yielding similar results and using an approach quite similar to the social feedback approach used in the present experiment but in a different setting, Goldstein et al. (2008) found in a controlled experiment that the use of descriptive norms is much

[8] See Appendix II for a copy of the feedback letter that Opower provided to households.

more effective in increasing the reuse of towels in hotel rooms compared to appeals of environmental protection. In other words, a sign saying stating how the majority of hotel guests reuse their towels is more effective than asking people to reuse their towels to save the environment. In a follow-up experiment, they also found that the closer the match to the individual's (hotel guest's) immediate circumstances, the further the increase in reuse rates. It was found that stating the percentage of previous guests in the same hotel room that reused towels was the most effective approach, leading to nearly half of guests receiving this message to reuse their towel. In comparison, the standard 'save the environment' type approach yielded a reuse rate of about 37 percent. Perhaps the most interesting result was that towel reuse participation rates "were actually highest for the reference group [same room identity descriptive norm] that participants felt was the least personally meaningful to them (but most physically proximate)" (Goldstein et al, 2008: p. 479). Individuals thus underestimate the impact of norms on their behavior, even though norms can be the strongest predictor of individual behavior.

The findings associated with *Visit* and *Treatment* also demonstrate that small interventions can facilitate drastic change among employees. This suggests that other small interventions that invoke new workplace norms could be implemented to address other sources of potential energy savings in office buildings, namely those relating to lighting, heating/cooling, and office electronics that consume greater levels of energy compared to computer monitors when left on during non-working hours.

The output from the quasi-binomial model demonstrates that the third explanatory variable *Sector* was statistically insignificant. The impact of the behavioral interventions was hence relatively similar across the three sectors. The insignificance of *Sector* indicates that small interventions can work equally well across sectors in changing behavior. The behavioral strategies work in and of themselves in facilitating change, regardless of the type of organization involved and energy saving efforts that have already been implemented by an organization. Moreover, because similar proportions of observed on/off monitors were found across sectors before and after beginning the experiment, it appears that no sector is particularly better than the other in capturing potential energy savings associated with behavior change.

Finally, it was found that the fourth explanatory variable *Organization* was also statistically insignificant. The interpretation of this result should be similar to that of sector: the interventions worked equally well in facilitating change across organizations. However, it is true that what is captured by *Organization* will be related to *Sector* given the nature of the number of organizations participating in this study. Yet it should be recalled that the purpose of having the *Organization* variable was to make intra-organizational analyses and, more specifically, to compare the impact of the interventions on Merton Council's Environmental versus Children, Schools and Families divisions. The insignificance of the *Organization* variable therefore should be interpreted as indicating that the behavioral interventions were similarly effective in bringing about statistically significant behavior change in both divisions.

Electricity meter readings: results and discussion

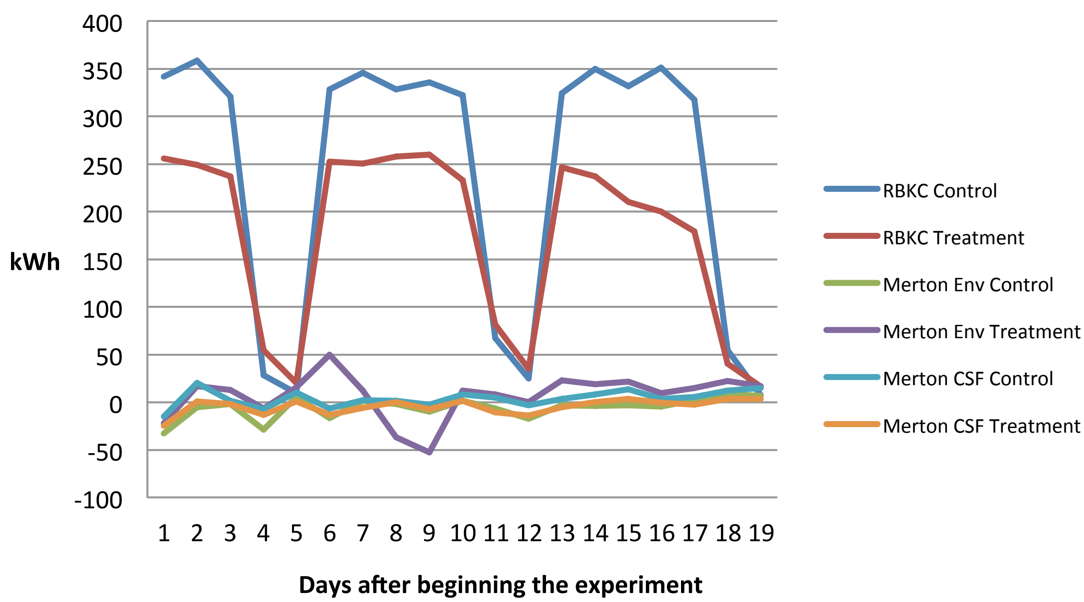
The general linear model output[9] indicates that the impact of the behavior change interventions on building electricity consumption were, as expected, insignificant. In addition to *Intervention* being insignificant, the explanatory variables *Days*, *Organization*, and *Monitors* (and any of their interactions) were also insignificant. Even though energy savings were achieved through the significant changes in behavior that were observed, these savings were too small to significantly change the participating buildings' overall energy use.

However, the explanatory variable *Hours* proved to be highly significant for RBKC but not for Merton Council. The stark difference in electricity consumption between working and non-working hours at RBKC and Merton Council can be visually observed in Figure 8 below. RBKC tends to have much lower electricity consumption during non-

[9] See Appendix II for general linear model output.

working hours compared to working hours, while Merton Council hovers a near zero difference between working and non-working hours. It is worth noting that due to the nature of how meter readings were collected, weekend days were included in the 19 days of RBKC's data but not for Merton Council's, hence helping to explain the sharp dips in RBKC's electricity use on days 4, 5, 11, 12, 18, and 19 after the experiment began. While there was little difference in RBKC's electricity consumption during these weekend days between the AM and PM hours, though, the overall level of electricity consumption was similar to (and often less than) non-working hours during weekdays[10]. RBKC thus sharply reduced energy use during both non-working hours on weekdays as well as all hours of weekend days. Merton Council, on the other hand, consumed similar levels of electricity at all hours.

Figure 8: Difference in electricity consumption between working and non-working hours



RBKC's recent energy efficiency retrofit, automated lighting controls throughout the entire building, use of energy efficient office electronic devices, and lack of PCs (employees use laptops that are connected to monitors during the day and then store them at night) may explain the significant difference between energy use during working and non-working hours. At Merton Council, which has not yet made these types

[10] See Appendix II for electricity meter readings data.

of investments, energy use is relatively similar during all hours of the day, whether or not people are in the office. These results therein suggest the importance of using best available practices and technologies in reducing energy use, as was shown to be the case in RBKC's Town Hall. It seems that greater investment should be made by other organizations to ensure that – in addition to behavior change – that best available technologies and practices are put in place.

Should this be of interest, the level of energy savings for the specific strategies used in the experiment can be roughly estimated nonetheless based on the observed changes in behavior. The estimates include the following assumptions: 0.5246kg CO_2 per kWh and £0.13/kWh for UK grid electricity (Carbon Smart & Ricardo-AEA, 2013), 14 hours per weekday and 24 per weekend day that are non-working hours, and ~1 watt saved per monitor turned off (Webber et al, 2006). Based on this, for every 100 computer monitors it can be expected for the social feedback prompts to yield £33.50 in annual cost savings plus 135.20kg reductions in CO_2 emissions, the public commitment prompts to yield £26.86 in annual cost savings plus 108.37kg reductions in CO_2 emissions, and the control (doing nothing) to yield an increase in annual costs by £1.60 and CO_2 emissions increase of 6.44kg. These values would be greater for less efficient monitors.

Experimental process: comments

Several comments should be offered in regards to the implementation of the behavior change interventions during the experiment. Unsurprisingly, given that the interventions were put in place on each and every monitor in the experimental groups, several employees submitted electronic messages were either asking questions or filing a complaint in regards to the interventions. Yet, given the fact that there were over 1,100 employees involved in the experiment, it was surprising that only eight messages were received by the author. Six messages were forwarded from employees at RBKC and one message was forwarded from both Imperial College and Merton Council. The six messages from RBKC largely reflected a frustration that – due to the use of hot-desking and the fact that social feedback was provided based on monitors – individual efforts to turn off monitors were not necessarily reflected on social feedback prompts at the desk where an employee would choose to sit the following day. The pair of messages submitted by employees from Imperial College and Merton Council – where public commitment prompts were installed – expressed a disliking of the intervention because it seen as antagonizing or a belief that the intervention would lead to more harm than good.

Nevertheless, despite the (relatively few number of) messages submitted by employees, the behavioral interventions led to a statistically significant change in behavior. While it may have been interesting to have observed how employee beliefs and perception were affected by the interventions, what matters more is that a significant change in behavior occurred. Were the interventions designed differently so that computer monitor's energy use was less salient for employees, then such interventions may have been more widely supported yet also less effective.

There was a potential risk in conducting the experiment that members of staff would recognize the author. This could in turn compel employees – upon seeing the author present in the office – to turn off monitors of other employees that had already left the office. However, because site visits took place during non-working hours the offices were in most cases entirely empty. There were a few employees (approximately five) at RBKC's Town Hall that happened to still be in the office when visits were made and recognized the author, but they did not leave their desk during the time the author observed the status of computer monitors in their respective area of the office.

Limitations and opportunities for future research

There are several limitations of the experimental findings as well as the study more broadly. The limitations must be considered in relation to what may be expected should similar behavioral approaches used in the experiment be applied in other settings or on a larger scale. By considering the limitations it can be ensured that the interpretation of the experimental findings considers the scope of this experiment. Moreover, these limitations present new research questions and thus opportunities for future research.

First and foremost, this experiment involved behavior change interventions targeting a small source of potential energy savings and related reductions in CO_2 emissions. However, due to there being only three months to enact all of the components involved in this experiment there was only so much time available to identify sources of potential energy savings as well as design and implement the interventions. Furthermore, computer monitors left on or in standby mode was a source of wasted energy in each of the sites that agreed to participate and thus enabled cross-organizational comparisons. The desired change in behavior was also easy for employees to adopt and thus provided an opportunity to evaluate whether a small intervention could bring about dramatic changes across different organization types.

The experiment only addressed the role of behavioral interventions in reducing energy use. There are certainly many opportunities to boost energy savings through more efficient technologies, such as insulation, double glazed windows, improved lighting and lighting control systems, as well as more efficient computing systems. However, many of these energy efficient technologies yield greater costs than behavioral measures and sometimes possess a multi-year payback period that can be longer than an occupant plans to stay in a given building. By focusing solely on behavior change the present study therefore investigates to potential energy and related cost savings that any organization can pursue with little to no financial cost.

Due to the limited timeframe of the experiment, it was not possible to determine whether the changes in behavior were enduring much beyond several weeks. It would have been ideal to see whether the new behaviors 'stick' over a longer period of time and become ingrained habits, but only three months were available to recruit participants, run the experiment, and interpret the findings. In accordance with the literature review, it seems likely that the behavior change would stick if (and only if) the norms/expectations, organizational culture, and broader organizational mission became aligned with objective of reducing energy use. Because the interventions revolved around creating a new set of expectations among employees and the fact that the changes remained intact for several weeks, it seems fair to presume that a measurable portion of changes will remain intact moving forward.

The nature of the timeframe available for the study also meant that the behavior change interventions could only be implemented and observed during the summer months. It would have been preferable to observe the impact of the interventions over an entire year in order to see if there would be differences in the scale of energy savings across seasons. There may have also been other potential opportunities for energy savings during winter months and a related alternative possible behavior change interventions that could be implemented.

The aim of the study was to assess the energy savings that could be achieved by organizations within the context of office buildings. It did not assess opportunities for energy savings in the physical goods or services that participating organizations provide.

The study did not assess the spillover effects in terms of how organizations use cost savings from reduced energy consumption. It is possible that the cost savings from reducing energy use could be invested in measures that lead to greater carbon dioxide emissions than that which was saved through the energy reductions. This could occur directly, such as more frequent business trips by plane, or indirectly, by employees using higher salaries to buy new products or services that emit more carbon dioxide than what was saved. This issue presents a topic of future research.

Different building types will have different levels of potential energy savings through behavior change. The kinds of behavior change interventions involved in this study may have a larger impact on buildings that are less efficient more generally in its use of energy as well as buildings possessing occupants whose work is more energy intensive. There is likely therefore less potential for behavior change to significantly reduce energy use in some of newer, highly energy efficient buildings containing energy efficient devices.

The participants in the experiment were those responding to the initial recruitment related communications and thus may have certain characteristics uncommon to other organizations. Participating organizations were hence receptive to reducing energy use as well as CO_2 emissions. Nevertheless, it is likely that organizations receptive to the aims of the experiment would have already enacted at least some efforts to reduce energy use. It is thus probable that behavioral opportunities for energy savings may be greater among non-participants.

The findings may be limited because the experiment only involved buildings in London and may capture neither the physical characteristics nor the workplace culture in office settings found elsewhere across the globe. Nevertheless, this limitation may also serve as a strength: since office buildings in London are likely to be more energy efficient compared to other buildings across the globe and since the climate is relatively mild, the scope for energy savings through behavior change is probably greater elsewhere. And despite the fact that all participating buildings were located in London, because the experiment focused on the broader opportunities for energy savings through behavior change in office buildings and involved participants from several sectors it is fair to presume that similar behavioral interventions focusing on creating new expectations and norms among employees could be applied in buildings across the globe to capture the various forms of behavioral opportunities for energy savings.

Finally, the present study does not raise deeper questions regarding the broader relationships between employees and the various ways in which energy has become structurally embedded in the office. Future research should investigate methods for completely reorganizing office work and reducing the structurally embedded energy use found in the typical workplace.

Policy recommendations

There are significant opportunities to capture energy savings in office buildings, especially during non-working hours. Existing research and the experimental results from the present study indicate that these savings can be reigned in through both behavioral and technological means. Moreover, the potential reductions in energy use and related costs generally range from 'free' or low cost measures to ones that pay back in just a few years. The empirical evidence, however, is that many organizations are reluctant to take advantage of these opportunities, meaning that currently available and major climate change mitigation opportunities rest on the shelf. In other words, organizations appear at present to be generally failing in capturing the so-called low-hanging fruit of climate change mitigation. As such, there is a need for new approaches that unleash a wave in the adoption of both behavioral and technological energy savings in office buildings.

Any organization that plans to remain in place for longer than at least a handful of years has a basic financial incentive to adopt measures that save energy as well as address climate change, due to the expected scope and interlinkages of its impacts. Yet it appears that the financial incentive is largely insufficient on its own. The adoption of voluntary measures to reduce energy use and CO_2 emissions seems to have reached a plateau. It therefore appears that a wide gap exists between the private and social costs associated with energy consumption and related greenhouse gas emissions. The negative externalities associated with greenhouse gas emissions that organizations impose on society by failing to adopt energy saving measures inflict too small a cost on organizations. In other words, polluting is cheap. And thus the solution is quite simple: all that is required of policymakers is to simply resolve this instance of market failure by establishing more accurate prices. Thus all that policymakers need to do is establish a price on greenhouse gas emissions. Such a law could be written in a few sentences (unlike for strategies like cap-and-trade). In order to ensure the simplicity and market efficiency, these prices should be implemented through a tax on greenhouse gases across the entire economy, without exceptions, without asterisks. Otherwise failed markets will continue to exist and reap unnecessary financial, environmental, and other social costs.

It is likely that a (steep) tax on greenhouse gases would encourage organizations of all shapes and sizes to quickly find ways to reduce their energy consumption. This would be achieved in as efficient a manner as is possible. Unlike one-size-fits-all strategies like technology standards, a universal greenhouse gas tax inherently possesses the flexibility that allows organizations to choose the strategies that best 'fit'. While both a tax and, for example, setting new standards for buildings would likely compel organizations to encourage their employees to adopt new energy saving behaviors, the tax better enables organizations to do what makes sense given the context of its particular office(s). A tax does not confine the options taken to reduce emissions. The behavior change – as well as technological – measures that work in one office context may not work in another. And if an organization does not wish to adopt the changes, then it just pays a tax to better account for the social costs associated with its activities.

However, due to the lack of willingness by policymakers on all parts of the political spectrum to do what is necessary to create a more properly functioning market – which yields fewer social costs and greater future prosperity by mitigating the effects of climate change – it is likely that a tax on greenhouse gases will not be established in the near future. It is therein worth exploring second-best policy measures. As was indicated in the meter readings collected for the present study, buildings where the latest energy efficiency improvements are made significantly reduce energy use during non-working hours compared to working hours. All buildings should make similar improvements. In addition to requiring all new office buildings to meet a certain level of energy efficiency – both in terms of materials (insulation, windows, lighting fixtures, etc.) and technologies (automated controls for temperature, lighting, electrical outlets, printers, etc.) – policymakers should also require any office space put on the market to meet similar energy efficiency standards before it can exchange hands. Many office buildings will thus require energy efficiency retrofits before they can be sold, leading to higher prices for office spaces. This essentially is a roundabout way to implement a tax on greenhouse gas emissions, under the name of 'building standards'. While the creation of buildings standards is less economically efficient than a carbon tax, it may be more palatable to policymakers and therein in fact be implemented.

The recruitment and experimental process undertaken here has highlighted the challenge of change within organizations. The forces of organizational inertia combined with bureaucratic obstacles and feelings of reluctance among employees to adopt new habits render behavior change measures in office buildings even more difficult that may have been expected. Because behavior change in organizations is more difficult to implement in practice than in theory, the easiest route to reducing the energy use directly associated with individual behavior is to remove the 'behavior' from the equation. For instance, in the case of the present experiment, were monitors to turn off entirely on their own without needing the power button to be pressed than the behavior change targeted in the experiment would become irrelevant. There would be nothing left to change; the energy would be saved through the technological improvement. Similarly, the use of automated temperature settings, lighting controls, printer settings, and electrical outlet timers would reduce the need for behavior change in office settings. These technical switches would likely be installed by organizations should a tax be established for greenhouse gases. Otherwise, they should be included within the proposed office building standards requirements for new and existing buildings.

The recruitment and experimental process in the present study indicated that organizations – no matter how much they may or may not like the sound of behavior change – shirk to wholeheartedly embrace behavior change measures. It was certainly the case that universities and public sector organizations were much more receptive to being involved in the experiment in comparison to private sector organizations. From the various conversations that took place with representatives of universities and public sector organizations, it appeared that these organizations place greater value on the need to reduce greenhouse gas emissions and reduce operating costs, even if these reductions are relatively small and achieved in relatively 'boring' ways. It seemed that these organizations were eager to find ways to reduce costs, especially if the cost reductions measures were 'free' in financial terms. The recruitment results may thereby compel a favorable opinion of the functioning of universities and public sector organizations, while also an unfavorable opinion of the lacking participation among private sector organizations. Perhaps because universities and governments increasingly have their own CO_2 emission reduction targets helps explain why they are making more efforts to reduce emissions and related costs. However, an increasing number of private sector organizations – including many of those that did not participate in this study – also have their own internally set CO_2 emission reduction targets and aims to reduce waste throughout their organization. This then suggests several potential explanations for a lack of interest by private sector organizations to participate in the experiment. One may then conclude that perhaps private sector organizations are confident that they already have in place best practices in terms of efficient use of resources in their office buildings, that they place much more emphasis on increasing revenues than reducing costs in evaluating their bottom line and do not want to distract employees from core tasks, that they have realized the difficulties associated with organizational change and decided it was not worth investing time and effort in behavior change measures, that they find the energy use and cost savings from behavior change to be meager in comparison to those associated with new technologies and thus not worth adopting, and/or perhaps that behavior change is simply not sufficiently exciting to warrant attention. Nevertheless, whatever the rationale, the lack of expressed interest by private sector organizations was stark.

Yet the experiment revealed the interesting result that there are few differences in the impact of energy saving – in this case, behavioral – measures once they were implemented. Strategies that sought to create new expectations and norms among employees in private sector, public sector, and university buildings led to significant reductions in the targeted wasteful energy practice. This suggests that for at least some behavior change measures that the impact will be similar across sectors. The lack of receptivity in the recruitment and experimental process should thus be the center of focus; the focus should be placed on how to effectively spur widespread energy saving measures in office buildings. This signal does not appear to reflect the scale of impact of energy saving measures. Because it appeared in the recruitment process that organizations have largely plateaued in the efforts they are willing to make on their own to reduce greenhouse gas emissions, it seems that an external force – primarily, law – is essential to capture the full scale of opportunities to address climate change through energy efficiency.

Voluntary efforts are insufficient on their own to compel the change needed to alleviate the scale and scope of the expected impacts from climate change. There is a dire and justifiable need for strong, expansive policy measures that better resolve the collective action problem known as climate change and provide public goods like environmental quality. The point of having a government in the first place is to address those – and primarily those – situations where no individuals have the direct interest to contribute, yet where if no one contributes then everyone is worse off. If it is not possible for government action to be made to resolve collective action problems and provide public goods that directly supports the foundation upon which all of society rests, then one should doubt the legitimacy of government and its institutions.

Conclusions

Small interventions in office buildings can compel dramatic change in behavior associated with energy use. With a minimal set of conditions being met – i.e. by creating a new choice context, which in the case of the present experiment involved employee expectations and workplace norms – behavior change measures can bring about energy saving behavior.

Organizations appear to be generally failing to capture the low-hanging fruit of energy savings. There exist behavioral opportunities to reduce energy use in office buildings, especially during the non-working hours when they are empty, that organizations could – and should – fully seize but at present are not. The question therein becomes how best to encourage organizations to capture these savings so that they reduce energy use and associated negative externalities such as greenhouse gas emissions. Based on the observations made both during the recruitment and experimental process suggest that efforts by organizations to address energy use have plateaued. Policymakers (and other stakeholders) should find ways to ensure that organizations reduce energy use, especially the often 'free' or minimal cost low-hanging fruit that organizations do not even appear to be fully capturing.

While organizations are composed of a unique set of individuals and vary in the way they go about their work, there are certain components of behavior change measures conducive to increasing adoption rates as well as their 'stickiness', or their endurance over time. People will behave in relation to the context of their respective organization's workplace culture and thus it is unlikely for a large share of employees to capture behavioral opportunities for energy savings in office buildings in a context where energy use fails to be salient or important. Similarly, by bringing about a new context wherein energy use is salient and important it is likely that organizations can facilitate energy saving behaviors.

Behavioral interventions involving a social dimension (such as norms and socially oriented feedback) that modify what people expect of each other and what each individual thinks others expect of them – and therefore bring about a new decision-making context – appear to be likely to facilitate lasting behavior change. Even though the way in which an organization might go about making existing pro-environmental behavioral norms salient or facilitating new pro-environmental behavioral norms in an office setting may very well differ, the need to engage in these types of actions is critical across all organizations to reduce energy use and related greenhouse gas emissions. Should the objective be to instill lasting behavior change, it is therein essential that interventions directly address the values, meanings, and expectations that shape the context of individual decision-making in the office. Otherwise – as is at present most often the case with the general approach pursued by organizations to encourage pro-environmental behaviors – the desired changes in behavior will merely be adopted by a fraction of employees in an inconsistent fashion.

It is difficult to say exactly how further behavioral measures should be implemented to capture energy savings. They can likely be applied to address various sources of unnecessary energy waste existing in office buildings. The behavioral interventions used in the present experiment provide insights such as the role of modifying employee expectations and norms in creating a new choice context that is conducive to energy saving behavior. However, the particularities of each potential energy saving behavior imply that different factors should be taken into account when designing behavioral interventions. For example, behavioral interventions associated with temperature or lighting may involve greater coordination between employees. These questions present an offering for future research.

The field experiment presented in this paper highlights one step that organizations can take to reduce energy use. By creating a new set of expectations among employees, organizations across various sectors can expect change to occur in the behaviors associated with energy use in the workplace. There are likely other and larger measures that organizations can pursue – such as investments in energy efficient technologies and the enactment of automated controls for lighting, temperature, electrical outlets, and office electronics – to dramatically modify relationships employees have with energy in office buildings as well as the choice context associated with office energy use. The potential energy savings in office buildings is therefore rife with opportunities for further research, both in terms of how energy use can be transformed in office environments as well as how best to ensure that such transformations are in fact implemented by organizations.

Barring a transformational transition to non-carbon energy sources in the very near future, energy efficiency rests at the core of climate change mitigation strategies. Yet despite widespread knowledge about how to save energy, the availability of energy saving technologies, and broad support to adopt energy efficiency measures, organizations are failing to capture the low-hanging fruit of climate change mitigation. The clock keeps ticking with each passing day as the accumulation of greenhouse gases in the atmosphere continues due to fossil fuel-based energy sources and as the period of time passes in which mitigation strategies like energy efficiency will have their greatest impact. It seems quite clear that strong policy measures such as a tax on greenhouse gases or, as a second-best approach, greater energy efficiency requirements for both new and existing office buildings are needed to catalyze the adoption of the vast array of mitigation strategies currently available. Otherwise the positive impacts associated with the low-hanging fruit of climate change mitigation may very well sour over time and therein demand a larger scale of adaptation measures to be taken than should be necessary.

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Appendix I – Figures from background research

Data from US Department of Energy's Buildings Energy Data Book, 2012

Figure A: US primary energy consumption, by type

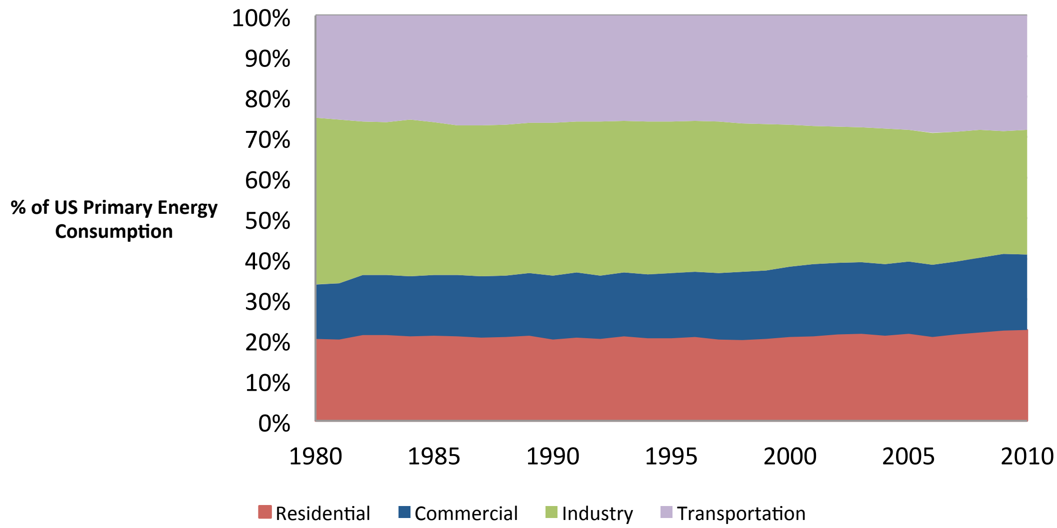


Figure B: Share of US primary energy consumption, by type

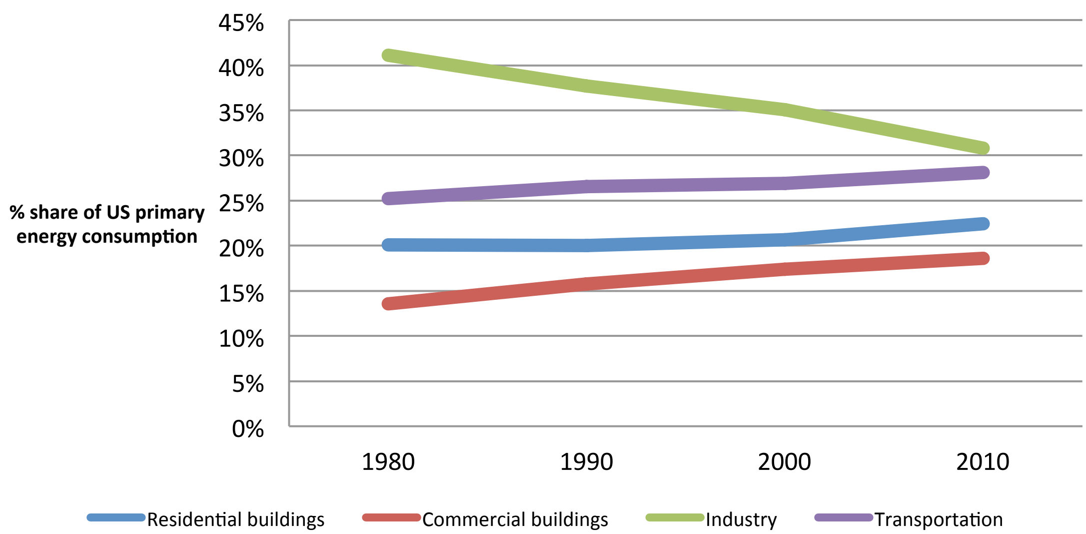


Figure C: Commercial buildings electricity consumption

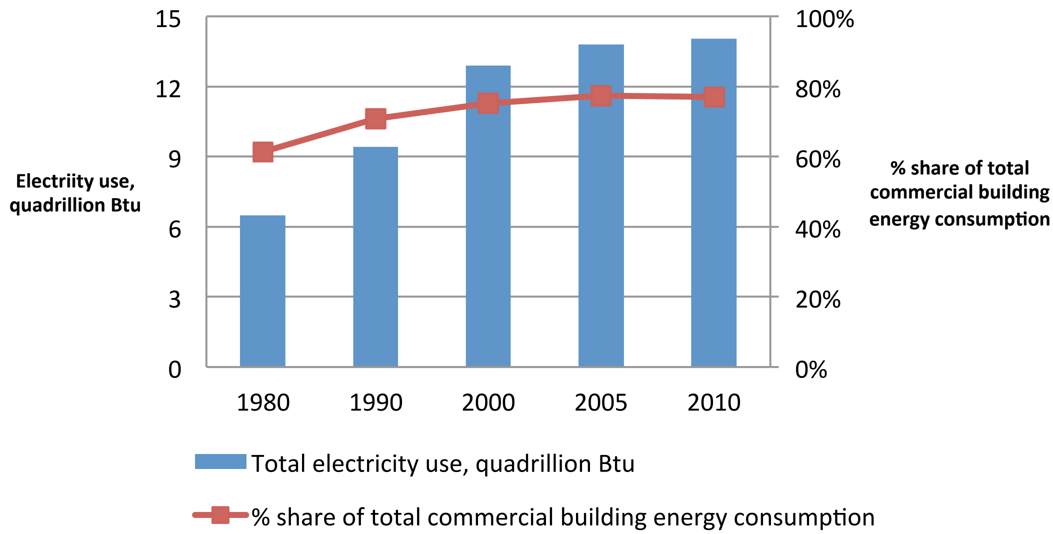


Figure D: 2010 Commercial buildings energy consumption, by end use

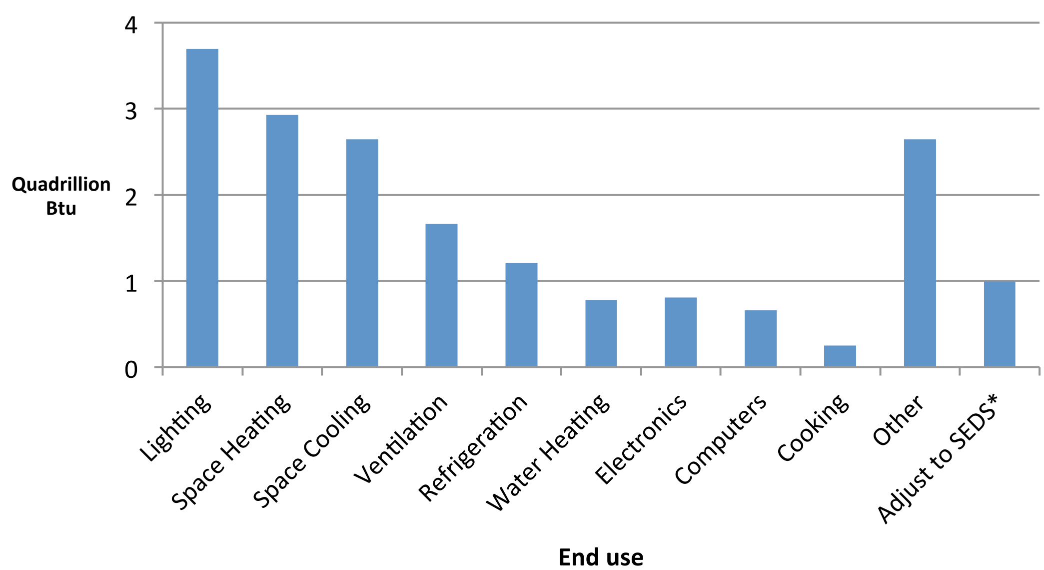


Figure E: Commercial buildings energy consumption, by % share end-use (2010)

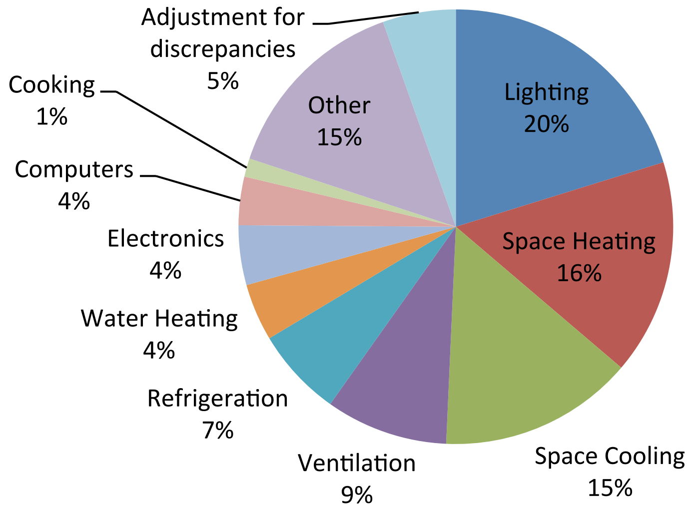


Figure F: 2010 Commercial energy end-use expenditure splits ($2010 billion)

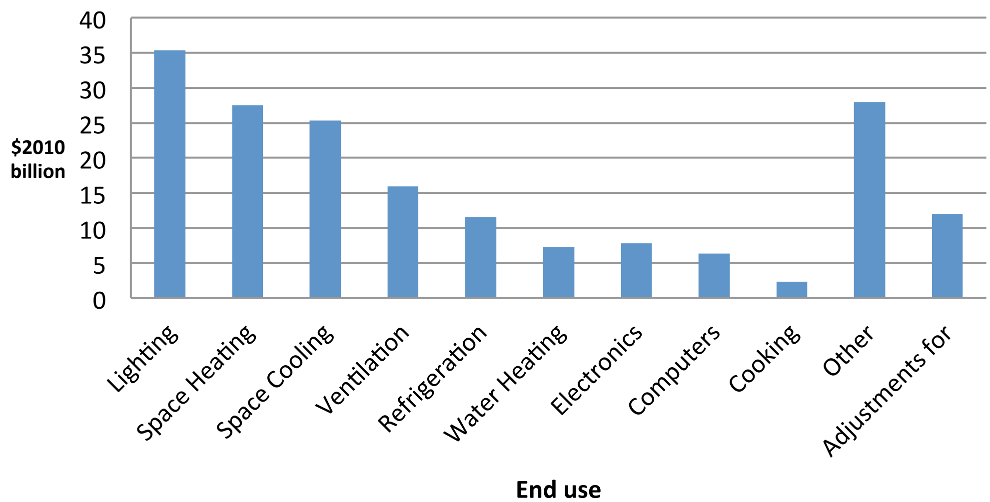


Figure G: Commercial buildings energy expenditures, by % share end-use (2010)

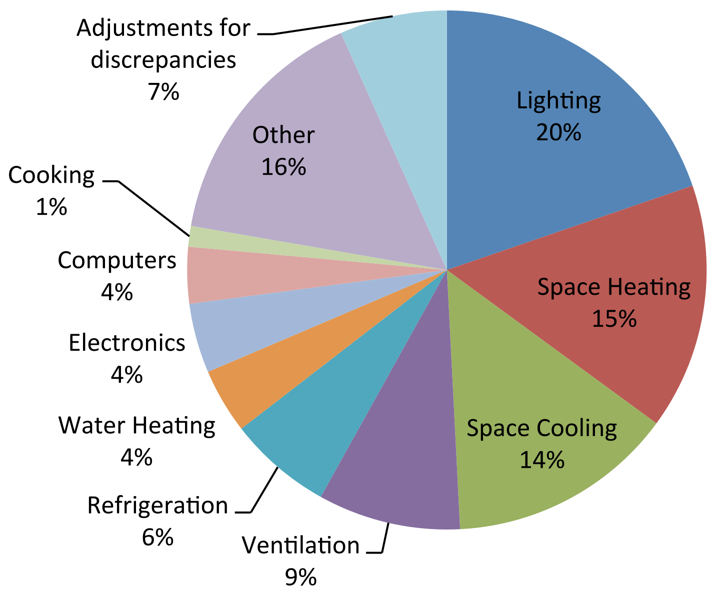


Figure H: CO_2 emissions from US commercial buildings energy consumption

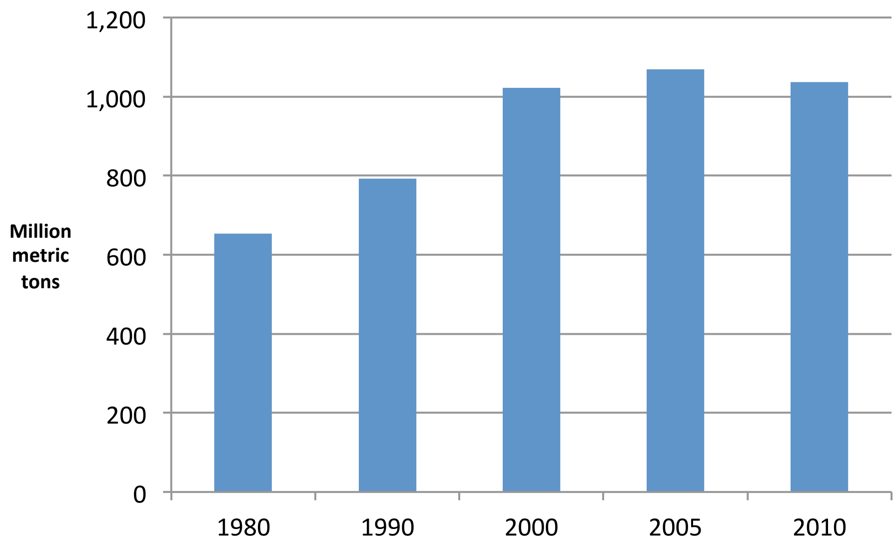


Figure I: Commercial buildings energy end-use CO_2 emissions, by end-use (2010)

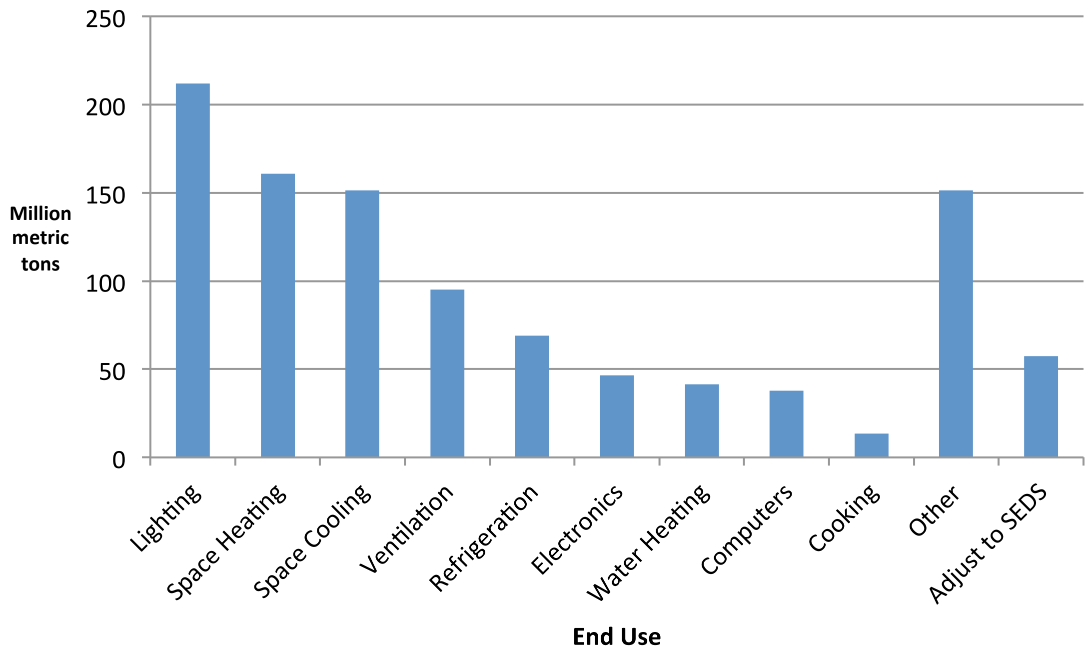


Figure J: Commercial buildings energy end-use CO_2 emissions, by % share of total (2010)

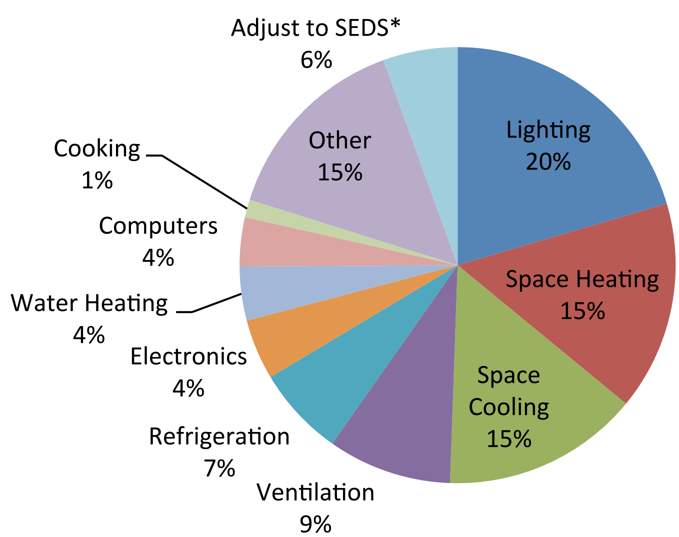


Figure K: Energy expenditures per square foot of office floor space ($2010/SF)

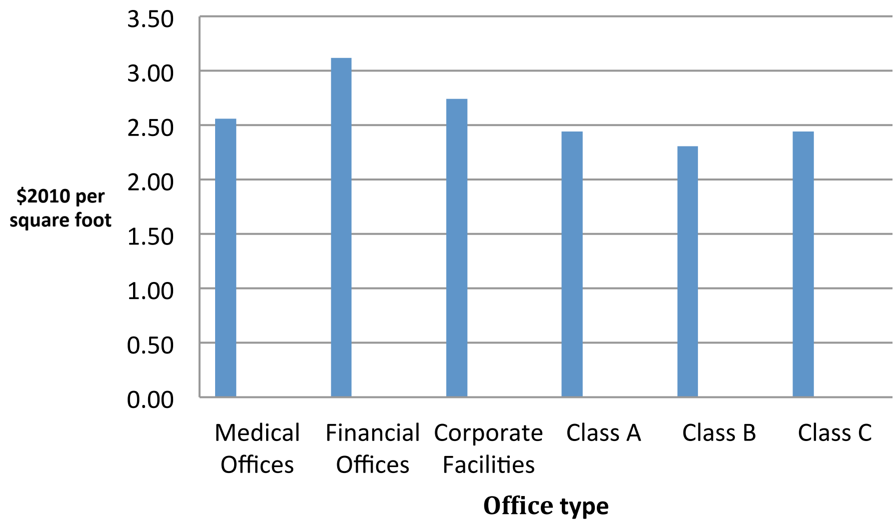
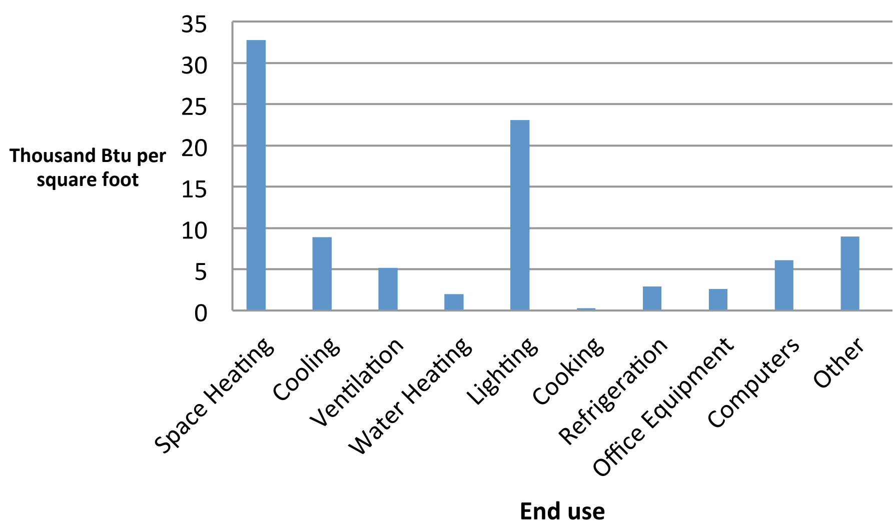


Figure L: Office buildings delivered energy end-use intensities, by building activity



From Nguyen & Aiello (2013)

Figure M: Energy-unaware behavior uses twice as much energy as the minimum that can be achieved

(Nguyen & Aiello, 2013: p. 246)

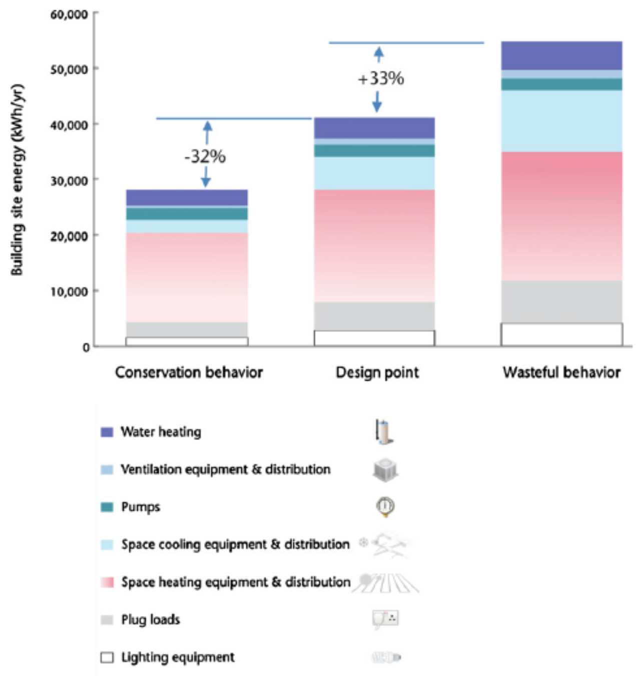
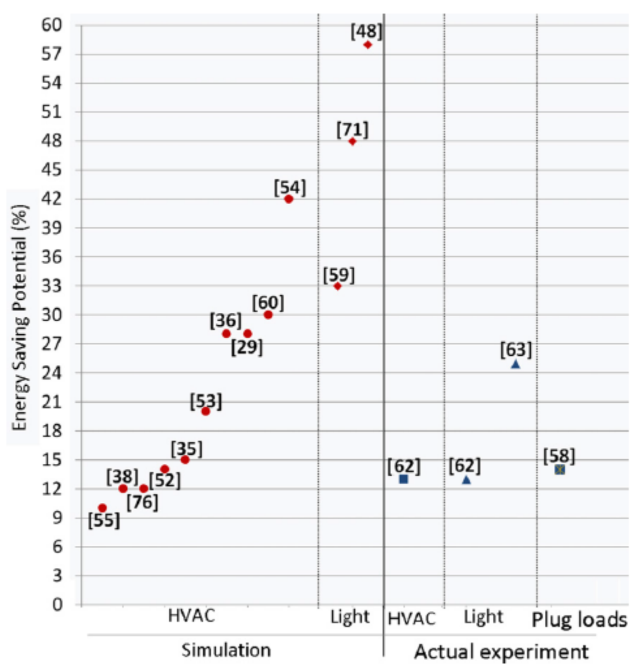


Figure N: Energy saving potential

(Nguyen & Aiello, 2013: p. 251)



From Lopes et al. (2012)

Figure O: Potential behavioral energy savings and reduced emissions in residential and services buildings

(Lopes et al, 2012: p. 4099)

Buildings	Region	Approach	Energy savings or reduced emissions	Reference
Residential	World	Review of non-technological factors influence on energy consumption and carbon emissions in buildings (80 studies)	Approximately 29% of the projected baseline emissions by 2020 can be avoided	[7]
	USA, Japan, Denmark, Finland, Germany, the Netherlands, Sweden, Switzerland, UK	Feedback review study (26 projects)	Electricity savings range from 1.1% to over 20%. Usual savings are between 5% and 12%	[9]
	USA	Use of available technologies and non-business travel actions combined, without reducing the household well-being	123 Mton carbon/year within 10 years representing 20% of residential buildings direct emissions or 7.4% of USA emissions	[50]
	North America and Japan	Feedback review paper on 12 utility pilot programmes, in particular, in-house displays feedback	Electricity savings range from 7% without an electricity prepayment system, to 14% with that scheme	[51]
	Japan	Feedback study using an on-line residential energy consumption information system	9% reduction in power consumption	[23]
	China	Energy-saving education strategy in 124 households	More than 10% electricity use (this contributed as much as insulation measures to reduce CO_2 emissions during 40 years)	[48]
	Kuwait	Simulated occupancy patterns using ENERWIN software	Behavioural change concerning lighting patterns could save 29% (37 MWh/year) and AC thermostats adjustments could save around 50 MWh/year	[49]
	Europe	Review on 100 behavioural intervention projects on 11 European countries	Savings potentials may reach 20%	[10]
		Replacement the appliances by the most efficient ones and reducing the stand-by consumption. Sample: 1300 households in 12 countries	Electricity savings of 50% (165 TWh/year; 72 Mton CO_2 emission savings) EU27: 268 TWh/year and avoided emissions of 116 Mton CO_2/year	[47]
	The Netherlands	Feedback strategy using an internet-based tool combined with tailored information, goal setting, and tailored feedback	5.1% energy savings	[19]
Services	South Africa and Botswana	Energy audits in commercial buildings	Electricity savings of 56% trough lighting and equipments turned off in non-working hours	[52]
	USA	Feedback strategy using an energy information system at four commercial enterprises and university campuses	18–35% in energy use	[54]
		Energy audits in commercial buildings to determine turn-off rates and power mode rates for office equipments	Although no direct savings were calculated, only less than 50% of the equipments were turned off and less than 10% of desktop computers entered low power mode, while 53% of monitors initiated power management	[53]

From Wang et al. (2012)

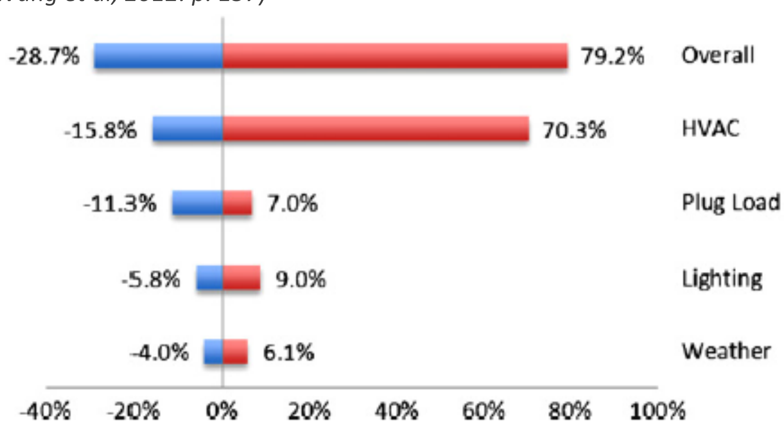
Figure P: Range of practice in building operations for a medium-size office building

(Wang et al, 2012: p. 154)

Operation parameters	Good practice	Average practice	Poor practice
Lighting control	Dimming control based on illuminance setpoint and occupancy sensor	Light on/off based on occupancy sensor	Manual switch on/off
Plug-in equipment control	Turn off when occupants leave	Sleep mode by itself	No energy saving measures
HVAC equipment operation schedule	6am to 8pm and one hour warm-up period	6am to 10pm and one hour warm-up period	5am to midnight and two hours warm-up period
Room temperature setpoints for occupied hours	20 °C for heating; 25 °C for cooling	21 °C for heating; 24 °C for cooling	22 °C for heating; 23 °C for cooling
VAV box minimum-flow setting	15% of design flow rate	30% of design flow rate	50% of design flow rate
Economizer cycle	Integrated economizer with dry bulb temperature control	Non-integrated economizer with dry-bulb temperature control	No economizer
Night setback	12.7 °C for heating set point and 30 °C for cooling set point for unoccupied hours	15.6 °C for heating set point and 28.4 °C for cooling set point for unoccupied hours	18.3 °C for heating set point and 26.7 °C for cooling set point for unoccupied hours
SAT control	SAT reset based on warmest zones	SAT reset based on stepwise function with outdoor air temperature	Constant SAT
Vacant spaces	Range of room setpoints: 12.8–32.2 °C; no lighting/plug loads	N/A	Rooms setpoints are the same as occupied space, no plug loads, 30% of design lighting loads

Figure Q: Uncertainties in annual site energy consumption by category

(Wang et al, 2012: p. 157)



Literature review

A summary of the general themes from prior behavior change research, as applicable to an office building setting, is presented below. Several of the themes directly served as inspiration for the behavior change interventions developed for a field experiment conducted in London office buildings.

Figure R: Themes from literature review

General themes from the literature review
1. Tailored approach that fit for the people and organization involved 2. Emphasizing convenience: making change easy 3. Limiting the cognitive demand of behavioral changes 4. Utilizing heuristics and other cognitive biases in favor of behavior change 5. Leading change efforts with a non-prescriptive approach 6. Creating an enabling choice environment with conditions favorable to new behaviors/habits 7. Showing the value of change and building a mission around it 8. Engaging actors directly through a team-based approach 9. Tying behavior change along with other changes/disruptions that may take place 10. Using participatory methods for decision-making and intervention design 11. Establishing new office norms as the glue which hold together the changes in behavior 12. Benefitting from the cost-effectiveness of the intervention 13. Engaging employees and establishing notions of (cognitive) ownership 14. Instilling notions of self-efficacy among employees 15. Mapping the barriers and related interventions 16. Barriers as both external and internal constructs 17. Providing active feedback and support to actors involved in intervention 18. Delineating the role of employees and mitigating pluralistic ignorance 19. Understanding the situation in the workplace from the actors' perspective 20. Staying without the bounds of the actors' tolerance for interventions 21. Building support/trust and engaging with both *promoters* and *detractors* 22. Setting realistic expectations 23. Attending to the desire for consistency and aversion of cognitive dissonance 24. Rehearsing new behaviors
Themes specifically from previous experiments on energy related behavior change in office buildings
1. Occupant behaviors significantly affect office building energy use 2. Occupant behaviors lead to significant variations from intended energy use for office buildings 3. Behavior change measures to reduce energy use bear little to no financial costs to adopt 4. Opportunities for energy savings through behavior change vary based on climate as well as the size and composition of the office building 5. While technological solutions typically lead to larger energy savings, behavior change measures are also achieve significant energy savings

6. Potential energy reductions in office buildings can reach 35 percent of current consumption
7. Non-work hours as a major opportunity to reduce energy use in office buildings
8. An additional opportunity to reduce energy use during work hours when people leave their work station
9. Group-level feedback facilitates energy saving behavior
10. Peer educators ('coaches') facilitate energy saving behavior
11. Moderate changes more likely to remain in place and be supported than drastic changes
12. Preference towards strategies promoting the adoption of new energy saving behaviors rather than the reduction of wasteful energy behaviors
13. Behavioral interventions more likely to succeed when compatible with/supportive of work-related interests of employees
14. Communication of desired behavior change must be clear, consistent and involve direct feedback
15. Interventions targeting office norms increase the likelihood of success
16. Potential need to tailor behavioral interventions to engage different personality types found in the office
17. Crucial role of physical comfort among employees while in the office and their receptivity to/support of behavior change measures
18. Potential opportunity to develop energy saving interventions that focus on increasing employees' physical comfort and productivity

From Lockton et al. (2013)

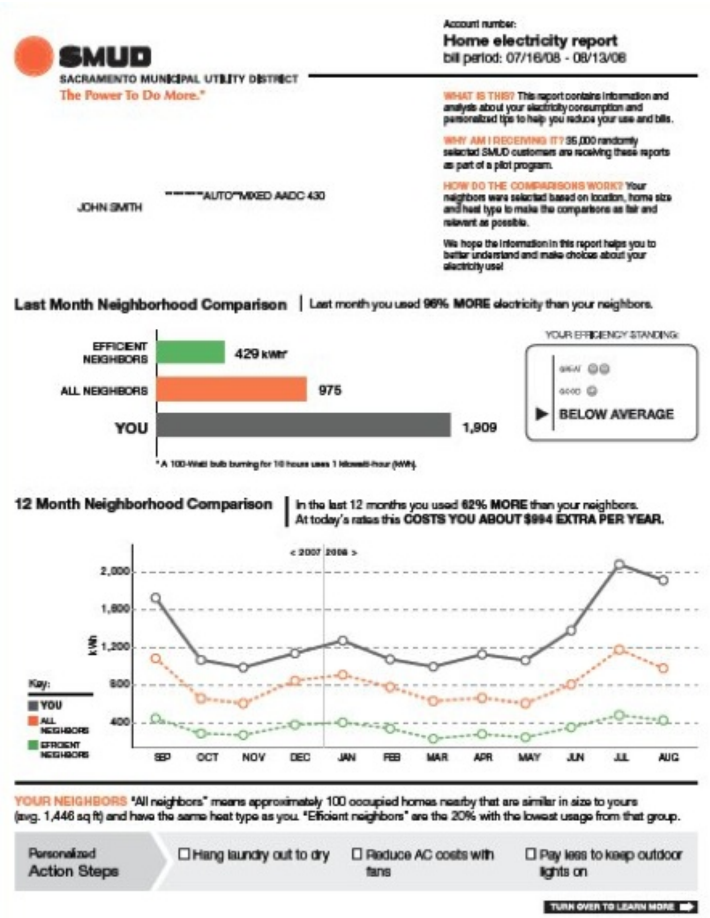
Figure S: Possible heuristics, and design implications, extracted by workshop participants (Lockton et al, 2013: p. 11)

Example	Possible heuristics	Possible implications for design choices
Codecademy	If something helps me improve myself, do it.	Show users that they are improving themselves.
	If I feel like I am accomplishing something, then keep going.	Make it clear what users are accomplishing.
	If something makes me feel better about my self-discipline, do it.	Congratulate users for their self-discipline.
	If it makes me look more knowledgeable in the eyes of others, then I will continue to take part.	Enable users to show off their knowledge to other users.
	If I can track my progress, then I will stay engaged.	Enable users to track their progress easily.
	If the challenge pushes me the right amount, then I will stay engaged.	Make sure that the level of difficulty progresses in line with users' developing abilities.
OPOWER	If my neighbour does it, I should do it.	Show users what their neighbours are doing.
	If life's a competition, I will try to win it.	Frame activities as part of a competition.
	If I can see that it saves me money, I will do it.	Show users the money they will save.
	If I set myself goals, I will try to meet them.	Make it easy for users to set themselves goals and track their progress.
	If I don't want to be the 'weak link', I will act in the desired way.	Emphasise that trying will avoid the user becoming the 'weak link'.
	If I want to be 'normal', I should do it.	Emphasise what is 'normal' for the group.
	If I get appreciation from others, I will continue to do it.	Give users explicit appreciation, from other users as well as directly.
	If it stops me being the 'bad guy', I will do it.	Congratulate users for being the 'good guy'.
	If it stops me feeling guilty, I will do it.	Enable users to overcome guilt.
	If it makes me feel good about being sustainable, then I will do it.	Show users that they are being more sustainable, and congratulate them for it.
Foodprints	If I get a reward, then I will do it.	Give users rewards for taking part.
	If it is not too much effort, then I will do it.	Make it easy to take part without much effort.
	If I can feel good about myself, then I will do it.	Make it easy for users to feel good about themselves.
	If I can show off about how well I am doing, then I will do it.	Enable users to show off what they're doing to other users.
	If I can see benefits in more than one part of my life, then I will do it.	Emphasise multiple benefits in different areas of life (e.g., carbon footprint and health).
	If it makes me feel healthier, then I will do it.	Emphasise health benefits and show users how taking part could be helping their health.
	If it does not punish me for days when I don't take part, then I will keep going.	Don't punish occasional users or those who miss days.
	If everyone else is doing it, then I will do it.	Show that lots of other people are using the service and taking part.

From Allcott & Mullainathan (2010-b)

Figure T: Example of Opower social comparison letter

(Allcott & Mullainathan, 2010-b: p. 16)



Appendix II – Experimental results

Behavior change: output from quasi-binomial generalized linear model

Output from quasi-binomial generalized linear model

	Coefficients	Estimate	Std. error	t value	Pr(>|t|)
Visit	Visit1_Pre	-0.3591	0.1273	-2.822	**0.0113 ***
	Visit2_Post	-0.4751	0.1865	-2.548	**0.0202 ***
		Deviance residuals Min: -4.0619, 1Q: -0.5470, Median: 0.3394, 3Q: 1.4731, Max: 4.4859 (Dispersion parameter for quasibinomial family taken to be 4.701707) Null deviance: 114.275 on 19 degrees of freedom Residual deviance: 83.483 on 18 degrees of freedom AIC: NA Number of Fisher Scoring iterations: 4			
Sector	Coefficients	Estimate	Std. error	t value	Pr(>|t|)
	Private	-0.2113	0.8010	-0.264	0.795
	Public	-0.4293	0.8091	-0.531	0.603
	University	-0.1038	0.8478	-0.122	0.904
		Deviance residuals Min: -5.6076, 1Q: -0.6783, Median: 0.8791, 3Q: 1.8324, Max: 3.3879 (Dispersion parameter for quasibinomial family taken to be 6.027187) Null deviance: 114.28 on 19 degrees of freedom Residual deviance: 105.97 on 17 degrees of freedom AIC: NA Number of Fisher Scoring iterations: 4			
Treatment	Coefficients	Estimate	Std. error	t value	Pr(>|t|)
	Control	-0.4000	0.1483	-2.697	**0.0153 ***
	Commitment	-0.2761	0.2407	-1.147	0.2672
	Feedback	-0.4264	0.2527	-1.687	0.1098
		Deviance Residuals Min: -4.124, 1Q: -1.468, Median: 1.040, 3Q: 1.843, Max: 3.865 (Dispersion parameter for quasibinomial family taken to be 5.621411) Null deviance: 114.275 on 19 degrees of freedom Residual deviance: 96.284 on 17 degrees of freedom AIC: NA Number of Fisher Scoring iterations: 4			
Organization	Coefficients	Estimate	Std. error	t value	Pr(>|t|)
	Imperial	-0.31508	0.29005	-1.086	0.296
	MC_CSF	-0.25800	0.39885	-0.647	0.528
	MC_Env	-0.09965	0.38085	-0.262	0.797
	RBKC	-0.43565	0.3302	-1.319	0.208
	Work_AE	0.72055	1.67930	0.429	0.674
	Work_CA	-0.12024	1.03311	-0.116	0.909
		Deviance residuals Min: -4.7233, 1Q: -1.0321, Median: 0.7006, 3Q: 1.4082, Max: 3.2259 (Dispersion parameter for quasibinomial family taken to be 6.566206) Null deviance: 114.275 on 19 degrees of freedom Residual deviance: 95.651 on 14 degrees of freedom AIC: NA Number of Fisher Scoring iterations: 4			

Significance codes*:** **0 '' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

Electricity meter readings: output from general linear model

Output from general linear model

Coefficients	Estimate	Std. error	t value	Pr(>|t|)
(Intercept)	63.56667	29.67488	2.142	**0.0334 ***
OrganizationMC	31.57368	41.96662	0.752	0.4527
OrganizationRBKC	62.13018	41.96662	1.480	0.1403
InterventionY	5.28246	41.96662	0.126	0.9000
HoursWork	-2.32456	41.96662	-0.055	0.9559
Days	-0.48140	2.60266	-0.185	0.8534
OrganizationMC:InterventionY	-34.14035	59.34977	-0.575	0.5658
OrganizationRBKC:InterventionY	29.47491	59.34977	0.497	0.6200
OrganizationMC:HoursWork	-13.98947	59.34977	-0.236	0.8139
OrganizationRBKC:HoursWork	290.38316	59.34977	4.893	**2.02e-06 *****
InterventionY:HoursWork	-8.66140	59.34977	-0.146	0.8841
OrganizationMC:Days	-0.09316	3.68072	-0.025	0.9798
OrganizationRBKC:Days	-0.25333	3.68072	-0.069	0.9452
InterventionY:Days	-0.11561	3.68072	-0.031	0.9750
HoursWork:Days	0.63772	3.68072	0.173	0.8626
OrganizationMC:InterventionY:Hours:Work	22.06491	83.93325	0.263	0.7929
OrganizationRBKC:InterventionY:HoursWork	-50.19702	83.93325	-0.598	0.5505
OrganizationMC:InterventionY:Days	0.76088	5.20532	0.146	0.8839
OrganizationRBKC:InterventionY:Days	-0.03560	5.20532	-0.007	0.9946
OrganizationMC:HoursWork:Days	0.42579	5.20532	0.082	0.9349
OrganizationRBKC:HoursWork:Days	-5.50747	5.20532	-1.058	0.2913
InterventionY:HoursWork:Days	0.02140	5.20532	0.004	0.9967
OrganizationMC:InterventionY:HoursWork:Days	-0.06754	7.36143	-0.009	0.9927
OrganizationRBKC:InterventionY:HoursWork:Days	-0.60935	7.36143	-0.083	0.9341

Deviance residuals
Min: -291.333, 1Q: -4.691, Median: 2.449, 3Q: 11.689, Max: 153.656

Residual standard error: 62.14 on 204 degrees of freedom
Multiple R-squared: 0.7481, Adjusted R-squared: 0.7197
F-statistic: 26.34 on 23 and 204 DF, p-value: < 2.2e-16

Significance codes*: 0 ‘’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1**

Electricity meter readings: RBKC and Merton Council data

Organization	Treatment	Days	Hours	Reading	Monitors
RBKC	Y	1	Work	430.31	317
RBKC	Y	2	Work	426.77	317
RBKC	Y	3	Work	401.65	317
RBKC	Y	4	Work	168.31	317
RBKC	Y	5	Work	139.72	317
RBKC	Y	6	Work	416.09	317
RBKC	Y	7	Work	436.56	317
RBKC	Y	8	Work	427.96	317
RBKC	Y	9	Work	419.37	317
RBKC	Y	10	Work	382.42	317
RBKC	Y	11	Work	184.74	317
RBKC	Y	12	Work	144.63	317
RBKC	Y	13	Work	402.81	317
RBKC	Y	14	Work	405.1	317
RBKC	Y	15	Work	387.66	317
RBKC	Y	16	Work	380.49	317
RBKC	Y	17	Work	362.8	317
RBKC	Y	18	Work	150.01	317
RBKC	Y	19	Work	130.74	317
RBKC	Y	1	Non	174.12	317
RBKC	Y	2	Non	177.37	317
RBKC	Y	3	Non	164.56	317
RBKC	Y	4	Non	113.58	317
RBKC	Y	5	Non	119.26	317
RBKC	Y	6	Non	163.74	317
RBKC	Y	7	Non	186.13	317
RBKC	Y	8	Non	170.06	317
RBKC	Y	9	Non	159.71	317
RBKC	Y	10	Non	149.21	317
RBKC	Y	11	Non	103.34	317
RBKC	Y	12	Non	109.46	317
RBKC	Y	13	Non	156.11	317
RBKC	Y	14	Non	168.19	317
RBKC	Y	15	Non	177.52	317
RBKC	Y	16	Non	180.63	317
RBKC	Y	17	Non	183.48	317
RBKC	Y	18	Non	109.63	317
RBKC	Y	19	Non	114.20	317
RBKC	N	1	Work	473.23	288
RBKC	N	2	Work	487.72	288
RBKC	N	3	Work	456.6	288
RBKC	N	4	Work	116.1	288
RBKC	N	5	Work	94.4	288
RBKC	N	6	Work	462.79	288
RBKC	N	7	Work	480.21	288
RBKC	N	8	Work	465.03	288
RBKC	N	9	Work	478.87	288
RBKC	N	10	Work	448.82	288
RBKC	N	11	Work	148.94	288
RBKC	N	12	Work	107.23	288
RBKC	N	13	Work	456.31	288
RBKC	N	14	Work	481.65	288
RBKC	N	15	Work	474.92	288
RBKC	N	16	Work	477.74	288
RBKC	N	17	Work	449.99	288

(Continued)

RBKC	N	18	Work	141.66	288
RBKC	N	19	Work	94.29	288
RBKC	N	1	Non	131.41	288
RBKC	N	2	Non	129.46	288
RBKC	N	3	Non	135.53	288
RBKC	N	4	Non	87.71	288
RBKC	N	5	Non	84.49	288
RBKC	N	6	Non	134.29	288
RBKC	N	7	Non	134.75	288
RBKC	N	8	Non	136.6	288
RBKC	N	9	Non	143.28	288
RBKC	N	10	Non	126.6	288
RBKC	N	11	Non	81.5	288
RBKC	N	12	Non	81.95	288
RBKC	N	13	Non	132.18	288
RBKC	N	14	Non	132.06	288
RBKC	N	15	Non	143.54	288
RBKC	N	16	Non	126.81	288
RBKC	N	17	Non	132.62	288
RBKC	N	18	Non	86.94	288
RBKC	N	19	Non	86.92	288
MC_CSF	Y	1	Work	48.1	134
MC_CSF	Y	2	Work	63.9	134
MC_CSF	Y	3	Work	77	134
MC_CSF	Y	4	Work	49.5	134
MC_CSF	Y	5	Work	55	134
MC_CSF	Y	6	Work	55.1	134
MC_CSF	Y	7	Work	54.4	134
MC_CSF	Y	8	Work	62.9	134
MC_CSF	Y	9	Work	65.1	134
MC_CSF	Y	10	Work	65.1	134
MC_CSF	Y	11	Work	53.3	134
MC_CSF	Y	12	Work	40.9	134
MC_CSF	Y	13	Work	61.8	134
MC_CSF	Y	14	Work	57.5	134
MC_CSF	Y	15	Work	61.3	134
MC_CSF	Y	16	Work	57.6	134
MC_CSF	Y	17	Work	58.1	134
MC_CSF	Y	18	Work	65.7	134
MC_CSF	Y	19	Work	58.9	134
MC_CSF	Y	1	Non	72.8	134
MC_CSF	Y	2	Non	62.9	134
MC_CSF	Y	3	Non	78.6	134
MC_CSF	Y	4	Non	62.6	134
MC_CSF	Y	5	Non	53.8	134
MC_CSF	Y	6	Non	68.1	134
MC_CSF	Y	7	Non	60	134
MC_CSF	Y	8	Non	62.5	134
MC_CSF	Y	9	Non	72.3	134
MC_CSF	Y	10	Non	63.6	134
MC_CSF	Y	11	Non	64.1	134
MC_CSF	Y	12	Non	54.6	134
MC_CSF	Y	13	Non	67.1	134
MC_CSF	Y	14	Non	57.6	134
MC_CSF	Y	15	Non	58	134
MC_CSF	Y	16	Non	58.1	134

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MC_CSF	Y	17	Non	60.5	134
MC_CSF	Y	18	Non	62	134
MC_CSF	Y	19	Non	55.5	134
MC_CSF	N	1	Work	51.7	56
MC_CSF	N	2	Work	68.9	56
MC_CSF	N	3	Work	78.8	56
MC_CSF	N	4	Work	47.8	56
MC_CSF	N	5	Work	63.1	56
MC_CSF	N	6	Work	58.3	56
MC_CSF	N	7	Work	61.1	56
MC_CSF	N	8	Work	64	56
MC_CSF	N	9	Work	70.3	56
MC_CSF	N	10	Work	70.3	56
MC_CSF	N	11	Work	63.9	56
MC_CSF	N	12	Work	46.5	56
MC_CSF	N	13	Work	63.4	56
MC_CSF	N	14	Work	59.9	56
MC_CSF	N	15	Work	66	56
MC_CSF	N	16	Work	59.9	56
MC_CSF	N	17	Work	63	56
MC_CSF	N	18	Work	70.4	56
MC_CSF	N	19	Work	66	56
MC_CSF	N	1	Non	66.6	56
MC_CSF	N	2	Non	48.4	56
MC_CSF	N	3	Non	76.9	56
MC_CSF	N	4	Non	55	56
MC_CSF	N	5	Non	52.5	56
MC_CSF	N	6	Non	64.5	56
MC_CSF	N	7	Non	58.8	56
MC_CSF	N	8	Non	62.2	56
MC_CSF	N	9	Non	72.7	56
MC_CSF	N	10	Non	62.3	56
MC_CSF	N	11	Non	59.3	56
MC_CSF	N	12	Non	49.8	56
MC_CSF	N	13	Non	60.1	56
MC_CSF	N	14	Non	51.3	56
MC_CSF	N	15	Non	52.6	56
MC_CSF	N	16	Non	56.5	56
MC_CSF	N	17	Non	57.5	56
MC_CSF	N	18	Non	58.1	56
MC_CSF	N	19	Non	51.2	56
MC_Env	Y	1	Work	60.6	87
MC_Env	Y	2	Work	86	87
MC_Env	Y	3	Work	99.6	87
MC_Env	Y	4	Work	64.9	87
MC_Env	Y	5	Work	79.6	87
MC_Env	Y	6	Work	73.9	87
MC_Env	Y	7	Work	31	87
MC_Env	Y	8	Work	36.8	87
MC_Env	Y	9	Work	37.1	87
MC_Env	Y	10	Work	85.8	87
MC_Env	Y	11	Work	85.4	87
MC_Env	Y	12	Work	62.2	87
MC_Env	Y	13	Work	95.8	87
MC_Env	Y	14	Work	85.6	87
MC_Env	Y	15	Work	85.5	87

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MC_Env	Y	16	Work	76	87
MC_Env	Y	17	Work	88.2	87
MC_Env	Y	18	Work	94.2	87
MC_Env	Y	19	Work	82.6	87
MC_Env	Y	1	Non	82.7	87
MC_Env	Y	2	Non	69.3	87
MC_Env	Y	3	Non	86.5	87
MC_Env	Y	4	Non	71.6	87
MC_Env	Y	5	Non	63.9	87
MC_Env	Y	6	Non	24	87
MC_Env	Y	7	Non	18.4	87
MC_Env	Y	8	Non	73.7	87
MC_Env	Y	9	Non	89.6	87
MC_Env	Y	10	Non	73.8	87
MC_Env	Y	11	Non	76.9	87
MC_Env	Y	12	Non	61.8	87
MC_Env	Y	13	Non	72.7	87
MC_Env	Y	14	Non	66.9	87
MC_Env	Y	15	Non	64	87
MC_Env	Y	16	Non	66.3	87
MC_Env	Y	17	Non	73.5	87
MC_Env	Y	18	Non	71.5	87
MC_Env	Y	19	Non	65.7	87
MC_Env	N	1	Work	66.7	138
MC_Env	N	2	Work	82	138
MC_Env	N	3	Work	106	138
MC_Env	N	4	Work	60.9	138
MC_Env	N	5	Work	83.2	138
MC_Env	N	6	Work	80.2	138
MC_Env	N	7	Work	83.6	138
MC_Env	N	8	Work	87.2	138
MC_Env	N	9	Work	94.8	138
MC_Env	N	10	Work	94.8	138
MC_Env	N	11	Work	83.5	138
MC_Env	N	12	Work	59.8	138
MC_Env	N	13	Work	89.7	138
MC_Env	N	14	Work	80.3	138
MC_Env	N	15	Work	82.1	138
MC_Env	N	16	Work	76.3	138
MC_Env	N	17	Work	89.4	138
MC_Env	N	18	Work	99.2	138
MC_Env	N	19	Work	90.9	138
MC_Env	N	1	Non	99.4	138
MC_Env	N	2	Non	87.2	138
MC_Env	N	3	Non	107.9	138
MC_Env	N	4	Non	89.5	138
MC_Env	N	5	Non	77.3	138
MC_Env	N	6	Non	96.8	138
MC_Env	N	7	Non	81.9	138
MC_Env	N	8	Non	89	138
MC_Env	N	9	Non	104.7	138
MC_Env	N	10	Non	93.5	138
MC_Env	N	11	Non	89.9	138
MC_Env	N	12	Non	77.3	138
MC_Env	N	13	Non	92.6	138
MC_Env	N	14	Non	84.1	138

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MC_Env	N	15	Non	85	138
MC_Env	N	16	Non	80.5	138
MC_Env	N	17	Non	87	138
MC_Env	N	18	Non	90.7	138
MC_Env	N	19	Non	84.2	138