Reducing UK Household Energy Consumption During Peak Demand

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Energy Consumption - Misconceptions and Flawed Awareness

“There is no energy crisis, only a crisis of ignorance”. This statement made by Buckminster Fuller encapsulates 1) the lack of attention made to people’s flawed awareness and knowledge of what, when and how they consume energy and 2) the improper consideration of this as a leading cause to the inefficient consumption of energy. This is not to say that there have been no attempts to address the inefficient consumption of energy, but rather that the focus has mainly been on technological improvements in energy efficiency; with the UK’s 2022 energy-security strategy favouring alternative clean energy flows that are expensive and slow to build, many of these costs ultimately expected to be added onto customers’ energy bills (Otto, Kaiser and Arnold, 2014). However, technological improvements in energy efficiency are not sufficient; total UK energy consumption decreased only by 1% between 2018 to 2019 (DBEI, 2020). Moreover, the current state of the UK's economy does not allow for further investments into technological improvements for energy efficiencies (Independent, 2022). It is therefore pivotal to think realistically about the way people consume energy on a day-to-day basis to develop solutions that are cost-effective and implementable in the short-term.

As societies have developed to depend on greater energy flows, energy has become a largely invisible resource (Brandon & Lewis, 1999, p. 75; Tainter, 2011). Consequently, there are many misconceptions around how to optimise energy. Misconceptions are formed through a lack of knowledge around the technical aspects of energy provision (Thomas et al., 2019) as well as cognitive shortcuts. The availability heuristic is a cognitive shortcut where people misperceive the likelihood of an event occurring because of how easily we recall similar events (Kahneman et al., 1982). In an energy use context, this translates to cognitive accessibility (Schley & DeKay, 2015) where people believe appliances they use most often consume more energy than they really do. For example, in a survey of 2,200 UK residents, when asked what actions they planned to take to reduce energy bills, most said they would turn off lights (KPMG, 2023). In reality, almost half of the final energy consumption in the UK’s domestic sector is used to provide heat, where 57% of this heat goes towards meeting the space and water heating requirements in homes (Ofgem, 2016).

Moreover, a principal issue that the energy market faces is managing the storage of energy; an issue that has low awareness among the UK population (Thomas et al., 2019) and can be optimised through a change in energy consumption around peak demand. Peak demand refers to the time period when household energy consumption is the highest. It is difficult for distribution grids to supply power when most households reach peaks during the same time in a day because utilities use stored quantities of electricity to supply power to customers (EIA, 2011). This makes the process indirect and costly (Hategekimana, 2017). For this reason, the price of energy consumption rises during peak demand. According to the National Grid Report (2008), revised electricity demand profiles show that, on average, there are two windows of peak demand: in the morning between 07:00 to 11:00 (GMT) and in the evening between 17:00 and 21:00 (GMT) (BRE, 2008). In the UK, the problem has become severe as there has not just been an increase in energy demand, but also a recent decrease in supply. First, the rise in demand for electricity is due to a growing population, developments in policy and technology, and the increased availability and consumption of inefficient domestic appliances (Ayan & Turkay, 2018). Second, due to Russia's withdrawal of energy sources in response to the UK sanctions on Russia (due to their invasion of Ukraine), the UK is experiencing a decreased energy supply (Dillon and Mawhood, 2022).

Defining the Problem

With an increase in population sizes, incomes and urbanisation, energy consumption is gradually becoming a major environmental, social and economic problem (Attari et al., 2010). In this context, the inefficient consumption of energy can be placed at the heart of two crises: climate change and the cost of living. First, two-thirds of global greenhouse gas emissions are caused by the burning of fossil fuels to meet the demands of energy consumption (IEA, 2020). Second, inefficient energy consumption coupled with the rise in energy prices is a main driver in the cost of living crisis; the number of households in fuel poverty has increased from 4.5 million to 6.7 million from October 2022 to March 2023 and is predicted to continue to rise to 7.5 million by the end of April 2023 (NEA, 2023). Public perception about their household energy consumption is gravely flawed (Attari et al., 2010), specifically differentiating between high and low energy consuming activities (Attari et al., 2010) and the effect size of consuming energy at different times during the day (Thomas et al., 2019).

Many existing interventions tackling domestic energy consumption focus on the “deliberate decisions” of energy-using individuals and neglect the “collective determinants” of habitual behaviour (Schwanen et al., 2012). However, with energy being a largely invisible resource, studies have found that consumers are far from “rational” decision makers (in the traditional economic sense), in that their energy consumption behaviour does not always align with their personal values (e.g. pro-environmentalism) or their material interests (e.g. cutting costs) (Frederiks et al., 2015). Therefore, social psychology acts as a valuable lens through which we can depart from orthodox decision-making models that focus primarily on personal and economic incentives and, instead, take into account the broader socio-psychological factors that influence the habitual nature of energy related decision-making (Lewis, 2008; Frederiks et al., 2015; Sorrell, 2015).

To this end, this paper will examine the social-psychological determinants of the overconsumption of energy during peak demand amongst households and propose relevant solutions to reduce their energy consumption during peak demand to minimise its serious environmental, social and economic consequences. Moreover, this paper acutely focuses on the domestic sector, ie. the consumption of energy in households, since the domestic sector has the highest consumption of energy (Government UK, 2022; Statista, 2023). First, activity theory is used to define the scope of examination of energy as a means, not an end. Second, understanding and addressing the underlying drivers of energy consumption during peak demand through the three layers of installation theory. Finally, low-cost practical solutions are presented to address the issue of overconsumption of energy during peak demand.

Understanding Energy as a Means, Not an End - Activity Theory

For most consumers, energy is an abstract resource consumed as a means to an end (Shove & Walker, 2014). Energy is not in demand for its own sake, but "in combination" with goods and services that require energy (Sorrell, 2015). To illustrate this, consider Nosulenko et al's (2005) view of activity theory. Activity theory is a holistic framework that allows one to divide broad behavioural patterns into a specific goal-oriented sequence (Lahlou, 2017). Through activity theory, one can describe how free-ranging subjects (or collective agents) attempt to accomplish their goals to satisfy their underlying motivations[1]. The goal is a representation of the final desired state[2] and subgoals are tasks (problems to solve) which can be conscious or deliberate.

In the context of household energy consumption, the overarching goal is not to consume energy because one does not consume energy just for the sake of it. Instead, it is part of the subgoal process where completing a task requires the use of energy. To illustrate this, consider Emma who is cold because the temperature in her room has dropped *(initial state)*. Here, Emma's goal is to feel warmer *(desired state)* in order to be comfortable *(motivation)*. Figure 1 illustrates Emma's subgoal process in achieving her final desired state by using the radiator in her room to increase the temperature: identify where the radiator is, go to the radiator, turn the thermostatic valve. This example shows how energy is consumed in the subgoal process as a means to achieve the overarching goal, transferring the subject from their initial state to their desired state. To reduce energy consumption during peak demand, one can either 1) reduce the energy consumed in the subgoal process or 2) encourage other means (no energy) to achieve the overarching goal. Given the word limit of this paper, the focus is only on the former.

[1] A motive can be satisfied by multiple goals and a goal can satisfy multiple motives (Lahlou, 2017).
[2] The final desired state can be negative (to avoid something) which is reached through a trajectory of achieved subgoals where external conditions and contextual factors influence the agent's actions (Lahlou, 2017).

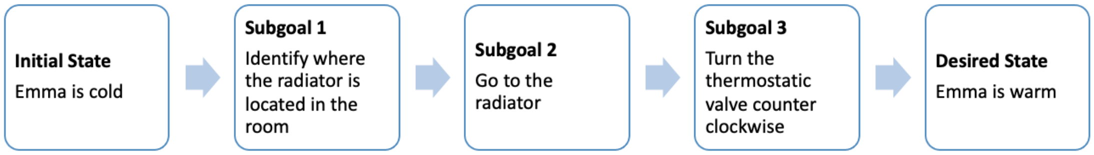

Figure 1: A Simplified Version of Activity Theory

Channelling Energy-Use Behaviour - Installation Theory

Installation theory analyses human behaviour through a holistic framework, illustrating how societies (situations) can be interpreted as installations that channel specific behaviour. At the fundamental level, installation theory is composed of three layers: the affordances of the physical environment, the embodied competence of the subject and the social regulation of institutions asserted directly or indirectly by others (Lahlou, 2017, p. 149). At the intersection of the three layers, the subject's possibilities of action are narrowed and thus their behaviour is predictably funnelled (figure 2). Since installation theory is a macro-level framework, the three layers apply detailed concepts that allow for a comprehensive understanding of a specific activity. This paper examines the underlying drivers of energy consumption during peak demand through the three layers of installation theory. First, this paper will identify the challenges to reducing energy consumption within each layer to further narrow the scope of analysis and addressability of this paper. Subsequently, it will derive and present practical solutions to address the identified challenges for each layer. Finally, this paper will discuss the conceptual and methodological limitations and a summary of the findings.

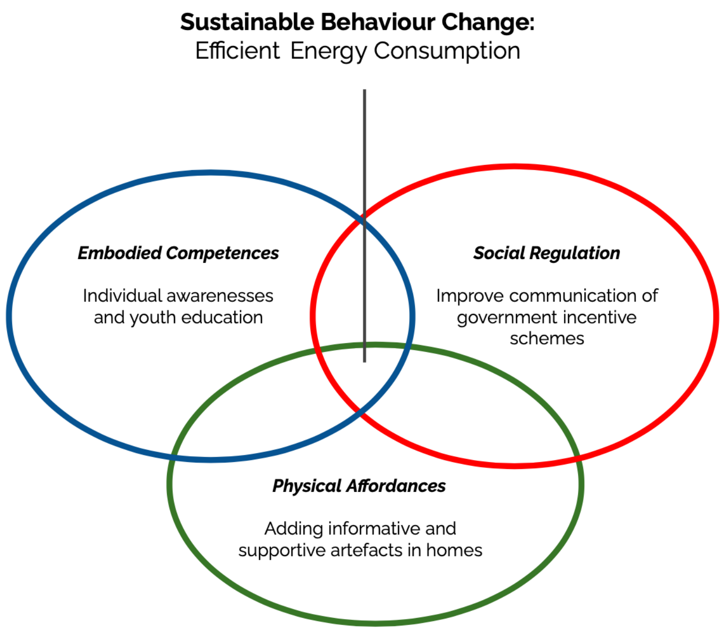

Figure 2: Installation Theory Applied to Over Consumption During Peak Demand

Installation Component	Prioritised Problem	Proposed Solution	Explanation
Physical affordance	Lack of artefacts in the home that intentionally inform and support households to reduce their consumption of energy	Stickers placed on high energy-consuming appliances	Reminder at the point of action
		Beeping thermometer	When house exceeds a temperature, this acts as a reminder for individual action
		Smart metres	In-Home Display shows prices in near-real time to trigger households to reduce consumption; Also connects to APP and IoT.
Embodied competence	Lack of knowledge about how energy is consumed within own households.	Personalised and actionable feedback on bill	Effective transmission of the necessary knowledge to the user of how to reduce their energy consumption.

		Reminder notifications of peak demand hours	Enabling households to reduce their energy consumption around the hours of peak demand.
	Lack of knowledge about the consequences of energy consumption during peak demand.	Children's education	The future generation will embody a process of interpretation of a situation (e.g., peak demand times) or an object (high energy consuming dryer machine) that leads to an emergence of action.
Social regulation	Social norm on prioritising comfort over energy conservation	Increasing participation in financial incentives by the UK Government & Energy Companies through improved communications.	Replace the norm of consuming for comfort by instilling a sense of financial gain.

Table 1: Overview of the Prioritised Problems and Proposed Solutions

Physical Affordances

The Problem

The first layer addressed by installation theory are physical affordances. Physical affordances form the objective layer that exists in the physical environment (Lahlou, 2017). This means it is external to the subject - such as a washing machine or a thermometer. The layer does not just refer to objects in terms of material entity, but an "entity that is as-a-whole relevant for action" (Lahlou, 2017, p, 92). Therefore, the importance is the connotation for action of the objects (not their physical boundaries). The subject's interpretation of the object's connotation for activity is the affordance of the physical object. The affordances of these objects can either support, inform or constrain activity. For example, a desk can inform the place for a meal but can also constrain the space where food manipulation can take place (Lahlou, 2017, p. 92). To reduce energy consumption during peak demand, there should be affordances within UK homes that either inform or support household activity to consume less energy or constrain certain household activities completely - currently, this is practically non-existent. As human behaviour in a given context is ultimately driven by the physical affordances in the built environment (Lahlou, 2017), the physical environment should be re-constructed at the point of action to guide household behaviour. For example, when consumers intend to use their washing machine during peak hours, they must feel the “resistance” before they load their laundry or press the “start” button.

The Solutions

Stickers on electrical appliances

Entrenched behaviours present a barrier to reducing and optimising energy consumption, especially concerning peak energy use brought on by external factors such as sunlight and seasons (Mahmoud & Alajmi, 2010). Research has found that traditional media campaigns that promote pro-environmental insights and attitudes through simple information sharing leads to increased knowledge levels but not to lasting behaviour change (Casado, Hidalgo & Garcia-Leiva, 2017; Borawska, Borawski & Latuszynska, 2022). However, studies have also found positive results from messages containing motivational priming that outline specific guidelines for action (Gifford & Comeau, 2011, cited in Casado, Hidalgo & García-Leiva, 2017). Therefore, this paper proposes an intervention at the point of consumption of energy use: a variety of instructional stickers that can be placed on high energy-consuming appliances (e.g., washing machines, dryers, heaters).

The stickers will be informative, acting as motivational priming, as well as aim to have a lasting impact on behaviour through its longstanding placement at the point of consumption. This will help to disrupt and redirect activity where, to illustrate using activity theory, when trying to get clean clothes during peak demand *(goal)*, one will load dirty clothes into the washing machine *(subgoal)*, at which point the they will see the sticker and be reminded that it is better for the environment and more cost efficient to start their laundry at off-peak times *(disruption of activity)*, encouraging consumers to delay starting the washing machine *(new subgoal)*.

This is a solution that can be adopted and rolled out by several stakeholders with vested interests in seeing domestic energy consumers reduce their peak energy demand such as energy companies or the UK government. This is also a low-cost solution that does not require any new technology; therefore it can be produced quickly, easily and cheaply.

Figure 3. Sticker mockups

Limitations

Potential obsolescence – Due to the stickers' text containing specific guidelines, there is a risk that the stickers will become obsolete if the hours of peak demand change. For example, during the COVID-19 pandemic, hourly electricity demand saw a curve flattening – especially during peak hours (Abu-Rayash & Dincer, 2020). The solution to this limitation, in the event of a major change in peak hours, will be to replace the stickers with updated information. While it is a low-cost intervention, this only remains the case if the stickers do not need to be changed on a regular basis.

Placement – Household energy consumers will be responsible for placing the stickers, meaning there is potential for misuse - rendering the stickers ineffective. To ensure the stickers are utilised as effectively as possible, it is important that the distributor include clear guidelines on where to place the stickers. For example, a sticker informing consumers on when to start their washing machine should be placed on the machine itself, at the point of action.

Types of appliances – It is important to consider that this solution may be effective depending on the type of appliance. For example, radiators can be using energy consistently without the consumer physically interacting with the radiator dial or thermostat itself - so a sticker placed at the point-of-use will not be as effective. Therefore, it is important to consider alternative methods for different types of appliances. An alternative method for making this type of invisible energy source visible to consumers is proposed in the following section.

<u>Beeping thermometer when house exceeds a certain temperature</u>

There is mounting evidence suggesting that smoke alarms reduce the number of household deaths related to fire (Rohde et al., 2016). Specifically, people are eight times more likely to die from a fire when they do not have a working smoke alarm in their household (Home Office, 2022). The smoke alarm functions by instigating a sound that is specifically designed to trigger instinctive danger responses (DLUHC & CFRA, 2012). Particularly, to increase the likelihood of the response effect, the pitch of the sound has to be within the sensitive range of human hearing (3000 Hz) and persistently beep (DLUHC & CFRA, 2012). In the context of reducing energy-consumption during peak demand, this paper proposes the solution of alerting households using sounds when the temperature of the space in the house exceeds a certain degree. The affordance of the "beeping thermostat" is that it informs residents to lower the room temperature. However, since fire alarms inform evacuation from instinctive danger, the beeping thermostat cannot and should not have the same sound. This paper proposes that the sound of the thermostat will have a slightly different pitch, persistence, and volume to distinguish it yet maintain the benefits of the fire alarm's distinctive features. Specifically, this paper proposes that the pitch is high enough to distinguish the sound and persistent in beeping to ensure it cannot be tuned out as one can do with many other sounds in everyday life. Furthermore, to increase the likelihood of the response effect, the volume of the sound should be at 85 decibels from 3 metres. (DLUHC & CFRA, 2012). To put this into perspective, an aeroplane from a mile away has around the same volume in decibels. As a result, the sound will be successfully informative and trigger action, as well as have a long-lasting impact on behaviour through its consistent activity in close proximity to energy consumption.

Limitations

Reduced response to other alarms – Alarm fatigue is a decrease in the response effect due to high exposure to noise alarms (Sendelbach & Funk, 2013). Specifically, this is recorded among clinicians who have high exposure to emergency alarms (Woo et al., 2020). The high exposure causes desensitisation to the sound and thus a delayed response. Therefore, the limitation of adding an additional noise alarm within households is a decrease in the response effect for both the fire alarm and the thermostat alarm, where the former can be lethal.

Lack of knowledge – Given that most households do not have knowledge about peak demand consumption of energy (Thomas et al., 2019), this intervention would not be effective without raising awareness and educating residents first. The knowledge about peak demand does not have to be extensive, but enough for the household to understand that the noise activated by the thermostat encourages the reduction of energy consumption during peak demand to minimise energy costs and promote overall improved sustainable living.

Smart metres

A smart metre measures the quantity of gas and electricity a household uses, converts the information into digital form, and sends those automatic readings to the energy supplier via fixed communication networks. It comes with an In-Home Display (IHD) screen to help consumers visualise their energy usage, which shows households their actual energy usage and pricing information (expressed in pounds and pence) in near-real time (DBEI, 2021). This feature enables individuals to know how their daily activities contribute to their energy bills. Thus, a smart metre would act as the artefact that constantly informs households of their energy consumption patterns and empowers residents with the autonomy to reduce unnecessary energy usage.

The benefits of smart metres are not restricted to the demand side – they also provide suppliers with more precise data, which facilitates a more efficient energy production and distribution process. With this, they can conduct extensive data analysis, identify households' electricity consumption patterns, and classify "clustering" (Toussaint & Moodley, 2020). This helps to construct households' energy consumption archetypes and optimise long-term energy planning and grid system management, hence it improves electricity production and makes transmission more cost-efficient.

There is an existing programme for smart metre rollout across Great Britain, spanning government and industry. By the end of June 2022, 45% of domestic metres operated by large energy suppliers were smart metres (Official Statistics, 2022). Given the benefits of smart metres, the rollout should be continuously promoted. However, the current smart-metre solution can not inform peak time usage explicitly or provide energy-saving incentives at the point of action.

To maximise the effectiveness of smart metres, this paper proposes the development of a mobile application connected to household smart metres using the internet. Within the application, consumers would be able to do the following:

- Keep track of energy use in real-time on their phone and get direct feedback on their energy usage. This physical affordance enables consumers to know "the most expensive appliances".
- Set monthly budgets and make their consumption more planned; the remaining amount displayed creates a sense of urgency for energy-saving.
- Receive notifications during peak hours, advising them against using high energy-consuming appliances and suggesting deferring operation.
- The mobile APP also provides a platform for other functions, such as personalised energy usage feedback from suppliers (more detailed explanation in the next section) and energy-saving tips.

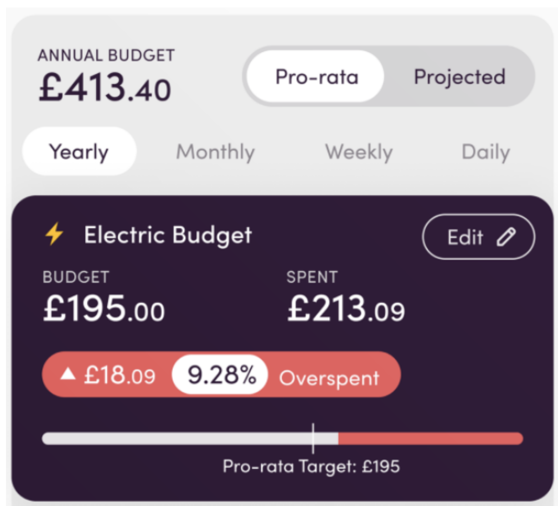

Figure 4. Exemplary Budget Setting Interface (HUGO, 2023)

Figure 5. Illustration of Possible Notification

The automation of electronic devices solves the problem of inaction; smart metres could be connected to the Internet of Things (IoT), such as thermostats and other smart devices. The IoT enables functions such as the monitoring of energy consumption of a specific device with a cloud-based interface for central management (Mathew et al., 2018). IoT also enables users to take proper control of electronic devices remotely. Furthermore, consumers can configure settings of energy load and allow specific appliances to turn off automatically during peak demand periods. For example, a smart dishwasher may delay operation until off-peak hours. Thus, connecting the smart metre with IoT provides physical affordances for consumers to operate the devices more flexibly and overcome the difficulties from intention to action.

Limitations

High costs of new technology – It is expensive and impractical to change existing home appliances to smart appliances. Thus, it is suggested to primarily target new residents, as their previously established habits have been disturbed (Maréchal, 2010).

Other layers needed – A smart metre on its own cannot enhance personal knowledge or form social norms. Though households may have the intention to reduce energy consumption, they lack embodied competence of the desirable energy-saving behaviour. As a result, they have little self-efficacy to act (Schwartz, 1977). Therefore, other interventions focusing on embodied competences and social regulation layers that can inform messaging and content provided by the smart metres should be considered, which will be elaborated below.

Embodied competences

The Problem

The second layer addressed by installation theory is embodied competences. It refers to the human input in a determined situation where the participation is driven by embodied interpretative systems (Lahlou, 2017). These systems connect the subject's perception of the situation to action (Lahlou, 2017). Therefore, embodied competences refer to internal representations that guide their actions.

It is impossible to address the reduction of peak energy consumption in households without taking a close look at embodied interpretive systems such as the skills, knowledge, reflexes, representations, mental models, habits, common sense, that are all involved in the way that a person consumes energy (Lahlou, 2017). First, one of the biggest problems with energy consumption for households during peak demand is the fact that most residents do not know how energy is consumed in their household, nevertheless during peak demand. In a 2021 nationwide poll, 16% of UK residents claimed to know how to reduce their energy consumption (GGF, 2021). Second, residents are not aware of the impact that their consumption has besides the obvious increase or decrease in their overall monthly bill. However, studies show there is little clarity on how their consumption is distributed within their home. A recent survey found that half of UK residents are unaware that almost half of their energy consumption is used to provide heat (Home Truths, 2023). Additionally, there exists a flawed awareness of the consequences of energy consumption, specifically during peak demand. To minimise energy consumption during peak demand, the following section aims to address people's interpretation of how energy is consumed during these periods of time and the power they hold to adjust their own habits and actions.

The Solutions

Push notifications

Previous experiments have demonstrated the effectiveness of notification reminders sent via text messages prior to the start of the peak times, to reduce peak demand. (Jorgensen et al., 2021) Particularly appealing for groups that are less responsive to economic incentives, for example, residents that are not themselves payers. Reminding residents of when the peak times will start, will enable those who are willing to adjust their habits and activities around the home to become more energy efficient. This would be particularly effective during the first months, as individuals have lived their whole lives with these routines, and to balance peak times, suddenly residents need to change their daily habits. Therefore, although notifications will be useful, its effectiveness will be dependent on the willingness of the household to act.

Detailed and motivational invoices

To address the information and education-related barriers surrounding energy efficiency (Schleich et al., 2013), this paper proposes innovative and informative monthly energy bills for households. These new invoice designs will inform and educate individuals on their energy use patterns and their relation to energy costs as well as environmental impact. The effectiveness of this intervention is based on two different concepts: the first is providing personalised feedback and actionable improvement tips, and the second is reinforcing social norms by generating feelings of pride or guilt.

Personalised feedback - Research demonstrates that providing personalised feedback to households is significantly more effective in changing behaviour than general feedback (Kim et al., 2020). Therefore, this intervention refers to providing households with detailed insights such as times when most energy was used throughout the month, rooms of the house where consumption was higher, times of the month where peak demand was balanced including graphs to make it more understandable. However, when feedback is combined with other behavioural interventions, the likelihood of improving energy-saving behaviour is higher (Bird & Legault, 2018). Hence, the insights would be followed by specific actionable tips based on the feedback received, to guide residents to improve the energy efficiency of their homes.

Norm setting messages **-** To include choice-architecture techniques to activate social and personal norms among residents. Because humans are expected to make mistakes (Thaler et al., 2010), well-designed messages can be used to inform residents about their energy consumption through phrases that reinforce a positive behaviour change in their energy usage, establish a social norm based on the behaviour of their community, generates emotional activation, such as pride or guilt; research has found this to be effective when promoting behaviour change (Trujillo et al., 2021). These techniques effectively activate personal beliefs related to sustainability, as well as contribute to reducing the attitude-behaviour gap (Trujillo et al., 2021), thus favouring the adoption of energy-saving behaviour among households. Although there is strong criticism against choice-architecture techniques due to it being perceived as a paternalistic and manipulative approach, choices are always affected by circumstantial factors that are external to the decision maker. Likewise, energy consumption is highly influenced by external factors, therefore it is already subject to some level of nudge-like intervention (Kasperbauer, 2017).

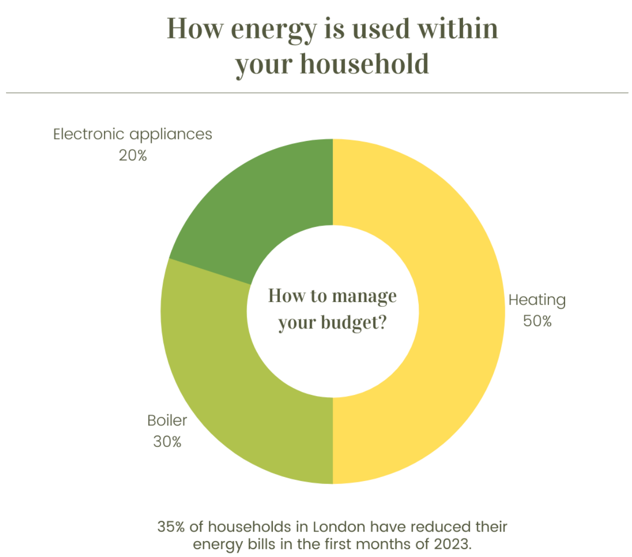

Figure 6. Example of content for the invoices

Limitations

Constant exposure – Although feedback and notifications demonstrate to be effective in the short-term, people can get used to it after a period of time and decrease in its efficiency in the long-term.

Level of concern for social norms – Previous experiments have demonstrated that effects of the interventions vary within the population. Mostly due to the level of concern that individuals may have with social norms. As the literature demonstrates for example, individuals with high levels of concern for social norms reduced their peak energy consumption by 14%, while occupants with low levels of concern for social norms increased their consumption by 5%. Additionally, the behaviour change was twice prevalent in the long-term among households with a high level of concern for social norms (Jorgensen et al., 2021).

<u>Youth education</u>

Child-focused interventions have been shown to develop energy-saving behaviours among both children and their parents (Boudet et al., 2016). A 2019 study by Mauriello extended this idea to pre-teens who are more engaged in their home's energy use and are more likely to have agency in energy-intensive activity like doing laundry (Mauriello, 2019). Therefore, this paper proposes an educational approach that will empower youth to introduce peak demand-reducing activities into their homes by generating awareness of peak demand and energy storage.

Mauriello's Know Your Energy Numbers (KYEN) pilot program demonstrated a positive impact where participants reported continued engaging in energy-saving behaviours at home. A workshop-style intervention aimed at raising awareness of energy conservation like the Know Your Energy Numbers program integrated into schools can be introduced as a method of boosting. Boosting targets people's abilities - "fostering their existing competences" - rather than their immediate behaviour, to encourage better decision-making (Hertwig & Grüne-Yanoff, 2017, p. 974). The program would also apply the Norm Activation Model (Schwartz, 1977), which suggests that behaviour originates from personal norms, which are activated by awareness of need and consequences, ascription of responsibility, outcome efficacy and self-efficacy. Based on this, the following practical applications are proposed:

Personal norms (perceived moral obligation) - Energy-inefficient behaviour presented and labelled as 'environmentally unfriendly' or causing harm and physical injury to the environment. Using an ontological metaphor and anthropomorphising the social cause creates feelings of anticipatory guilt and encourages people to understand the impact of human activity and behave prosocially (Ahn et al., 2014).

Awareness of need and consequences, and ascription of responsibility - The detrimental consequences of not acting would be emphasised, for example, the consequences of the greenhouse effect, increased intensity of natural disasters. This would increase participants' awareness of consequences of energy-inefficient behaviour at home.

- Anthropomorphic illustrations, e.g., a crying earth (Ahn et al., 2014).
- Utilising identifiable victims (Genevsky et al., 2013) and narrative structures (Shaffer et al., 2018) to highlight the tragedy of polar bears and other animals losing habitats and being at risk of extinction to increase motivations for energy conservation.

Outcome efficacy - In the education programme, participants are empowered to use and read energy metres to perform calculations on household energy usage. As the KYEN pilot study demonstrates, participants reported the exercise being very effective and helped them to understand seasonal patterns of energy use and effects of household activities on peak load patterns (Mauriello, 2019).

Self-efficacy - Energy-saving solutions at home to alleviate environmental problems will be introduced. This increases their self-efficacy as participants can identify energy-conserving activities as environmentally friendly and believe in their agency to fight environmental detriment and reduce costs.

Additionally, secondary schools can integrate peak demand concepts and daily energy-consumption scenarios into problems in mathematics and physics curricula. Eric Gutstein has a body of research centred around dialectically interweaving real-world issues into mathematics curriculum, which has proven to support adolescents in reading the *world* through reading the (mathematical) *word* (Freire, 1994, in Gutstein, 2016). For example, 'Peak time electricity costs 30p/kWh and off-peak electricity costs 25p/kWh. James uses XX kWh from 8 - 10:30pm, how much will he be charged for this use?'. This intervention also utilises boost and outcome efficacy and self-efficacy mechanisms from the Norm Activation Model (Schwartz, 1977), increasing awareness of peak and off-peak time differentiation and encouraging energy-saving behaviours.

Limitations

Minimising climate anxiety – There are ethical issues with placing onus on teens for matters concerning the environment. Studies on climate anxiety have found that 84% of teens are at least moderately to extremely worried about climate change (Hickman et al., 2021). It is therefore important to design curricula to focus on empowerment by highlighting actions that participants can take to reduce energy-use versus highlighting environmental detriment.

Parental agency – It is worth noting that while adolescents have more agency than children in the household context, due to the habitual nature of energy consumption, parents and guardians ultimately exert greater influence on household energy use.

Social Regulations

The Problem

Social regulations, which relate to the norms, rules, and expectations that exist in a social setting and influence people's behaviour, are an essential element of the installation components. Social regulations can take different forms and are powerful drivers of behaviour, as individuals are motivated to regulate their behaviour in ways that conform to the expectations of their social environment, with the involvement of entities such as communities, organisations, or institutions (Lahlou, 2017, p. 114). In the context of residential peak demand, installation components consist of rules, social norms and rewards which contribute to energy consumption habits. Although consumers may be aware of the benefits of energy-saving behaviours, they may feel obligated to follow social norms that place comfort over energy conservation. As a result, they may be comfortable with their current habits and be reluctant to adopt new ones. Several studies found financial incentives, dynamic pricing strategies in particular, to be effective in reducing peak energy consumption when designed and communicated effectively to households (Fais et al., 2016; Khan, 2018).

The benefits of peak and off-peak pricing are contingent on two factors: consumer acceptance and active consumer response in the form of altered consumption patterns (Nicolson et al., 2017). So, it is critical to comprehend whether residential energy users are willing to accept peak and off-peak prices as well as the factors influencing this acceptance. The more energy users accept peak and off-peak pricing, fewer new investments in power capacity during peak hours are required. Only 26% of respondents part of 2018 research in China, a nation with a long history of peak and off-peak pricing, were aware of peak and off-peak tariffs. It should be highlighted that more than half of the consumers had never heard from their energy company regarding peak and off-peak pricing. Yang et al. (2018) suggest that there is an important lack of efficient marketing and communications from the government & energy firms. Unavailability of tariffs, seeming complexity of their structures, an inconvenience for certain households and a perceived risk regarding Time of Use Tariffs (ToUTs) are some of the other barriers.

The Solution

Public Policy and Effective Communication

The government and the energy industry has long sought to reduce household peak energy consumption, to avoid having to build and maintain expensive marginal capacity, through financial incentives (Darby & McKenna, 2012; Ofgem, 2010). A growing number of initiatives to try and encourage a demand side response were put in place in the household market and tariff-based incentives are frequently used to respond to consumer demand (Bradley et al., 2016). The UK government and energy firms have introduced schemes aimed at reducing households' peak-time energy usage. The ToUT scheme (Energy Saving Trust, 2020) and ESO's Demand Flexibility Service provides financial incentives for households to adjust their energy consumption habits, encouraging more flexible and efficient energy usage during periods of high demand. Because energy prices are much higher during peak-hours under ToUT, maintaining old habits will be significantly more expensive compared to a conventional flat rate. By shifting their energy usage to times when it is more cost-effective, households can reduce their overall energy bills, while on a national level, the scheme reduces the burden on the grid by distributing electricity demand more evenly throughout the day. To assist users in tracking their energy use, many of the schemes also offer free smart metres.

Despite the benefits, ToU tariffs have struggled to gain widespread adoption in the UK, the need for increased availability and improved communication strategies are necessary for ensuring higher participation rates. The problem with the existing solutions stems from a lack of accessibility, low rates of awareness and participation from the British public. As mentioned earlier, a growing body of research shows that while marketing campaigns can be effective in achieving short-term behaviour change, they may not be sufficient on their own to achieve sustained habit change in sustainable behaviour. However, this is not a limitation in the context of ToUTs, as the tariff itself acts as a driver of behaviour change, a one-time sign up is required.

The new campaign, launched by the National Grid in close collaboration with energy companies, can incentivise and encourage increased availability of ToU tariffs, while offering clear and concise information, including how the scheme works and what the potential benefits are. A coordinated marketing campaign that targets consumers across multiple channels, including traditional media, social media, and direct mail is required. An emphasis on the financial benefits of ToU tariffs for consumers is crucial, previous studies on communication strategies have shown that motivations to reduce energy consumption were more economic than pro-environmental (Casado et al., 2017). Households need to be made aware that by shifting their energy usage to off-peak hours, they can take advantage of the lower rates and save money on their energy bills. ToU tariffs help consumers make informed decisions about when to use energy-intensive appliances or devices. This can help consumers to manage their energy usage more effectively and potentially reduce their overall energy consumption. With different pricing structures and varying rates throughout the day, ToU tariffs can be complex. This complexity can make it difficult for customers to understand the potential cost savings and may discourage them from switching. To address this perceived risk, the messaging should be as concise and simplified as possible, additionally, energy companies could offer personalised online advice to consumers about how they can optimise their energy usage to take advantage of ToU tariffs. Although the focus of the campaign should be the incentives for households, consumers should also be made aware that their participation in the scheme will greatly contribute to reducing the strain on National Grid, along with decreasing the overall demand, leading to more sustainable energy consumption patterns.

Limitations

Inconvenience **-** ToU rates may not be feasible or convenient for some households, particularly for those who work long hours or have unpredictable schedules. Higher energy prices may arise from this lack of flexibility, particularly if consumers are obliged to use energy during peak times.

Conclusion

To conclude, the solutions outlined in this paper aim to raise awareness of peak demand amongst UK households and provide practical measures to reduce energy consumption. By applying activity theory to understand energy consumption as a means, not an end, the solutions tackle the resistant, "irrational" behaviour that typically presents a barrier to developing new, long-term energy-saving behaviour. Thus, the paper outlines ways to integrate non-financial as well as financial incentives to change the habitual activity often seen in energy consumption. By using installation theory and the existing installations in which UK households consume energy, allows for a holistic approach that considers the physical affordances, embodied competences and social regulations involved in channelling energy-use behaviour.

The effectiveness of each solution proposed in this paper will depend on other interventions too. The grounds for introduction and implementation of each solution - such as public policy, financial and practical logistics, and the collaboration of external stakeholders including energy companies, schools, and the government - should also be considered for the rollout of these solutions. While many of the proposed solutions focus primarily on individual change, the immense power of public policy and external stakeholders is not to be overlooked and is an important topic for further research. Pilot programmes run by governments and these stakeholders will be beneficial to test the validity of the more theoretically bound facets of the solutions. Further research can also apply similar solutions to those proposed in this paper in domains beyond the household, such as in office buildings or hotels.

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