Power to the People: Dynamic Energy Management Through Communal Cooperation

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ABSTRACT

In this paper we propose that design and HCI research address domestic energy management as a matter of timeliness, and organised on a community scale. We argue that instead of focusing on the financial benefits of energy saving, technologies can be used to connect users in systems that promote better understandings of the impact of their behaviours. We review current policy and practice and outline design proposals for systems that bring people together to work as a team to reduce the strain on national energy generating infrastructure. We argue that by exposing some of the complexity of power generation people can make more informed energy consuming choices.

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Research through design, Sustainable HCI, Dynamic demand, Community energy management.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous - Design;

General Terms
Design

INTRODUCTION

Over the last number of years HCI research has shown an increasing interest in design for sustainability. Often this work takes the form of user trials of new (and old) technologies that promote domestic energy reduction practices and environmental concern [1,5,8,9]. Most of these studies begin with the assumption that consuming energy is a bad thing to do and therefore must be reduced by as much as possible by giving users real-time feedback on their consumption [6].

However the kinds of information used in this feedback can raise various issues. Many studies have shown that users desire to have comparative feedback of their usage [8], often in the form of a figure of average consumption. For instance, when comparing electricity usage, a comparator may be the average consumption for a household of the same typical size and occupancy. However studies show that in the case of users using less than this average, there can be increased consumption up to the average, a trait referred to as the 'boomerang effect' [18].

Interest in domestic electricity monitoring is of course not confined to HCI research; on a policy level the UK government has legislated that smart meters will be rolled out to every house in the country in a bid to reduce the nation's carbon footprint. The authors of this paper, a team of designers working in an HCI context, are unconvinced that the policy of individual monitoring will the have long-term impact that is expected and believe there are other possible solutions that look at the problem from different perspectives. To investigate this is a matter of adjusting the agenda for interactive systems that are relevant to sustainable energy practices.

A major drawback that we see with current electricity monitoring practices is the disconnection between consumption and the national infrastructure distributing the power, the National Grid (NG). If the goal of energy reduction is to lower emissions, then it is not simply a matter of using less, it is also a case of knowing *when* and *when not* to consume, to consider the timeliness of use. As we see later in the paper, there are times when it makes great sense to use power and times when it does not. We also believe that greater reductions can be achieved by giving people both the tools to understand better the infrastructure and the means to work together as a team to coordinate usage, than individuals acting on their own.

In this paper we outline proposals for design scenarios and briefs that address new ways of monitoring electricity consumption, that move reduction from an individual to a collective effort at community level working with the NG, not in isolation from it. There are two main sections in which we discuss our arguments. First, we overview the UK government policy for mandating smart metering in every household and the current trends in electricity monitoring and reflect upon how these tend to be used in relation to attitudes on domestic comfort. We also examine the practice of how the NG responds to demand from its

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users and various technologies that can be employed to flatten demand.

In the second section we describe a design space through proposals and studies. We outline a case study in which a community in a UK street collectively measured and shared their electricity consumption data in an experiment of community energy reduction. In addition we overview design proposals for devices that allow small groups of households to collectively work towards balancing their overall demand with the supply from the NG, via communally organised energy practices.

To be clear from the outset, neither the case study nor the design proposals are presented as scenarios or fully-fledged artefacts to be evaluated, but exist to outline areas of design opportunity that this paper aims to reveal. Our literature review also serves to describe all of the considerations taken into account within our design process and how we have re-orientated the issue to situate the design space.

CURRENT POLICY AND PRACTICE: A CRITICAL REVIEW

The UK government Department for Energy and Climate Change (DECC) is working to reduce the carbon footprint of the country by 25% (below 1990 levels) by 2015 and aims for an overall reduction of 80% by 2050 [7]. A key policy measure for tackling this target is the introduction of mandatory smart metering for every home. The timescale for this rollout has been accelerated by the coalition government and DECC plans to have the majority of UK homes equipped with smart meters by 2014 [7]. One energy supplier has already installed 2 million units and is fitting more at the rate of 1000 per day [www.centrica.com/].

The domestic energy consumer represents 30.5% [www.decc.gov.uk] of the overall energy consumed in the UK and policy would indicate that smart metering is considered by the government at least be a potentially successful method for tackling climate change. This technology imposes responsibility for energy reduction on personal consumption and on the ability on the user to make informed decisions based on feedback from the device. It also assumes (or hopes) that individuals are both committed to tackling climate change and can in some way quantify the impact of their behaviour in relation to the overall carbon reduction framework.

Since the policy decision there has been an avalanche of domestic smart electricity monitors onto the UK market in a bid to become market leader through partnerships with energy suppliers. Current Cost, Owl, Wattson, AlertMe, Efergy, Ecosaver [7] all manufacture devices that provide various iterations of graphically displaying domestic electricity consumption.

Typically, such a device consists of an inductive clamp placed around the electric mains that wirelessly transmits data to an electronic display with which it is paired. This allows data from the usually ill-located domestic electricity meters to be represented in a more accessible location within the home. With only a few exceptions, they all assume people can understand energy as units of (real-time and historical) consumption.

Currently most smart monitors don't automatically publish data, however with some models users can choose to publish and further analyse their own data using numerous emerging web applications such as Current Cost [www.currentcost.com] and Holmes [www.diykyoto.com]. By 2020 at the latest all smart meters will have to transmit their data back to the electricity company supplying the energy which opens up further opportunities for data analysis. The DECC itself are now publishing their data from the HQ in central London [www.carbonculture.net/orgs/decc/whitehall-place/].

Issues with Current Smart (Electricity) Meters

The approach adopted by personal energy monitors implies that energy reduction is an individual concern and that people should not use 'too much', creating what Abrahamse et al. refer to as consequence interventions (positive or negative feedback on use) to reduce consumption. Some of these systems have shown limited success, but systems that imply that people should not use 'too much' energy may well be resisted as leading to feelings of guilt and inadequacy or be explained a way as being insensitive to justifiable local demand [1].

In addition, we believe that it is difficult to make informed judgements about individual energy use within a domestic space that is isolated from its surroundings. The communication of data within our own home may reveal a unit (financial cost or carbon footprint) of our energy consumption, but it ignores a connection to our own immediate environment as well as the conditions of the system in which our energy supply and demand exists.

The graphical display and calculation of this unit ignores the details and context of our energy consumption. By communicating a real time calculation of the level of consumption and financial cost, the energy monitor draws attention to the spikes of consumption. If an individual boils an electric kettle, they will witness a surge of electricity and be alerted to an increase in cost of their energy consumption as it assumes a new sustained level of consumption. However, in reality this surge of electricity is momentary and the cost of energy returns to its original level. The details of our energy saving practices are also ignored; an energy monitor displays the considerable rise in cost of consumption when boiling a kettle, yet it will not recognise whether the individual has boiled enough water for one or ten cups of tea. The energy monitor ignores any real-time energy saving efforts from an individual.

A private display of individual energy consumption leads to a diffusion of ecological responsibility [4]. With a number of individuals focusing on their own display, there may be a tendency to expect others to reduce their energy use, or to question the impact of one's own actions and feel that one's attempts are insignificant in the grand scheme of things. However, if the individual were provided with a scale that contextualised their actions, they may feel greater responsibility for behaviour.

Abstract Representations of Immaterial Energy

Energy can be thought of as an invisible commodity [17]. The infrastructure that carries it into our homes is largely hidden from our view; pipes and cables are buried underground and even within our homes this delivery infrastructure is hidden beneath floors and walls, only emerging at points for convenient access. Our experience of energy comes in the form of enabling or supporting actions i.e. the flame on a hob that enables us to cook dinner, the electricity in the wall that allows us to switch on the television.

The Supergrid [13] also obscures the origin of the power: the source of the energy delivered to our homes is 'undifferentiated' [17]. In the UK electricity is generated through a variety of renewable and non-renewable sources both onshore and offshore and is comprised of coal (generating 28.9%), natural gas (44.2%), nuclear (17.3%), renewables (7.9%) and other (1.7%) [13]. Unless you live near a power station one could argue that we are totally disconnected from the production of energy and that our quantitative understanding of energy is only through cost to the individual. Additionally, there is no connection to the qualitative nature of energy as the percentages of the mix of our energy supplies vary over time.

Energy infrastructure is invisible to us by way of design [17], it is therefore, a matter for designers to address the systems that support sustainable energy practices. One way in which we feel this could be tackled is by closing the relational gap between energy production and energy consumption.

Behaviours and the Tangibility of Numbers

Studies of smart meters show that there is limited flexibility in people's everyday practices. When energy monitors are first introduced into a home there is a period of reduction before the energy saving practices level off, albeit at a reduced rate [2]. People can change to a point but we cannot undo years upon years of evolving social norms. Schultz's studies show that social norms have a powerful effect on people's consumption behaviour. When people could see the energy use of their neighbours they used this to justify and set their own level - if they consumed more than their neighbours they would seek to lower their usage, but if they used less they would actually increase their usage [18].

The majority of energy used is to maintain levels of comfort in the home [19]. In the UK we can sit and look out at a dark stormy sky whilst we sit in the comfort of a climate that would be naturally experienced closer to the equator. Looking at an electronic display that shows '20 Celsius, 286 watts' has little value because it has no context. If those numbers were put alongside the outdoor temperature, the number of generators powering the NG, the sources of energy generation etc. it would give the numbers greater meaning and situate them within the wider world.

Our relationship with energy consumption has less to do with numbers and more to do with the things that we do and use, from making toast in the grill to cleaning laundry in the washing machines. We believe there is an opportunity to re-script the feedback of energy use from numbers to tangibility of behaviours. Existing energy monitors' 'predominately follow the logic of *micro-resource* management, rather than domestic life' [20], but we believe there are examples of resource management that are *domesticated,* from maintaining stock levels of groceries to balancing household finances. If we can design systems that embrace affordances of domestic resource management rather than micro-resource management, we believe energy consumption could be made more tangible to the user.

The National Grid and Demand

Unlike coal and gas, we do not yet have the technology to store electricity at a large scale, which instead needs to be generated real-time in response to consumption. With the often unpredictable and varied demand of electricity from the UK's households and industry, the NG face a considerable task in generating enough electricity to balance the supply with demand. In anticipation of UK demand, the grid employ a specialist forecasting team [14] to predict the levels of supply required. The forecasting team communicate this information to the National Grid Control Centre, where operators can regulate supply through powering up or closing a variety of power stations and generators. The grid deploys various methods when producing electricity to meet the demands of the UK domestic and industry, all of which have different response times before they can contribute to the grid. The different reaction times vary considerably: coal fired power stations require 12 hours compared to hydroelectric plants, which can add to the supply after a swift ten seconds [14].

Predictable Demand

The skill of the NG forecasters and operators lies in their ability to understand the idiosyncrasies and habits of the nation. The everyday practices of the UK household, including heating the home, cooking dinner and watching television all contribute to the peaks and troughs of UK demand. These individual practices are often synchronised and can cause quite an effect on the grid's supply. For example, the exact moment a soap opera finishes on television may cause a considerable spike in demand. In a short moment a significant proportion of the nations population boil kettles, open their fridge doors, and activate water pumps by flushing toilets. The working habits of the nation also affect the rhythm of demand, as houses will often be kept at a higher temperature during the evenings in the working week and over the weekends when occupied.

Unpredictable Demand

The grid's electricity supply also needs to deal with less predictable patterns of behaviour. Political, sporting and other national and global events have significant impact on the UK demand that are often difficult to predict. The 2011 royal wedding of Prince William and Kate Middleton produced an increase in demand for electricity by 2,400 Megawatts (MW), the equivalent of nearly a million water kettles being turned on at the same time. The NG also registered a 1,500MW drop in demand when the bride's wedding dress was first revealed on screen. This drop was accounted for by people gathering around their televisions, rather than continuing with other electricity-hungry activities [15]. There are no exact blueprints for our behaviour in these events. The NG looked back at data for Charles and Diana's wedding in 1981 but in predicting the supply needed for Kate and William's wedding, the NG had to take a complexity of factors into account i.e. the current popularity of the Royal family and the fact it was a bank holiday.

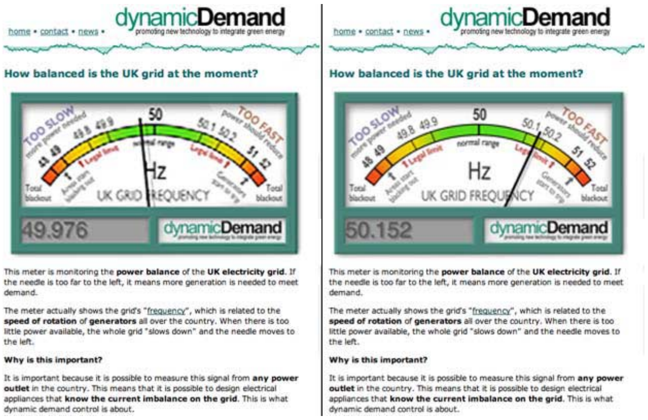
The weather is another variable in the UK demand of electricity. Seasonal changes result in regular annual patterns for UK demand where a home's heating will differ in relation to the changing weather. However, unpredictable weather patterns, such as cold snaps in the winter, can cause more of an unexpected strain on the UK electricity supply. A drop in temperature and heavy snow can cause disruptions to public transport and road traffic, changing people's work habits. In turn this would cause more domestic activity in the working week and less demand for electricity from industry, providing more of a conundrum for the forecasters and operators at the National Grid Control Centre. The UK's changeable weather also has a direct impact on the supply of electricity: an increase in wind helps the grid to generate electricity through onshore and offshore wind farms, whilst severe storms can disrupt the supply of energy.

There are instances where the grid observes a considerable drop in demand, which if overlooked can result in wasted energy as any oversupply means that the grid runs too fast. The two-minute silence during Remembrance Day produces a dip in consumption of electricity. These scheduled events provide some warning to the forecasters, however the scale of the public's response to them is largely unpredictable. The grid reported [15] a 620MW reduction in electricity demand during the two-minute silence on Remembrance Day in 2011, which is three times the size of the 206MW drop seen in 2006. A spokesperson from the NG believes this to be accounted to "a result of UK military involvement in Iraq and Afghanistan in recent years". In this instance, it is not just a national event that causes variations in UK energy demand, but also the changing attitudes and beliefs of the public that needs to be understood and predicted by the grid.

New technologies also add to the complexities of forecasting the UK electricity demand. Mobile devices such as smart phones, laptops and tablets require their batteries to be charged daily, often at unpredictable times. Household appliances such as washing machines include timers that allow users to choose start/finish times independent from other domestic routines. Developing smart technologies, such as LG's 'THINQ' [www.lg.com] provide apps that for users to manage appliances remotely, for instance to operate a robotic vacuum cleaner or set the temperature of the oven. All of these technologies contribute to new and changing patterns of energy consumption.

Dynamic Demand

Timeliness (of consumption) is everything. The normal system frequency is 50Hz and the NG has statutory obligations to maintain the frequency within -/+0.5Hz of this target [14]. If the demand exceeds the supply, the frequency will drop as the infrastructure is put under strain, which may force the NG to switch off parts of the grid in order to remain inside this operating window. To meet sudden spikes in demand, hydroelectric plants are often activated and if demand is still not met, the NG may turn to their 'Short Term Operating Reserve' (STOR), a contracted 'Balancing Service' whereby a service provider delivers a contracted level of power to the Grid, often produced from quick-starting diesel generators [13]. However, if the supply is too great, the NG risks wasting electricity (see figure 1).



How balanced is the UK grid at the moment?

49.976

This meter is monitoring the **power balance** of the **UK electricity grid**. If the needle is too far to the left, it means more generation is needed to meet demand.

The meter actually shows the grid's "frequency", which is related to the **speed of rotation** of **generators** all over the country. When there is too little power available, the whole grid "slows down" and the needle moves to the left.

Why is this important?

It is important because it is possible to measure this signal from **any power outlet** in the country. This means that it is possible to design electrical appliances that **know the current imbalance on the grid**. This is what dynamic demand control is about.

How balanced is the UK grid at the moment?

50.152

This meter is monitoring the **power balance** of the **UK electricity grid**. If the needle is too far to the left, it means more generation is needed to meet demand.

The meter actually shows the grid's "frequency", which is related to the **speed of rotation** of **generators** all over the country. When there is too little power available, the whole grid "slows down" and the needle moves to the left.

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Figure 1. The image on the left shows a demand slightly exceed supply on a typical day; the image on the right was taken during Earth Hour 2009 showing supply greatly exceeding demand on the NG. © Demand Logic

Although it is the UK's power stations that provide the supply of electricity to the grid, it is the decisions that are made by individuals that regulate the balance of supply and demand. The relationship between the public and the operators and forecasters at the Grid is crucially intimate. The timeliness of the public's practices and the factors that may affect their behaviour has great impact on the UK demand of electricity. It is the decisions made by the NG's small team and their understanding of the beliefs, habits and behaviours of the public that is central to the successful delivery of electricity to the millions of homes in the UK.

Timeliness of Electricity Usage

There are a few products and services that strive to work with the timeliness of the NG. Economy 7 is a differential tariff provided by electricity suppliers, by using base load generation (that is the continuous supply from always on power stations that are set to meet the minimum level of UK demand) to provide cheaper off-peak electricity during a seven-hour period at night.

RLtec's Dynamic Demand [www.rltec.com/] technology also works in relationship with the frequency of the grid, controlling the energy consumption of an appliance in response to the available supply of electricity. The technology is software that can be incorporated into the control unit of motor driven electrical appliances, including fridges, air conditioners and heaters. It measures the operating frequency of the grid to choreograph the power usage of these appliances, for instance coordinating the pumps in a group of connected fridges to prevent them all switching on at the same time. As an effect, RLtec aims to ease the demand of electricity supply and reduce the need for back up generators and the grid's STOR service. This approach of response to energy demand is also becoming a focus of European policy [21].

In March 2010, RLtec contracted their technology to the heating and ventilation systems in 200 stores owned by Sainsburys Supermarkets [www.sainsburys.co.uk]. This commercial deal has in effect created a large network of appliances that now maintain a relationship with the grid with a consideration to the timeliness of consumption. Rather than work independently to the grid's supply of electricity, an infrastructure has been created for these appliances to work as a group of energy consuming individuals.

TOWARDS DESIGN: PROPOSALS AND STUDIES

Inspired by how RLtec's technology reduces energy production, we began to explore ways in which individual consumers can produce less variable demand on the grid without replacing major appliances. Instead of focusing on individual behaviour, this work addressed the timeliness of electricity demand and considered energy consumption as a collective concern rather than an individual one. The team believed that getting people to work as a team would help contextualise the impact of individual actions and motivate behaviour change through empathy for others [5]. While smart appliances may in the future automatically regulate domestic supply and demand, this work sought to help people make more informed judgements about energy consumption through collective organisation of domestic practices. The first steps in the process were to look at methods for collecting and sharing energy consumption data at local community or street level.

There is already much evidence of users sharing and publishing data from domestic energy practices. Some energy monitors such as Current Cost [www.currentcost.com/] and Wattson [www.diykyoto.com] have built in web services for this. The Holmes software is designed specifically for the community of users who own the Wattson to publicly share and compare their data together, subscribers can log on to the site and see the consumption historically and in real-time. Users of this device can also see the data of every other Wattson user and are actively encouraged "to share and compare how well you're doing". There are many DIY versions of data sharing, often using the Pachube [https://pachube.com/] service. This enables users to publish and share data collected by a variety of domestic sensors, from indoor air temperature and quality to gas and electricity monitors. Networks of comparing individual household consumption have also been adopted in user studies within academic research, which has promoted competition between households through 'ranking' participants in their energy consumption [16].

While many of these users sharing information may have different motivations and agendas for doing so, it is not entirely clear what they might expect others to do with this information. It makes no sense to compare directly ones energy consumption with an anonymous user online: households vary in size, lifestyles differ and the local climate may be very different. An alternative proposal is to think about connecting the consumption figures of a local neighbourhood in order to produce aggregated data, smoothing out this household variance to produce one set of figures. Where the impact of one's own actions can be observed through working towards a common goal, promoting teamwork rather than competitive 'team play' [5].

Tidy Street Proposals

As collaborators in the CHANGE project [www.changeproject.info] the authors designed numerous proposals for a public energy display(s) for a short-term study in Tidy Street, a residential road in Brighton UK. Comprised of around fifty similarly sized houses built in the 19th Century, the street has a strong sense of community and a third of the households in this street signed up to be participants in the energy behaviour change project. Initially the project brief had been to design a private display that would show a detailed breakdown on energy usage [2] and a public display giving an overall sum mounted in the front window for each household. It was hoped that the use of a public display of individual households energy use would be a key motivator for reducing electricity usage and help avoid the 'boomerang effect' [18].

Given the fact that varying occupancy levels in the participant's houses would give very different sums of both overall energy consumption and potential reduction however, we were worried that public displays of individual consumption might be misleading and even divisive. The volunteers themselves were not keen and it was felt that this concept of publicly displaying individual energy consumption raised privacy concerns as well as fostering a rather disciplinary approach to people's practices. Our team decided to explore more ways to emphasise community cooperation, rather than individual guilt and competition, in shaping new energy management habits.

Inspired by the strong sense of community observed among the participants, we decided to design concepts that focussed instead on the energy consumption of the street as whole. Individual data would be collected and combined to give an overall sum, which could be used in a system that explores how lower energy use might be negotiated by and distributed amongst the local community working together.

Demand Balancing

Working with the idea that not all energy use is bad, and that the timeliness of energy use can alleviate pressure on the NG we began to work with proposals with promote timely energy activity, and how this could be socially negotiated. We explored the idea of making a *Resource Scheduler* with which a community could reserve times for certain high consuming energy practices i.e. washing laundry [22]. With only a finite amount of allotted times to be shared amongst a street (for example) we imagined users would be more thoughtful in their practices i.e. a household of one may withhold from taking a prime time allocation for washing clothes if they know a family of four live across the street. Rather than being motivated to simply reduce energy consumption by financial cost or concern for large-scale environmental issues, the energy decisions become timely and more considered - motivated by empathy, or even altruism.

Design Proposals

Three design proposals were presented to project partners that addressed ways of combining overall consumption of the street with UK NG demand data aimed at tackling dynamic energy management. Each proposal incorporates a public display of real-time local and national energy demand as well as the private display of energy demand information. In juxtaposing situated energy consumption and national energy demand we seek to draw attention to the timeliness of energy consumption rather than a reduction to either/or decisions. The proposals varied in complexity, but all follow the logic of the street working together to moderate their impact on national infrastructure.

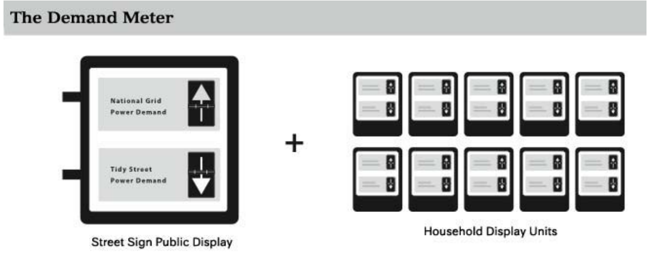


Figure 2. The Demand Meter provides residents with two kinds of display: a public street sign and smaller household units. Each visualises a binary comparison between the collective demand of electricity in the street and UK NG demand, indicating each state as either high or low. © Interaction Research Studio

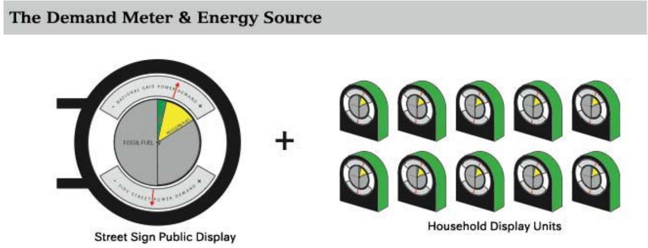


Figure 3. The Demand Meter + Energy Source Meter adds a scale to the demand levels and adds energy source information. Again using one public and multiple private displays, both include a percentage breakdown of energy sources (fossil, nuclear and renewables). © Interaction Research Studio

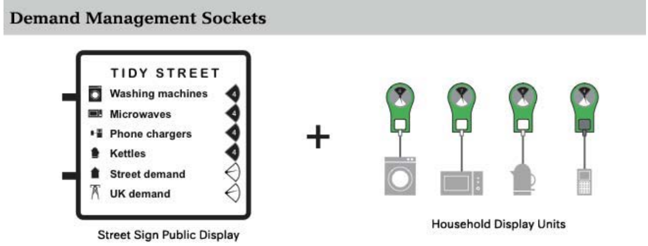


Figure 4. Demand Management Sockets highlights selected household appliance usage. The public street sign and individual display units show the number of such appliances in use by the street at any time, as well as local and NG demand. © Interaction Research Studio

The Tidy Street Case Study

Ultimately, these particular proposals were not developed. We were however, able to run a field trial of the notion of bringing together the community as a team to reduce energy consumption. After further development the idea became one of visualising average community usage compared to city average, using the surface of the road that runs the length of street to create a very large-scale public display.

The study ran began in March 2011 and lasted about a month (a follow up study, without road-marking, lasted a further five months). By reading their electricity meters, the volunteers recorded their energy usage on a daily basis and entered this data on a website constructed for the project [http://tidystreet.org/]. Here volunteers could log in, enter their readings and see a history of their own usage only. Behind the scenes however this data was aggregated with other households to produce an average figure of consumption of a typical Tidy Street house for the last 24 hours.

Figure 5. The Tidy Street road display.
© Interaction Research Studio

During the first week of the study, only consumption data was gathered, allowing time to iron out any bugs in the system. At the beginning of the second week the daily average usage of the participants started to be marked on a large street display, which demonstrated how Tidy Street compares to the average Brighton household's electricity usage (12kWh). With the help of a local graffiti artist [http://snub23.com/], daily electricity usage was marked using temporary chalk spray on a large chart mapped out on the surface of road recording the ups and downs of the street's average consumption against a fixed comparison line over a two-week period. The display developed over the duration of the project, during which time the residents energy use was reduced by 15% [3]

Dynamic Comparison

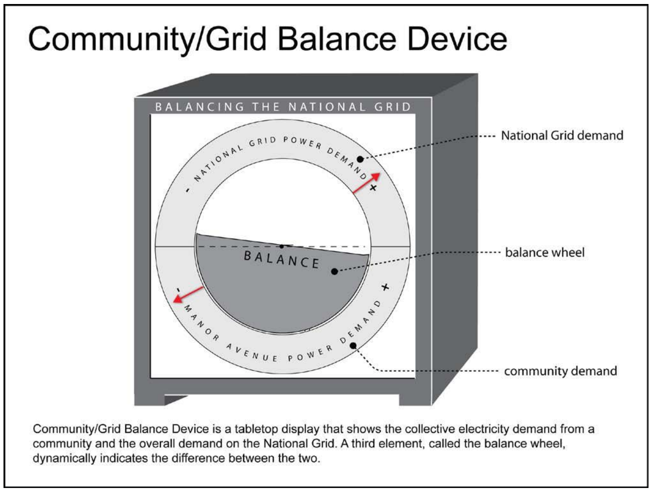
Although there was a quantifiable reduction of energy consumption during the trial, we believe that the dynamic comparator present in our early concepts could enrich future studies. We were encouraged by the willingness and motivation from the community to work together to alter consumption behaviour, which we believe supports the notion we have that people could be motivated by empathy to consider timeliness as well as overall consumption.

Further Design Proposals – Re-materialising Energy.

In a parallel project the authors continued to develop ideas for situated technologies that would allow communities to work in harmony with national infrastructure to use electricity in a timelier manner. These proposals consisted of various designs for a series of batch-produced prototype devices that could connect individual households within a group of participants. At this time the team produced a manifesto-style agenda against which design ideas could be measured:

> *The 'something – something' is a network of domestic devices that allows a community to balance their energy behaviour against the overall demand on the National Grid in real-time.*
>
> *Individual usage is aggregated to form a measure of collective consumption, which is displayed as a whole alongside a measure of national usage. In juxtaposing situated energy consumption and national energy demand we seek to draw attention to the timeliness of energy consumption rather than mandating energy reduction and lifestyle change.*
>
> *These devices produce outputs that depict the relationship between the situated and the national energy use to make the notion of a balance palpable. The overall aim is explore outputs that are specific enough to support awareness of the potential to balance supply and demand yet open enough to allow a range of responses. [Internal project workbook]*

During this phase of the project numerous proposals were developed through various design workbooks [11]. We highlight two here.



Community/Grid Balance Device is a tabletop display that shows the collective electricity demand from a community and the overall demand on the National Grid. A third element, called the balance wheel, dynamically indicates the difference between the two.

Figure 6. Community/Grid Balance Device
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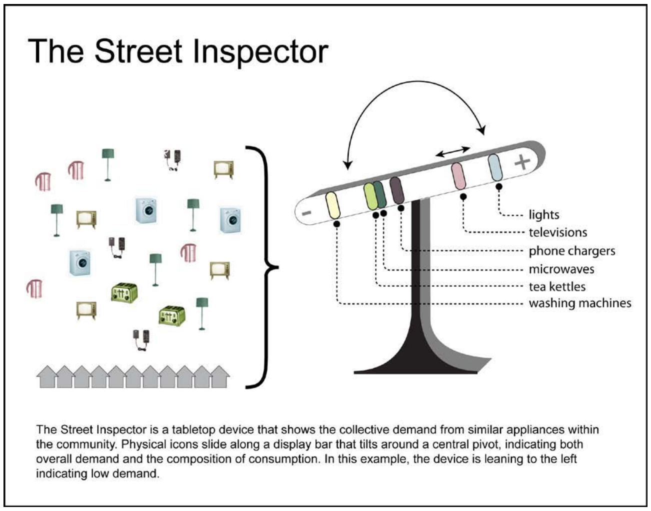
The first proposal, The Community/Grid Balance Device, is for a network of domestic tabletop devices that allows a community to balance their energy behaviour against the overall demand on the NG in real-time. Individual usage is aggregated to form a measure of collective consumption, which is displayed as a whole alongside a measure of national usage. In a similar way to the use of candlesticks as a diagrammatic metaphor in the visualisation of complex market data [12], these values are shown on two needle dial displays that feature no units, just a simple plus or minus at either end of the scale. An additional feature of this device, referred to by the design team as the *balance wheel*, provides an instant visual guide to how the community is consuming in comparison to the nation. In effect, the *balance wheel* combines a variety of different scenarios to give an impression of a power reserve, that is say whether the NG has enough generating capacity to feed the demand of the community.



The Street Inspector is a tabletop device that shows the collective demand from similar appliances within the community. Physical icons slide along a display bar that tilts around a central pivot, indicating both overall demand and the composition of consumption. In this example, the device is leaning to the left indicating low demand.

Figure 7. The Street Inspector
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A proposal for an additional prototype, the Street Inspector aims to complement the Community/Grid Balance Device by providing finer grained detail into the way in which the community is using its energy. This device is another tabletop sized device that incorporates a seesaw like balancing mechanism where mechanical icons representing appliances slide around to display usage throughout the group. In this scenario, rather than collecting and aggregating overall electricity usage between the households, individual appliance usage data is collected and shared among all the homes. Thus, if everybody in the collective were using the washing machine, then the icon for that device would slide to one end (the '+' side) of the balancing mechanism and tilt the overall display over. The aim of this proposal is to provide an accurate indicator of when it may be an appropriate time to use a particular appliance by effectively displaying how many of any one appliance is on at any on time. With similar intent to the earlier idea of the *Resource Scheduler*, the Street Inspector brings other people's practices into the living space, heightening one's awareness of others and increasing the likelihood of making an empathic judgement. For instance if the number of dishwashers is edging towards tipping the balance, maybe one would postpone dishwashing to make way for others in greater need.

It is envisaged that participants in the community study would work together as a team to produce flatter demand on the NG. By being members of a larger collective, users of the system will be able to quantify their behaviour as part of an assemblage. The devices add meaning to everyday actions by contextualising them in respect to the activities of neighbours and their impact on the national infrastructure. In this way, they highlight how individuals can positively impact the environment through collective cooperation.

CONCLUSIONS

At the time of writing there a number of new policies from the UK's DECC that are beginning to focus efforts on communities. These tend to concentrate on incentives like one-off discounts for groups coming together to purchase 'greening' equipment and materials such as PV panels or loft insulation. However these initiatives are more akin to bulk-buying agreements; while they acknowledge the value in bringing people together for environmental activities, none focus on sustained, long-tem cooperation; and the core incentive is still a financial one rather than one of genuine cooperation.

In this paper we have described work in progress and presented ideas still in development. Our aim has been to open a space of design opportunity surrounding community energy management and timeliness of use. During the Tidy Street case study we observed that people can be motivated by their neighbours actions to reduce energy consumption and work as a team for a common goal. We believe that if we could make use of this motivation within a system that allow a community to balance their demand with supply then we could not only offer a viable alternative to blanket energy reduction; but also re-materialise energy by making production salient and by linking consumption with behaviours and habits involving particular appliances.

The proposals presented in this paper offer simple solutions for community energy management that seek to use electricity in a more coordinated way, but what if further information could be layered into the articulation of energy infrastructures? We think it would be interesting to display data from various global events alongside the community and NG data. From a predicted storm over a North Sea wind farm to the movements of the volcanic ash cloud, there are numerous events that the authors believe may affect people's decisions around energy use when their actions are made palpable within a given framework or even a fiction.

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